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Scientific behaviors promoting an understanding of science and a positive attitude toward science as exhibited by selected high school physics classes.

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SCIENTIFIC BEHAVIORS PROMOTING AN UNDERSTANDING OF SCIENCE AND A POSITIVE ATTITUDE TOWARD SCIENCE AS EXHIBITED BY SELECTED HIGH SCHOOL PHYSICS CLASSES

A Dissertation Presented

by

Marvin R. Kendall

Submitted to the Graduate School of the

University of Massachusetts in

Partial Fulfillment of the Requirements for the Degree of

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TABLE OF CONTENTS

LIST OF TABLES

We labour, toyle, and plod to fill the memorie,
and leave both understanding and conscience emptie.
Montaigne, Of Pedantisme.[1]

CHAPTER I

BACKGROUND TO THE PROBLEM

Introduction

The two fundamental and closely-related purposes of American education are the development of the individual and the improvement of society. Since our democratic society is based upon the worth of the individual, the fostering of individual fulfillment is paramount.[2] In a publication by the National Science Teachers Association this purpose of education is expressed succinctly as part of the definition of the educational enterprise:

> Because American democracy is predicated on the dignity of the individual human being, the enterprise strives to promote this dignity and to enrich human living. It further strives to inculcate worthy moral and ethical standards in young people and to develop individuals who will live responsible and fruitful lives within the framework of American culture.[3]

These purposes of the educational enterprise can best

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[1]Montaigne, Of Pedantisme, quoted in R. Will Burnett, Teaching Science in the Secondary School (New York: Rinehart & Company, Inc., 1957), p. 57.

[2]John W. Gardner, Two Goals of Education, The Report of the President's Commission on National Goals for Americans (New York: American Assembly, Columbia University, 1960), p. 81.

[3]Planning for Excellence in High School Science (Washington, D.C.: National Science Teachers Association, 1961), p. 8.

be achieved by offering experiences in which the individual can perfect his ability to make judgments. That education improves society by developing the individual's ability to think was expressed by the Educational Policies Commission in the following statement:

> The purpose which runs through and strengthens all other educational purposes -- the common thread of education -- is the development of the ability to think. This is the central purpose to which the school must be oriented if it is to accomplish either its traditional tasks or those newly accentuated by recent changes in the world.[4]

Moreover, the Commission endorsed <u>problem-solving</u>[5] as the method of achieving this purpose:

> . . . . The rational powers of any person are developed gradually and continuously as and when he uses them successfully. There is no evidence that they can be developed in any other way.[6]

Perhaps the problem-solving method can best be described by contrasting it with its counterpart. Ultimately, there are two approaches to teaching subject matter: the lecture-textbook-centered method, and the problem-solving-laboratory method. Murphy condenses the various methods to either those in which the student actively participates or those in which the student passively ac-

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[4]Educational Policies Commission of the National Education Association, <u>The Central Purpose of American Education</u> (Washington, D.C.: National Education Association, 1961), pp. 11-12.

[5]Words underlined in this section are defined in Chapter II under the heading "Definition of Terms."

[6]Educational Policies Commission, p. 12.

cepts knowledge:

> Whether we refer to a teaching method as 'non-directive' or 'directive,' 'student-centered' or 'teacher-centered,' 'democratic' or 'authoritarian,' or coin terms of our own, the same basic distinctions remain. Fundamentally, contrasting methods employ either the active participation of students in the development of an inquiring mind or the inculcation of accepted knowledge and practices.[7]

According to Sund and Trowbridge, the active participation of a student in the problem-solving method involves the following activities:

> . . . identifying problems, observing, measuring, classifying, inferring, predicting or making hypotheses, discovering meaningful patterns, designing experiments, interpreting and analyzing data, and verifying.[8]

Problem-solving is generally accepted as the most effective way of teaching subject matter because the student's active participation is a strong motivational factor. Participation is generally agreed to lead to more effective learning than passive observation. In a report the National Science Teachers Association states that:

> Research in psychology has clearly shown that physical, emotional, and intellectual involvement in the learning process enhances its effectiveness. Granting that people can learn vicariously, it is increasingly clear that as a learning experience observation is inferior to more intense participation on the part of the learner.[9]

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[7]Glenn W. Murphy, "Content Versus Process Centered Bioloby Laboratories, Part I: Foundations of Biology Education," <u>Science Education</u>, LII (March, 1969), 143.

[8]Robert B. Sund, and Leslie W. Trowbridge, <u>Teaching Science in the Secondary Schools</u> (Columbus, Ohio: Charles Merrill Books, Inc., 1967), p. 39.

[9]<u>Planning for Excellence in High School Science</u>, pp. 10-11.

Dewey revived interest in active participation as a teaching method at the turn of the century by stressing that the "doing" of something was essential to understanding: "A separation of the active doing phase from the passive undergoing phase destroys the vital meaning of an experience."[10]

This belief was in sharp contrast to the philosophy underlying the report of the Committee of Ten in 1893 which stressed college preparatory courses for those select students who might be considered suitable for higher education. According to the Committee, the same courses could be profitably taught to terminal students also since it saw the purpose of education as primarily one of strengthening the mind through memory learning. The discipline of one's mind, not the accumulation of specific facts, was the objective of education. The "passive undergoing" phase took precedence over the "active doing" phase in the Committee's report.

Dewey's endorsement of problem-solving as a method was reflected in the shift of the aims of education from those of the Committee of Ten, which stressed memory learning, to those expressed in 1918 by the Commission on the Reorganization of Secondary Education, which emphasized value judgments.

According to the Commission, the basic goals of ed-

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[10]John Dewey, Democracy and Education (New York: The Macmillan Company, 1916), p. 177.

ucation, referred to as the Seven Cardinal Principles, are:

(1) good health
(2) command of fundamental processes
(3) worthy home membership
(4) vocational efficiency
(5) civic efficiency
(6) worthy use of leisure time
(7) ethical character[11]

While the Committee of Ten recommended education for the select group of young people fit for college, the Commission on the Reorganization of Secondary Education described an education which would implant understandings and proper attitudes in every person. It is of significance that the aims of secondary school education today are virtually identical with those propounded by the Commission.

Since the Commission's report, educators have spoken out in favor of problem-solving as the method of inculcating the important objectives of education. Piaget, according to Eleanor Duckworth, expressed the importance of the inquiry approach in the following statement: "The goal of education is not to increase the amount of knowledge, but to create the possibilities for a child to invent and discover."[12] Another endorsement of the skills of inquiry is Bruner's:

It is only through the exercise of problem-solving and

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[11]Cardinal Principles of Secondary Education, Report of the Commission on the Reorganization of Secondary Education, National Education Association, Bulletin 1918, No. 35 (Washington, D.C.: Government Printing Office, 1918), pp. 10-11.

[12]Eleanor Duckworth, "Piaget Rediscovered," Journal of Research in Science Teaching, II (1964), 174.

> the effort of discovery that one learns the working heuristics of discovery.[13]

Although problem-solving has been propounded by educators as the most efficacious means of teaching the important objectives of secondary school education, as a method, it has, in practice, been virtually ignored. In fact, the skills of inquiry have been sparingly applied even in the areas of mathematics and science "where one would expect to find the most meaningful use of effective thinking procedures."[14]

The Aims of Secondary Science Education

The purposes of secondary science education are parallel to the aims of general education. The Report of the Commission on the Reorganization of Secondary Education, which de-emphasized memory learning, had much to do with shaping today's secondary science curriculum. A publication of the National Science Teachers Association presents the significance of the shift of the objectives of science teaching in the following statement:

> When approached from an analysis of the nature of the educational and scientific enterprises, past science teaching has been primarily concerned with teaching what scientists know (the product), but has failed to yield proper understanding of the ways in which scientists ob-

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[13] Jerome Bruner, "The Art of Discovery," Harvard Educational Review, XXI (1961), 31.

[14] Richard E. Gross and Frederick J. McDonald, "The Problem-Solving Approach," Phi Delta Kappan, XXXIX (March, 1958), 259.

> tain this knowledge (the process). The latter is extremely important, not only for the training of future scientists, but also for the production of a scientifically literate citizenry capable of applying broadly the modes of scientific thought and sympathetic to the scientific endeavor.[15]

In an age in which the discoveries of science have such an impact, it is a natural consequence that one of the important objectives of science teaching should be to prepare the citizenry for changes effected by science. Whereas the early literature in science education had stressed the practical uses of science, or industrial applications, recent publications reflect the priority placed on understanding science and the fostering of a sympathetic attitude toward science.[5] The National Society for the Study of Education in Rethinking Science Education enumerated the objectives of science teaching as defined by science educators. As stated by Hurd, they include:

A. Understanding Science
   1. Knowledge of science concepts and principles
   2. Understanding of the nature of the scientific enterprise.

B. Problem Solving -- Including methods of inquiry, observation and the processing of data.

C. Social Aspects of Science -- The difference between science and technology and their interplay with human affairs.

D. Appreciations of:
   1. Importance of science
   2. Methods and procedures of science
   3. Scientists
   4. Intellectual satisfaction gained from pursuit of science either as a layman or scientist.

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[15] Planning for Excellence in High School Science, p. 4.

E. Scientific Attitudes. Among them:
   1. Open-mindedness
   2. Desire for accurate information
   3. Confidence in procedure
   4. Expectation that a problem may find solution through use of verified knowledge.

F. Careers and development of special interests in the science fields.

G. Abilities related to reading and interpreting, locating authoritative sources, use of tools in handling data properly, expression of ideas, using science knowledge for responsible social action.[16]

It is significant for this study that understanding science, problem-solving, scientific attitudes, and attitude toward science are listed as four of the primary goals of science education.

Although understanding science and a positive attitude toward science are now considered important objectives of science teaching, these concepts have been developed only recently and are not always clearly identified.

Understanding Science. -- Understanding science is defined in the Fifty-ninth Yearbook of the National Society for the Study of Education as the knowledge of science concepts and principles as well as the understanding of the nature of the scientific enterprise. Cooley and Bassett, who conducted a study in 1954 to determine if a gain in understanding science could be measured, described understanding science as one's image of science and scientists;

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[16]National Society for the Study of Education, Fifty-ninth Yearbook of the National Society, Rethinking Science Education (Chicago: University of Chicago Press, 1960), pp. 33-34.

understandings of the distinctions between science and technology; and an awareness of the nature of the scientific process.[17]

Cooley and Klopfer in 1960 undertook a more exhaustive study on a nationwide scale to measure understanding science. They divided it into three major components: understanding about the scientific enterprise; understanding about scientists; and understanding about the methods and aims of science.[18] Each of these areas was systematically defined in their study.

Understanding science is perhaps the primary objective of a discipline which has as its most significant function the production of a scientifically literate citizenry. Much of the misunderstanding about the power and authority of the scientific community could be resolved if the public understood the scientist and his work. Barnard expresses the relationship between understanding science and the fostering of the scientific endeavor in a free society in the following statement:

> Much has been said about the importance of children's, through their study of science, coming to understand the nature of the scientific enterprise. This is important for several reasons. In a free society, scientific advancement is dependent upon the will of the people: their will as decision-making citizens to support it and their will as individuals to become scientists.

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[17]William W. Cooley and Robert D. Bassett, "Evaluation and Follow-up Study of a Summer Science and Mathematics Program for Talented Secondary School Students," Science Education, XLV (April, 1954), 209.

[18]William W. Cooley and Leo E. Klopfer, Test on Understanding Science Manual for Administering, Scoring, and Interpreting Scores (Cambridge, Mass.: Harvard University Press, 1961).

> Therefore, liberally educated people in a free society should understand the nature of the scientific enterprise, the social, economic, and political factors that affect its development and the personal satisfactions that come to one who pursues a career in it.[19]

A Positive Attitude Toward Science. -- Science educators theorize that an understanding of the scientist and his work will foster a positive attitude toward science. Understanding science and a positive attitude toward science are inseparable since one may be the means of achieving the other. Ramsey and Howe, however, feel that a student's attitudes toward science may well be more important than his understanding of science since his attitudes determine how he will use his knowledge.[20] Noll, who pioneered work in scientific attitude[5] in the 1930's, based his research on the fact that:

> Charles W. Eliot, Huxley, Spencer, and more recently leaders in the field of science education like Caldwell, Downing, and Powers have stated from time to time that one of the most important outcomes of instruction in natural science is the scientific attitude.[21]

Hurd, in the Fifty-ninth Yearbook of the National Society for the Study of Education, included the development of sci-

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[19] J. Darrell Barnard, "What Can Science Contribute to the Liberal Education of All Children," The Science Teacher, XXXII (November, 1965), 24.

[20] Gregor A. Ramsey and Robert W. Howe, "An Analysis of Research on Instructional Procedures in Secondary School Science," Part I -- Outcomes of Instruction, The Science Teacher, XXXVI (March, 1969), 68.

[21] Victor H. Noll, "Measuring the Scientific Attitude," The Journal of Abnormal and Social Psychology, XXX (July-September, 1935), 145.

entific attitudes as one of the important objectives of science teaching.[22]

Although there is a diversity of opinion about what constitutes scientific attitude, there is a considerable degree of agreement. Hurd describes the scientific attitude as characterized by open-mindedness, the desire for accurate information, confidence in procedure, and the expectation that a problem may find solution through use of verified knowledge.[23] According to Dewey, the scientific attitude is composed of such qualities as "openmindedness, intellectual integrity, observation, and interest in testing their opinions and beliefs. . . ."[24] Haney states:

> To be scientific means that one has such attitudes as curiosity, rationality, suspended judgment, open-mindedness, critical-mindedness, objectivity, honesty, and humility.[25]

More importantly, he feels that the scientific attitude applies to all areas of life and is essential for living in modern times.

> Problem-solving skills are essentially amoral. Knowledge and intellectual prowess divorced from the controlling influence of desirable attitudes toward man and nature contribute to the phenomenon which Robert Cohen termed the 'frustration of humane living inherent

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[22]Rethinking Science Education, p. 34.

[23]Ibid.

[24]John Dewey, "The Supreme Intellectual Obligation," Science Education, XVIII (February, 1934), 2.

[25]Richard E. Haney, "The Development of Scientific Attitudes," Science Teacher, XXXI (December, 1964), 33.

in science of the twentieth century.'[26]

This similarity in the descriptions of scientific attitude suggests that a collection of the views of scientists and philosophers would be useful in determining a conclusive definition of the scientific attitude. Noll in 1935 expressed such a need when he stated:

> Specifically, might it not be desirable, and perhaps profitable, to begin by attempting to set forth a reasonable definition and description of the scientific attitude from the scientist's and the philosopher's point of view, and then to construct measures in accordance with the description thus evolved.[27]

Noll recognized the intangibility of measuring "a method of reacting or a viewpoint towards things in general."[28] Noll meant that scientific attitude is concerned with a person's response to any specific matter, for instance, racism. Furthermore, it would take a large number of tests to show how scientific an individual's attitudes are in general. A more practical approach would be to study scientific attitude as it is applied to one field. Vitrogan[29] conducted such an investigation in his study of attitude when he restricted its scope to one's attitude toward science.

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[26]Ibid.

[27]Noll, 147.

[28]Ibid.

[29]David Vitrogan, "Characteristics of a Generalized Attitude Toward Science," School Science and Mathematics, LXIX (February, 1969), 150.

Problem-Solving as a Method of Secondary Science Education

Most science educators concur in advocating problem-solving as a method of realizing such objectives of science teaching as understandings and attitudes. Barnard expresses the view that the method of inquiry used by scientists should be emphasized:

> Methods of inquiry are largely responsible for the successful development of the natural sciences. Physicists ask questions of nature and get answers in a variety of ways. These 'ways' of the physicists are characteristic of science. They deserve to be more widely known.[30]

The Science Advisory Committee to President Eisenhower recommended problem-solving in the following statement:

> Courses are needed which help the student think his way through and appreciate . . . how scientific concepts and laws are discovered, evaluated and tested.[31]

One would expect such a consensus of opinion to lead to widespread adoption of problem-solving as a method in science teaching. However, although recent literature in science education has stressed inquiry, the inquiry method has not been extensively employed.

Teachers generally do not use problem-solving as a means, nor do they stress the skills of inquiry as an important end of science teaching. According to a recent

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[30] J. Darrell Barnard, Physics in Your High School (New York: McGraw-Hill Book Company, Inc., 1960), p. 6.

[31] Education for the Age of Science, A Statement by the President's Science Advisory Committee (Washington, D.C.: U.S. Government Printing Office, May 24, 1959), p. 19.

survey of 1,112 school systems, Brandwein concludes:

> . . . Roughly 90 percent of the physics and chemistry and earth science teachers observed lecture 90 percent of the time in the classroom.[32]

Boeck points out the contradiction between the endorsement of problem-solving as a technique and the infrequency of its practice when he says:

> Teachers of science have wholeheartedly accepted this truly significant objective: The student should know and be able to use the methods of science in the solution of problems and display an accompanying scientific attitude. This acceptance, however, has not necessarily meant that anything constructive is being done in science classes to assure attainment of this objective by the students. Instead there has been a feeling or a hope that the typical pattern of teaching and materials in science courses is sufficient to bring about the desired results. Research findings indicate that possession of a scientific attitude and the ability to use the methods of science on the part of students are not natural consequences of being a member of a science class.[33]

The contradiction that is apparent between theory and practice is the result of several factors. Little of the research investigating problem-solving can be directly applied by the classroom teacher. Gross and McDonald report:

> In 1941 when Glaser was preparing his own research on critical thinking, out of some 340 studies which he reviewed he found fewer than thirty holding any practical application for teacher use in the classroom.[34]

Mowrer found, moreover, that few usable studies were done in

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[32]Paul F. Brandwein, "Observations on Teaching: Overload and 'The Methods of Intelligence,'" The Science Teacher, XXXVI (February, 1969), 38.

[33]Clarence H. Boeck, "Teaching Chemistry for Scientific Method and Attitude Development," Science Education, XXXVII (March, 1953), 81.

[34]Gross and McDonald, 259.

the ten years following Glaser's research.[35]

Even if the experimental findings of studies on problem-solving were meaningful, such findings have not been made available to the average teacher. With the exception of sections devoted to problem-solving in two yearbooks of the National Society for the Study of Education, most of the literature is not in a form easily utilized by the teacher in the lower schools.[36]

Perhaps the primary stumbling-block to employing more problem-solving in the classroom are the differing conceptions of what is involved in problem-solving. Gross and McDonald, who have conducted an extensive study of problem-solving, found that:

> There is at present no common agreement on what is meant by 'problem-solving behavior,' and, as a consequence, there is considerable diversity in the kinds of behavior that have been investigated as well as in the methods of investigation.[37]

Although problem-solving is accepted in theory as an effective teaching method, proof is needed to verify its significance in achieving the important goals of science education. Brandwein, science editor for Harcourt, Brace, and World, discusses the basic assumption by science educators of the effectiveness of problem-solving as a method and the corresponding lack of proof of its effectiveness:

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[35] O. H. Mowrer, "Learning as Problem Solving," _Review of Educational Research_, XXII (December, 1952), 478-81.

[36] Gross and McDonald, 259.

[37] _Ibid._

> Underlying the observations and discussion in this brief paper is the hypothesis that one learns the art of investigation by investigating, by giving students opportunities in true experimental procedure. I have pursued this hypothesis for many years, beginning with a search into the nature of those who would become scientists. The hypothesis remains unproved.
>
> . . . .at present, we must emphasize that there is little or no valid evidence that instruction and practice in the art of investigation in the elementary or high school years produces better students, better scientists, or better learners. To repeat, this remains hypothetical. Most practitioners in teaching merely assume that school science would be improved if students learned through investigation.[38]

Kruglak also expresses the need for proof that inquiry skills practiced in the laboratory are essential to the aims of science education:

> As scientists we are forced to admit that there is little objective evidence at present to tell us whether or not we are achieving the explicit and implicit aims of laboratory instruction.[39]

<u>Are the Behavioral Practices Employed in Problem-Solving Related to Understanding Science and a Positive Attitude Toward Science?</u>

The outcome of any educational endeavor is reflected in the behaviors of the student. Evidence that problem-solving does lead to the attainment of the important objectives of science teaching would appear, therefore, in the behaviors of the student. The confusion about what is involved in and meant by problem-solving points to the need for a compilation of the various behaviors that science

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[38]Brandwein, 39.

[39]Hyam Kruglak, "Evaluating Laboratory Instruction by Use of Objective-Type Test," <u>American Journal of Physics</u>, XXVI (January, 1958), 32.

educators associate with problem-solving. In addition, an evaluation of those behaviors is essential to determine which are most effective in promoting an understanding of science and a desirable attitude toward science.

Curtis recognized the importance of the relationship between understanding science, scientific attitude and student behaviors:

> Emphasis on the scientific attitudes, like that on scientific principles is not out-moded. . . . It is discouragingly difficult to inculcate them in boys and girls to the extent that the latters' subsequent behaviors will reflect them. But there is no hope if we assume a defeatist attitude toward attempts at such inculcation.[40]

Barnard saw the need of investigating student behaviors in an attempt to teach attitudes toward science:

> If science teachers are concerned about teaching the attitudes and methods of science so that they relate in a more functional manner to the education of young people in a democracy, they need to direct both the content and methods of their courses toward the achievement of positive overt behaviors.[41]

Therefore it appears that a need exists for offering experimental proof as to which behaviors really do relate to an understanding of science and an attitude toward science. The conclusion based on experimental evidence will be in usable terms for the teacher who is interested in

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[40]Francis D. Curtis, "The Thirty-First Yearbook in Retrospect and a Look to the Future," Science Education, XXXVII (February, 1953), 33.

[41]J. Darrell Barnard, "Teaching Scientific Attitudes and Methods in Science," The Bulletin of the National Association of Secondary School Principles, XXXVII (January, 1953), 181.

teaching for an understanding of science and a positive attitude toward science. Moreover, such a study should form the basis for more effective laboratory work, as well as for a measuring instrument more meaningful than achievement tests measuring factual information.

The Importance of Physics in Education

The physics course is valuable in fulfilling the goals of education in general and the specialized aims of science teaching. Today, more than ever, students grow up in a world where they witness technological phenomena. By means of radio and television students instantaneously share in the scientific exploits of our time. Rutherford points out the vital role that physics plays in contemporary society in the following words:

> Without such a study, as Galileo said, one may be lost in a dark labyrinth and not even know it; to be ignorant of physics may leave one unprepared for living in his own time. Some knowledge of physical science is required to participate or even to be an intelligent spectator in the great human adventures of our time. An appreciation of physics is needed to be an effective citizen and effective wage-earner today.[42]

While there are no rigid boundaries separating the scientific disciplines, physics does have a unique contribution to make to the sciences.

> Because physics concentrates on ultimates -- the ultimate particles of which all matter is built up, the ultimate principles that govern their interactions -- all other sciences rely upon physics for their own founda-

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[42] F. James Rutherford, Harvard Project Newsletter No. 7 of Harvard Project Physics (Spring, 1968), 3.

tions. Thus the study of physics is prerequisite to the serious pursuit of any science.[43]

Present Aims of Physics

The current aims of physics are best expressed in the objectives of two national curriculum revisions in physics. The earliest of these, the Physical Science Study Committee (PSSC), undertook to emphasize the process of science. It sought to introduce a spirit of inquiry in the teaching of physics. The Committee constructed a definite set of goals:

(a) to present physics as a unified yet living and ever changing subject

(b) to demonstrate the interplay between experiment and theory in the development of physics

(c) to have the students learn the basic principles and laws of physics by interrogating nature itself, thus learning not only the laws but also the evidence for them as well as their limitations

(d) to extend the student's ability to read critically, to reason and to distinguish between the essential and the peripheral, thereby improving his learning skills in general

(e) to provide a sound foundation for those students who plan to study science or engineering at the college level.[44]

A more recent curriculum revision of physics is the Harvard Project Physics. It too stresses understandings rather than factual information. Rutherford, the director,

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[43]Arthur Beiser, The Science of Physics (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1964), p. 1.

[44]Uri Haber-Schaim, "The PSSC Course," Physics Today, XX (March, 1967), 26.

outlines the goals of the Project in the following statement:

> . . . we are unalterably opposed to the rote memorization of the mere facts and minutiae of science. By contrast, we stand foursquare for the teaching of the scientific method, critical thinking, the scientific attitude, the problem-solving approach, the discovery method, and, of special interest here, the inquiry method. In brief, we appear to agree upon the need to teach science as process or method rather than as content.[45]

The origin of the present goals of physics are an outgrowth of an idea expressed by the Committee of Ten in 1893. A subcommittee of the Committee of Ten established by the National Education Association to investigate the high school curriculum examined the state of physics, chemistry, and astronomy. The subcommittee recommended (1) that physics be taught in the last year of high school so that the student would have sufficient time to acquire a thorough knowledge of mathematics; (2) that physics be required for admission to college; (3) that the teaching method employed be a combination of laboratory work, textbook, and authoritarian instruction; (4) that the laboratory work be largely quantitative; and (5) that the aim of the laboratory should be <u>to make a rediscovery of the laws of physics</u> (underlining mine).[46] The Committee offered little advice, however, on how to achieve this objective.

The objectives of the physics course as outlined in a publication of the National Society for the Study of Edu-

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[45]F. James Rutherford, "The Role of Inquiry in Science Teaching," *Journal of Research in Science Teaching*, II (1964), 80.

[46]*Report of the Committee of Ten of the National Education Association* (New York: American Book Company, 1894), p. 119.

cation in its Thirty-first Yearbook reflect the influence of the Seven Cardinal Principles of Secondary Education. These objectives indicate that factual knowledge as a goal of physics teaching was being superseded by those understandings and attitudes involved in making judgments. In the Thirty-first Yearbook, A Program for Teaching Science, three main goals of physics teaching were listed:

> I. Pupils in high school physics courses should develop better understandings (underlining mine) of the abilities to use those fundamental concepts and major generalizations of physics that will enable them to interpret natural phenomena, common applications to physical principles and industrial applications of physics.
>
> II. Pupils in high school physics classes should learn to use the process of reflective thinking and problem solving (underlining mine) which is best adapted to the solution of problems within the field of physics. This is to be interpreted as 'training in scientific methods' insofar as such methods are used in the field of physics and can be produced within the limits of one year's work within this field at the senior-high level.
>
> III. Pupils in senior-high school physics should develop those attitudes (underlining mine) towards facts and principles of physics and towards the methods of investigation employed in the field which will serve as guides in their use of physics materials and methods of problem solving.[47]

In essence these objectives of physics teaching may be summarized as the development of understandings, reflective thinking and problem-solving, and appropriate attitudes. These same basic aims were propounded by the two curriculum com-

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[47]National Society for the Study of Education, A Program for Teaching Science, Thirty-first Yearbook of the National Society, Part I (Bloomington, Illinois: Public School Publishing Company, 1932), pp. 250-51.

mittees involved in the revision of the physics course.

Failure to Meet the Current Aims of Physics

In the middle '50's several science educators (Kelley, Mallinson, F. Dow Smith[48]) expressed serious concern about the state of high school physics and its future. Additional discontent was reflected in the Agenda of the Greenbrier NRC-AIP Conference on the Productions of Physicists (1956):

1. Failure of high school physics enrollments to keep pace with expanding enrollments in the secondary school.
2. The fact that in each generation there are more than enough high ability youth to meet the demands which might be made by society for trained scientists and technicians, but that physics had not been able to interest the youth in such a career.
3. A critique of the teaching objectives in the secondary schools and the dilution of the school curriculum due to the elective system and inadequately prepared teachers.
4. The need for new and more equipment in the laboratories of secondary schools.
5. General deterioration of textbooks due to the dilution of concepts and the addition of numerous 'facts of science' in the form of practical applications.[49]

Student dissatisfaction with the physics course is apparent from enrollment figures. The decline in enrollment in physics courses from 1900 to 1954 is startling:

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[48]W. C. Kelley, "Will Physics Disappear From Our High Schools?" The Science Counselor, XVII (September, 1954), 88-89; George Mallinson, "The Role of Physics in the Merging High School Curriculum," School Science and Mathematics, LV (March, 1955), 210-16; and F. Dow Smith, "A Letter to Physics Teachers," School Science and Mathematics, LIV (March, 1954), 224-32.

[49]"National Research Council-American Institute of Physics Conference on Productions of Physicists," Greenbrier Hotel, White Sulphur Springs, Virginia, Physics Today, VIII (June, 1955), 6.

> Figures show that from a total enrollment reported in 1900 for the schools studied, 19% of the high school pupils were taking physics, while in 1954 there was a scant 4.6% of the high school population enrolled. This latter figure included only 24.5% of graduating classes.[50]

Except for a slight upsurge in enrollment after the PSSC course was introduced (1958), a further decline occurred.

> Recently compiled U. S. Office of Education figures for high school physics enrollments in 1964-65 confirm the long-term trend: far more students than ever before are taking no physics of any kind, and the percentage of high-school students in physics courses is at or near an all-time low.[51]

Although PSSC sought to emphasize understanding and the spirit of inquiry in the physics course, the program was never intended for every student. The Physical Science Study Committee designed its program for "the top 25% of the student population who are now taking high school physics."[52] Haber-Schaim relates the effect of this emphasis on enrollments:

> . . . . Although mathematical prerequisites were kept to a minimum . . . and with the content restricted to fundamentals, the course presents a considerable challenge to students and teachers alike. In this context, the Physical Science Study Committee never considered it to be its aim to increase the enrollment of students in high-school physics.[53]

Hurd, in "The Case Against High School Physics,"

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[50] Samuel Powers, "Physical Science in Our Secondary Schools," American Journal of Physics, XXVII (September, 1959), 420.

[51] Harvard Project Newsletter No. 4 of Harvard Project Physics (Winter, 1966), 10.

[52] "Physical Science Study Committee -- A Planning Conference," Physics Today, X (March, 1957), 28-29.

[53] Haber-Schaim, 31.

forecasts the final results of this decline in enrollment:

> . . . it [physics] is the most likely subject to be eliminated from the high school curriculum within the next decade as a separate science.[54]

Holton shares his concern:

> The whole problem of physics-course enrollments is nothing short of a national emergency. Out of two and one-half million high school seniors, more than two million take no physics; that is, more than 80% take none. As far as PSSC is concerned, though it is excellent for the kind of student it was meant for, still only about 4% of seniors took this course in 1964-65, according to recently released US Office of Education figures. . . . the decline in physics enrollments is extending into the colleges. Clearly if physicists are not to lose contact with society, some way must be found to overcome this trend. This job is far from done![55]

An examination of the methods employed in teaching physics appears necessary so that the important goals of understanding science and a positive attitude toward science are realized. Brandwein, who believes that the inquiry method is the most effective means of achieving the important goals of science education, recently reported in his observations of 1,112 school systems:

> . . . In the vast majority of cases (ca. 96-99 percent), where the laboratory was used in instruction, the laboratory materials were prepared in advance to the end that a satisfactory conclusion would be reached within the time limit of the laboratory period. . . . That is to say, the laboratory 'experiment' was not an 'experiment' at all -- but an exercise. . . . in the vast majority of school systems, ca. 95 percent, not one experiment . . . was planned or completed by the vast majority of high school students.[56]

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[54]Paul DeHart Hurd, "The Case Against High School Physics," School Science and Mathematics, LIII (June, 1953), 439.

[55]Gerald Holton, "Harvard Project Physics," Physics Today, XX (March, 1967), 31.

[56]Brandwein, 38.

His conclusion that the inquiry method is rarely used is significant:

> In fewer than 5 percent of the schools was a single student given the opportunity to experiment in the sense of the term used here. Inquiry -- as the relentless pursuit of a hypothesis in proof or disproof -- was generally not practiced. (underlining mine)[57]

The Necessity of Investigating Means for Achieving the Goals of Physics Instruction

An understanding of science and a positive attitude toward science are among the important aims of science teaching. Science educators generally agree that problem-solving is the most effective method for attaining these goals. However, little is known about the specific behaviors of science students engaged in problem solving. Science educators have also suggested numerous behaviors associated with problem solving which they theorize are related to understanding science and a positive attitude toward science. It is necessary, therefore, to determine which behaviors most effectively promote these important goals of science teaching.

Since the goals of physics have not been achieved, and since physics is basic to science, it should be the subject of investigations designed to make it a more meaningful course. One manner in which it is believed that significant improvement can be effected is by the identification of those behaviors that are related to the goals of

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[57] *Ibid.*

physics teaching. Then physics can be reinstated as a significant subject in the secondary school curriculum.

> We cannot take a single step forward in any inquiry unless we begin with a _suggested_ explanation or solution of the difficulty which originated it. Such tentative explanations are suggested to us by something in the subject matter and our previous knowledge. When they are formulated as propositions, they are called hypotheses. . . . The function of a hypothesis is to _direct_ our search for order among facts. The suggestions formulated in the hypothesis _may_ be solutions to the problem. _Whether_ they are, is the task of the inquiry.[1]
>
> F. S. C. Northrop 1948

CHAPTER II

THE PROBLEM

Need for the Present Study

The trend of both general and science education is away from the attainment of factual knowledge and toward the acquirement of understandings and attitudes which prepare the student to make judgments. A consensus of opinion exists among general and science educators that the problem-solving experience provides the most effective means of developing those understandings and attitudes essential for living in the twentieth century.

However, science educators recognize that the very means they are advocating demand further clarification and definition. Certain behaviors have been suggested by science educators as characteristic of the problem-solving technique, but none of the recommended behaviors have been

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[1]F. S. C. Northrop, _The Logic of the Sciences and the Humanities_ (New York: The Macmillan Company, 1948), p. 11.

tested and verified as to their effectiveness in promoting the important goals of science teaching. Therefore, there is a need to determine which behaviors associated with the problem-solving approach are most efficacious in fostering an understanding of science and a positive attitude toward science.

Since the objectives of high school physics instruction have not been attained, and since physics is considered a basic science dealing with ultimates, it is a suitable science subject to study for the relative effectiveness of suggested behaviors in achieving the significant goals of science education.

Statement of the Problem

What scientific behaviors, as exhibited by college preparatory physics students in selected high school classes, are related to an understanding of science and a positive attitude toward science?

Purpose of the Study

The purposes of this study were: (1) to identify and state those behaviors which, in the opinion of various scientists and science educators as expressed in their written statements, might foster an understanding of science and a positive attitude toward science; and (2) to determine which scientific behaviors as exhibited by students in selected high school physics classes are related to an understanding of science and a positive attitude toward science.

Hypotheses

Null hypothesis A -- No significant difference in understanding of science as measured by Test on Understanding Science[2] (part III -- methods and aims of science) exists between students practicing behaviors 1, 2, . . . 18 and students not practicing them.

Null hypothesis B -- No significant difference in understanding of science as measured by Test on Understanding Science (total score) exists between students practicing behaviors 1, 2, . . . 18 and students not practicing them.

Null hypothesis C -- No significant difference in an attitude toward science as measured by Vitrogan's Attitude Scale[3] exists between students practicing behaviors 1, 2, . . . 18 and students not practicing them.

Behaviors Hypothesized to Relate to an Understanding of Science and a Positive Attitude Toward Science

The following behaviors resulted from a systematic survey of the literature[4] of science educators.

(1) The student contributes to the procedure for solving a laboratory problem.

(2) The student constructs graphs and interprets them.

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[2]William W. Cooley and Leo E. Klopfer, Test on Understanding Science. Cambridge, Massachusetts: Harvard University Press, 1961.

[3]David Vitrogan, "Characteristics of a Generalized Attitude Toward Science," School Science and Mathematics, LXIX (February, 1969), 150-58.

[4]See Appendix IV.

(3) The student obtains, analyzes and interprets data.

(4) The student designs equipment.

(5) The student establishes the limitations of the experimental conclusions.

(6) The student uses unassigned reference material (excluding textbook).

(7) The student develops ways of testing his proposed conclusions.

(8) The student constructs conceptual models.

(9) The student criticizes his results.

(10) The student relates principles from one subject area to another.

(11) The student selects the mathematical operations to be performed on quantitative information.

(12) The student writes an essay report.

(13) The student observes and records accurately.

(14) The student realizes the limitations of the instrument he is using.

(15) The student re-evaluates his ideas and opinions.

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

(17) The student proposes additional problems as a result of laboratory activities.

(18) The students work on different problems at the same time.

Limitations of the Study

Any conclusions that can be drawn from the findings of this study are necessarily limited by the following:

1. The relatively small number of classes and the small population of each class. Ten classes participated in this study; the population of the classes ranged from 8 to 22.

2. The selection of high school classes observed during the school year 1968-69. In so far as possible, the investigator selected classes that either exhibited a majority of the behaviors or exhibited few.

3. The assumption that the instrument (Test on Understanding Science) does measure an understanding of science.

4. The assumption that the instrument (Vitrogan's Attitude Scale) does measure an attitude toward science.

5. The assumption that an environment conducive to the hypothesized behaviors will produce a greater incidence of high test scores.

6. The assumption that the behaviors observed were representative of a class' performance in all aspects of the physics course throughout the year.

7. The ability and objectivity of the two raters.[5]

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[5]Mark Waltz, an associate, who conducted a parallel study in chemistry, cooperated in surveying the literature, identifying the behaviors, and observing and rating class performances.

Definition of Terms

attitude -- For the purpose of this study, attitude is described as

> mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related. . . .[6] Attitudes regulate behavior that is directed toward or away from some object or situation or group of objects or situations. Attitudes have emotional content and vary in intensity and generality according to the range of objects or situations over which they apply. For the most part, attitudes are learned and are difficult to distinguish from such affective attributes of personality as interests, appreciations, likes, dislikes, opinions, values, ideals, and character traits.[7]

behavioral objectives -- For the purpose of this study, a goal for, or a desired outcome of, learning which is expressed in terms of observable behavior or performance of the learner.[8]

a positive attitude toward science -- For the purpose of this study, a positive attitude toward science is characterized by:

> . . . an ability to differentiate between controlled and reliable observation as opposed to casual observation . . . a basic notion that reality is to be regarded as a process implying continuous change; . . . structure in the form of relations and equations will be stressed over function; . . . greater concern for research rather than findings; greater emphasis on the inquiring, the questioning rather

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[6]Gordon Allport, "Attitudes," Handbook of Social Psychology (Worcester, Massachusetts: Clark University Press, 1935), p. 806.

[7]Richard E. Haney, "The Development of Scientific Attitudes," The Science Teacher, XXXI (December, 1964), 34.

[8]Earl J. Montague and John J. Koran, Jr., "Behavioral Objectives and Instructional Design," The Science Teacher, XXXVI (March, 1969), 10.

than the final answers obtained; . . . .[9]

process of inquiry -- For the purpose of this study, synonyms include scientific method, scientific methods, problem solving, problem doing, discovery, inquiry, processes of the scientist, processes of science, strategies for inquiry, strategies for problem solving, the "methods of intelligence."[10]

scientific attitude -- For the purpose of this study, to exhibit a scientific attitude "one has such attitudes as curiosity, rationality, suspended judgment, open-mindedness, critical-mindedness, objectivity, honesty, and humility."[11] A person may exhibit a scientific attitude towards any object or situation (like racism). It does not necessarily need to be found in the field of science.

understanding science -- For the purpose of this study, understanding of science is limited to understandings of the scientific enterprise, including such themes as the human element in science, communication among scientists, scientific societies, instruments, money, international character of science, and the interaction of science and society; understandings of the scientists, including such themes as institutional pressures on scientists, abilities needed by scientists, and generalizations about science; and under-

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[9]Vitrogan, 151.

[10]Paul F. Brandwein, "Observations on Teaching: Overload and 'The Methods of Intelligence,'" The Science Teacher, XXVI (February, 1969), 38.

[11]Haney, 33.

standings of the methods and aims of science, including such themes as generalities about scientific methods, tactics and strategy of sciencing, theories and models, aims of science, accumulation and falsification, controversies in science, science and technology, and unity and interdependence of the sciences.[12]

[12]Cooley and Klopfer, pp. 3-4.

For indeed it is one of the lessons of the history of science that each age steps on the shoulders of the ages which have gone before. The value of each age is not its own, but is in part, in large part, a debt to its forerunners.[1]

Sir Michael Foster, 1901

The first process therefore in the effectual study of science must be one of simplification and reduction of results of previous investigation to a form in which the mind can grasp them.[2]

James Clark Maxwell, 1855

CHAPTER III

REVIEW OF RELATED STUDIES

An understanding of science and a positive attitude toward science are among the important objectives of science teaching. Science educators generally agree that problem-solving is the most effective method for attaining these goals. However, although the effectiveness of a teaching method is manifested in a student's behavior, few studies on problem-solving have been conducted to determine which student behaviors are related to an understanding of science and a positive attitude toward science. Therefore, the review of related literature focuses on those studies designed to investigate an understanding of science, a favorable attitude toward science, and problem-solving as a science teach-

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[1]Sir Michael Foster, History of Philosophy, 1901, quoted in Scientific American, XX (June, 1959), 2.

[2]James Clark Maxwell, quoted in Phillipp Frank, Philosophy of Science (Englewood Cliffs, N.J.: Prentice-Hall, 1957), p. 308.

ing method.

Trent in 1965 attempted to compare the relative effectiveness of the traditional high school physics curriculum and the curriculum developed by the Physical Science Study Committee (PSSC) in attaining the objective "understanding of science." The term, understanding of science, as used by Trent in his study, referred to "the development of science and the scientific enterprise, the structure and methods of science, and science as a product of human intelligence"[3] as measured by the Test on Understanding Science.

Twenty-six schools were selected from forty-one available PSSC schools in California. The term "PSSC course" referred to a physics course in which the textbook and associated materials prepared by the Physical Science Study Committee were employed. The criteria for the twenty-six traditional schools selected for the study included: (1) a physics course taught in the junior or senior years; (2) a physics course which was a college preparatory science course; and (3) a course in which the PSSC textbook was not used. Experimental mortality, prior achievement of science, and scholastic aptitude were controlled. Uniformity in testing procedures was not ensured, since local teachers administered the tests.

[3]John Henry Trent, "The Attainment of the Concept 'Understanding Science' Using Contrasting Physics Courses" (Ann Arbor, Michigan: University Microfilms, 1965).

According to the results of Trent's study, the traditional and PSSC groups exhibited no significant difference in understanding science. It was suggested that more research designed to develop points of view and attitudes desirable for teacher and student be conducted. In addition, it was recommended that the characteristics of those classes that performed well on understanding of science be investigated.

Also in 1965, Crumb, in a study similar to Trent's, sought to determine if there was a significant difference in understanding science between students who had studied PSSC physics and those who had studied traditional physics. Crumb also attempted to "investigate the methods used by those teachers whose classes show a maximum mean gain in understanding science."[4] The PSSC course referred to one organized around the PSSC textbook and curriculum materials; the traditional course was defined as one not utilizing the PSSC materials. Teacher background was investigated to determine whether the teachers of both groups had been PSSC trained. The study population consisted of 1275 physics students from twenty-nine rural and urban high schools in four central states. Because of the possibility of mental ability and student's prior science background influencing their achievement in understanding science, these factors

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[4]Glenn H. Crumb, "A Study of Understanding Science Developed in High School Physics" (Ann Arbor, Michigan: University Microfilms, 1965).

were the dependent variables in analysis of covariance.

In contrast to Trent's study, Crumb's analysis of data provided evidence that a significant difference in understanding science existed between those students in PSSC physics and those in traditional courses. The difference favored those who studied PSSC physics. Moreover, the results indicated that the PSSC course may have greater impact over a short period of one semester than does the traditional physics course. To achieve the second purpose of the study, a questionnaire was directed by Crumb toward teacher practices in the laboratory. According to the results of the questionnaire, the greatest difference between the traditional and PSSC teachers was the extent of student participation they encouraged.

In 1935 Noll, by incorporating the points of view of scientists and philosophers, attempted to construct an instrument to measure scientific attitude. Scientific attitude was concluded by Noll to consist of the following "habits of thinking": (1) accuracy; (2) intellectual honesty; (3) openmindedness; (4) suspended judgment; (5) looking for cause and effect relationships; and (6) criticalness, including self-criticism. Using these six habits as a basis, a large number of test questions were devised that seemed to present situations which provided opportunities for the exercise of the habits. In trial forms of the test an attempt was made to eliminate all words not common to the vocabulary of seventh grade pupils. Noll considered his work tentative and recommended further experimental work on scientific attitude.

In 1950 Boeck endeavored to compare the inductive laboratory with the deductive-descriptive laboratory. The following areas were investigated: (1) knowledge of basic facts and principles of chemistry, (2) ability to apply these principles in new situations, (3) knowledge of and ability to use the scientific method, with an accompanying scientific attitude, and (4) the development of basic laboratory skills and resourcefulness.

A chemistry class at the University of Minnesota High School was compared with eight classes, one at the High School, the other seven in the surrounding area. In the experimental group the students, with the aid of their instructor, selected the experiments and planned the procedure. As a result, according to Boeck, the problems were of real interest to the students. The students were encouraged to recognize the assumptions inherent in the laboratory procedure. After the laboratory investigation, the students discussed the generalizations together. In contrast, the deductive approach group performed the laboratory experiments from a laboratory manual after they had discussed the principles. Boeck believed that the students' utilization of the methods of science and the inculcation of scientific behavior were as important as facts and principles. Therefore, written tests were constructed to measure attainment of application of principles, application of scientific method as well as knowledge of facts and principles. All three were given as pre-tests and post-tests.

According to the results of the study, the experimental (inductive) group did as well as or better than the control group in knowledge of facts and principles and performance of laboratory techniques, but was significantly superior in knowledge of an ability to use the scientific method, with an accompanying scientific attitude. Another outcome in favor of the inductive laboratory class was the ability to apply principles to new situations. Boeck did not determine exactly which behaviors the inductive laboratory group exhibited.

In a study in 1965 Coulter sought to evaluate the effectiveness of inductive laboratory, inductive demonstration, and deductive laboratory in teaching for scientific attitude. Inductive laboratory was defined as a laboratory in which students developed their own experimental design to solve problems that arose in class discussion or were suggested by their teacher. The inductive demonstration method was identical to the inductive laboratory with the exception that after the experiment was designed by the students, it was demonstrated by the teacher. The deductive laboratory was defined as one in which the activity was organized to check or substantiate the previously discussed principles or generalizations.

Scientific attitude, as measured by Coulter's Scientific Attitude Test, was define as: (1) ability to select valid hypotheses, (2) ability to identify the fixed or insignificant factors or variables, (3) ability to identify the necessary but yet unstated assumptions, (4) ability to select the reasonable course of action, and (5) ability to recognize valid conclusions. Seventy-five ninth grade biology students at the University of Minnesota High School were randomly assigned to three treatment groups. A complete log of classroom activities was compiled.

The inductive laboratory group and inductive demonstration group both had significantly higher mean scores in attitude toward science than the deductive laboratory treatment section. It was concluded that using either of the inductive treatments resulted in significant increases in scientific attitude.

Mahan in 1963 attempted to determine the effect of problem-solving and lecture-discussion methods on the attainment of an understanding of science, problem-solving skills, attitudes, interest, and personal adjustment in ninth grade general science. The Sequential Test of Educational Progress was used to measure problem solving skills and the Allen Inventory of Attitudes Toward Science and Scientific Careers was employed to measure growth in scientific attitude.

The problem-solving method was concluded to facilitate greater growth in science knowledge, problem-solving skills, and science interests. There was also some evidence to indicate that the problem-solving method fosters greater total personal adjustment and more desirable attitudes toward school.

In a study in 1966 Sorenson sought to analyze the change in critical thinking skills between students in laboratory-centered and lecture-demonstration-centered patterns of instruction in high school biology. Four high schools in Salt Lake City were randomly selected for the study. Student evaluations included: The Cornell Test of Critical Thinking, the Watson-Glaser Critical Thinking Appraisal, Rokeach's Dogmatism Scale, and the Test on Understanding Science.

According to the results of the Test on Understanding Science, the laboratory-centered group had significantly greater gains than the lecture-demonstration group. High ability students and low ability students changed about the same in understanding science. In addition, the laboratory-centered teaching method produced significant desirable changes in dogmatism.

Lahti in 1956 endeavored to determine the effectiveness of the laboratory in developing the students' ability to use the scientific method. All students had the same lecture, but four laboratory approaches were used: the inductive-deductive (also defined as problem-solving by Lahti); the historical, the theme, and the standard "get the right answer" method. Three experimental lesson units were designed for 338 college physical science students. The first unit consisted of laboratory experiments which would reflect the "meanings" in the scientific method. The second was designed to ensure that the students used the scientific method. The third evaluated the effectiveness of the teaching methods by testing the following hypotheses: (1) Individual laboratory work does not lead to greater resourcefulness in (a) solving new problems, (b) designing experiments, (c) interpreting results of experiments; (d) utilizing facts and principles; and (2) The hour of the day at which the session met was not important.

There appeared to be no significant differences between the four groups. However, the group using the first approach (problem solving) scored highest on tests for the three experimental lessons. This result would seem to warrant further investigation with different criteria to determine if this difference was caused by other variables.

In 1938 Burnett sought to contrast a problem-solving approach with a recitation technique. Sixty-two high school biology students participated in the study. The problem-solving approach appeared to be 7 per cent more effective in increasing the ability to think scientifically, in the recall of facts, and in the development of the scientific attitude.

Included in the purposes of Perlman's study in 1953 was an attempt to determine whether consciously teaching for scientific attitudes and abilities would result in significant gains toward these objectives. College physical science laboratory experiments were taught by a contemporary problem-solving method or a historical problem-solving method. Perlman believed that the justification for the laboratory lay in the fact that students could actively participate in the inquiry process. Therefore, primary emphasis in testing was placed upon a written and a performance test of scientific problem-solving.

The contemporary problem-solving group exhibited a significant increase in the ability to "think scientifically," whereas the historical problem-solving group did not show a significant increase. It was concluded that students increase their ability to think scientifically as they become involved in immediate problems of science in various areas of life.

Balcziak in 1953 attempted to compare three methods (individual laboratory, demonstration, and a combination of these two) of teaching college physical science. Six sections were tested for the following attributes of scientific attitude: openmindedness, cause and effect, application of scientific method, and suspended judgment.

Results of the study indicated that the three methods of laboratory instruction had no significant effect on the scientific attitude scores. Since the teaching methods were not explicitly defined, the demonstration method could have been carried out inductively, thus producing the same results as the laboratory method.

O'Connell in a study in 1961 sought to compare inductive and deductive methods of teaching high school chemistry. Phase I was designed to measure achievement; the understanding of chemical-equation balancing was investigated in phase II. The deductive method was defined as the descriptive traditional type of chemistry course, utilizing laboratory manuals. The inductive method was identified as that type of chemistry instruction in which the laws and theories were to be "discovered" by the student.

In phase I, students, matched by their intelligence, were administered The Anderson Chemistry Test and the Cooperative Chemistry Test. The results of testing indicated that the inductive laboratory group attained higher scores on both achievement tests. In phase II, the evaluative instrument employed, the Symbolic Unit Test, was a locally-developed test utilizing diagrams and verbal statements. The inductively-taught group also achieved higher scores in chemical-equation balancing.

Kruglak conducted a number of studies during the 1950's in an attempt to investigate the worth of the laboratory. In a study in 1952 he undertook to contrast two methods of teaching a non-technical physics course. Students were randomly assigned to a manual-report type of laboratory or to a demonstration group. A theory test, a written laboratory test, and two practical laboratory tests were the evaluative instruments.

It was concluded that the manual-report method was more effective than the demonstration method for teaching techniques and use of apparatus. Neither method was superior for the more complex laboratory problems. According to the results of the study, it would seem that the demonstration approach is as satisfactory as the conventional laboratory in teaching for understanding of elementary physical principles.

Cooley and Bassett in a study in 1954 endeavored to construct an instrument to measure understanding science. The instrument devised considered such aspects of understanding science as the image of science and scientists; understandings of the distinctions between science and technology; and an awareness of the nature of the scientific process. The test was administered to talented secondary school students who had worked with scientists in a ten-week summer program at Thayer Academy, Braintree, Massachusetts. The significant conclusion of the study indicated that a test could be designed which effectively measured a gain in a student's understanding of science and the scientist.

In 1935 Baumel and Berger sought to investigate the relationship between scientific attitude and science scores. They constructed an instrument designed "to keep within the range of student experience, avoid the expected-response type of question, and eliminate the need for a complicated response on the part of the student."[5] The test was administered to ninth grade general science students at the end of the school year. The results showed no relationship between high scores in science and scientific attitude.

Other investigators, including Davis (1935), Hoff (1936), and Wessel (1944) have also contributed to the field of scientific attitude.

Summary

The conflicting results of Trent and Crumb's studies suggest that the proper variables may not have been identified in at least one of these studies. PSSC physics should have been defined more explicitly than a course employing the PSSC textbook, since there is considerable evidence that every PSSC physics teacher may not be in agreement with the philosophy and aims of the PSSC Committee. Moreover, it is possible for a teacher to put into practice the inquiry approach outlined by the PSSC Committee without using their textbook. Within Trent and Crumb's definitions of a traditional class, the possibility also exists that a traditional class could exhibit behavior identical to the aims and processes of PSSC physics. A valid way to determine whether the processes and methods of PSSC are being utilized is to observe the students in the classroom.

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[5]Howard B. Baumel and J. Joel Berger, "An Attempt to Measure Scientific Attitudes," Science Education, XLIX (April, 1965), 268.

Studies dealing with the inductive-deductive methods also showed conflicting results. Again, this disagreement may indicate that in some studies, the proper variables were not isolated. Few of the reports completely identified the teaching methods. However, a majority of the reports contrasting the inductive-deductive methods favored the inquiry approach.

A teaching method may be clearly defined by carefully describing the resulting student behavior. Then, investigation designed to identify specific behaviors which promote an understanding of science and an attitude toward science could be conducted.

I shall begin by making some experiments before I proceed any further; for it is my intention first to consult experience and then show by reasoning why that experience was bound to turn out as it did. This, in fact, is the true rule by which the student of natural effects must proceed although nature starts from reason and ends with experience, it is necesssry for us to proceed the other way around, that is -- as I said above -- begin with experience and with its help seek the reason.[1]

Leonardo da Vinci 1500

CHAPTER IV

DESIGN OF THE STUDY

Introduction

An understanding of science and a positive attitude toward science are among the important aims of science teaching. Science educators generally agree that problem-solving is the most effective method for attaining these goals. The results of a teaching method are manifested in a student's behavior. Science educators have suggested numerous behaviors associated with problem-solving which they theorize are related to an understanding of science and a positive attitude toward science.

Previous studies designed to determine the effectiveness of problem-solving usually did not include an adequate description of the teaching methods. Since a

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[1]Leonardo da Vinci, Notebooks, circa 1500, quoted in Scientific American, CXCIX (October, 1958), 1.

variety of behaviors are related to problem-solving, the need for a more explicit description other than the simple inductive-deductive or laboratory-demonstration dichotomy is evident.

Therefore, it would be of value to examine the literature of well-known scientists and science educators in an attempt to ascertain what behavioral patterns they hypothesize to be associated with an understanding of science and a positive attitude toward science. Then, classes exhibiting these behaviors could be studied to determine whether the hypothesized behaviors do in fact promote an understanding of science and a positive attitude toward science.

The Development of the Criteria

The writings of prominent scientists and science educators since 1900 were systematically surveyed for statements suggesting behaviors relating to an understanding of science and an attitude toward science. Initially there appeared 82 such statements, obtained from approximately 200 articles and books. After duplications were omitted, the list was reduced to 42 behaviors practiced by both teachers and students. Those statements suggesting student behaviors were rephrased into behavioral terms, according to the suggestions of Kurtz, Andersen, and others.[2]

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[2]Edwin B. Kurtz, Jr., "Help Stamp Out Non-Behavioral Objectives," The Science Teacher, XXXII (January, 1965), 31; and Hans O. Andersen, "Preparing Performance Objectives," Readings in Science Education for the Secondary School (New York: The Macmillan Company, 1969), p. 154.

Through combinations, and the elimination of those behaviors difficult to observe, a list of 19 overt behaviors was devised.

The list of behaviors was analyzed in actual classroom situations to assure that they were readily observable. By this procedure, one item was omitted, and three others were modified. As a result the final list consisted of 18 behaviors theorized by scientists and science educators to promote an understanding of science and a positive attitude toward science.

An evaluative instrument was developed from the list of behaviors. Two samples from the evaluative instrument are: (See Appendix I for the complete list of behaviors.)

2) The student constructs graphs and interprets them.

6) The student uses unassigned reference material (excluding textbook).

Note was taken during class observation of the number of students performing or not performing each behavior or whether the behavior applied to the laboratory problem. When all the classes had been observed, a percentage point was selected to establish a dichotomy for each scientific behavior, for all the students in a class would not exhibit the same scientific behaviors. Since it is difficult to make a distinction within a few percentage points, either 25%, 50%, or 75% were used to determine whether a behavior was checked as "yes" (it was practiced by the students) or "no" (it was not practiced by the students).

Description of the Subjects and Their Selection

Since it is a recognized statistical procedure to operate with the ends of a continuum, the investigator selected classes that either exhibited a majority of the behaviors, or exhibited few. Recommendations from a science educator and secondary science teachers formed the basis for contacting the schools and teachers.

The schools chosen for the study cooperated in the following ways: (1) The teacher consented to the observation of physics classes by the investigator and an associate; (2) The teacher permitted the administration of TOUS and VAS during physics class time; (3) The teacher discussed such information as the nature of the classroom activities (i.e., the teaching method employed) and the textbook used; and (4) The principal and, in some cases, the superintendent gave approval to the classes' participation in the study.

Among the fourteen administrators of the schools invited to participate in this study, two declined by reason of inexperienced physics teachers; one refused because of school committee policy; and one withdrew because of serious teacher illness. As a result, 10 classes were utilized in the study. If a school offered multiple sections of physics, an average ability group was selected.

Physics is usually a twelfth grade subject in the geographical area of this study. Seven classes in Massachusetts and three in New Hampshire were studied. In the classes selected, approximately 80% of the students were in the twelfth grade, and less than 10% of each class were girls.

Description of the Instruments

Test on Understanding Science (TOUS). -- A close relationship exists between Hurd's definition of understanding science as listed in the Fifty-ninth Yearbook of the National Society for the Study of Education and the questions included in Cooley and Klopfer's TOUS. Therefore, for physics classes, TOUS was the most suitable instrument known by the investigator for measuring an understanding of science. TOUS was relatively simple to administer and could be completed by the student within a conventional forty-five -- fifty-minute period. These two requirements were essential if the cooperation of school administrators and teachers was to be enlisted so that the test could be administered during class time.

TOUS was designed to measure three components which, according to Cooley and Klopfer, constitute an understanding of science. The instrument is sub-divided into three areas: understandings about the scientific enterprise (18 questions); understandings about scientists (18 questions); and understandings about the methods and aims of science (24 questions). The authors systematically defined each of the three areas as follows:

Area I -- The Scientific Enterprise

Theme 1. Human element in science.
2. Communication among scientists.
3. Scientific societies.
4. Instruments.
5. Money.
6. International character of science.
7. Interaction of science and society.

Area II -- The Scientist.

Theme 1. Generalizations about scientists as people.
2. Institutional pressures on scientists.
3. Abilities needed by scientists.

Area III -- Methods and Aims of Science.

Theme 1. Generalities about scientific methods.
2. Tactics and strategy of sciencing.
3. Theories and models.
4. Aims of science.
5. Accumulation and falsification.
6. Controversies in science.
7. Science and technology.
8. Unity and interdependence of the sciences.[3]

Form W of the test consists of sixty questions with four alternative answers of a multiple choice design. Suggested working time is forty minutes. The test questions and the directions are included in booklet form with student response being made on a separate, special form IBM answer sheet.

Scoring is done by determining the number of correct student responses. A student's understanding of the methods and aims of science may affect his behavior more than his understanding of the scientific enterprise and the scientist. Therefore, for the purposes of this study subscores for Area III as well as the total scores were determined.

Total possible score is 60. From the manual,[4] mean scores are given from a nationwide sample of 3009 students

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[3]William W. Cooley and Leo E. Klopfer, Test on Understanding Science (Cambridge, Massachusetts: Harvard University Press, 1961), pp. 3-4.

[4]Ibid., p. 12.

tested in October, 1960; mean score for grade eleven is 31.57; for grade twelve, 32.25. According to a study by Schmidt (1966),[5] the mean scores of 115 scientists in Iowa was 50.8.

"Reliability was determined by applying the Kuder-Richardson Formula 20 for Form X test data from 2535 students."[6] The results of that analysis showed the total reliability to be .76. The reliability is applicable to Form W as well since, except for minor improvements, it is the same as Form X.

An indication of external validity is discussed in the manual.

> TOUS was administered twice, once at the beginning of July and again at the end of August, 1960 to 78 talented high school students in two summer programs. In both these programs, the students were in active contact with working scientists. The observed significant changes in their responses to items on TOUS toward the desired 'correct' responses at the end of their summer science experience gives some indication of the validity of the test. A similar group of students who were not participating in such special summer science programs did _not_ tend to move toward the correct responses.[7]

Attitude Toward Science Scale. -- Since scientific attitude is a way of responding to any situation, a narrower field, attitude toward science, was selected by Vitrogan in his study of attitude. Vitrogan's _Attitude Toward Science Scale_ (_VAS_) is the only instrument which measures this

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[5]Donald J. Schmidt, "Test on Understanding Science: A Comparison Among Several Groups," _Journal of Research in Science Teaching_, V (1967-68), 365.

[6]Cooley and Klopfer, p. 10.

[7]_Ibid._, pp. 6-7.

attribute.

In the construction of this instrument Vitrogan reviewed the contributions to scientific thought of such philosophers as John Dewey, Karl Pearson, Wendell Johnson, Morris R. Cohen, Ernest Nagel, Bertrand Russell, Fritz Kahn, J. J. Schwab, and Lawrence K. Frank. The writings of such scientists as James B. Conant, J. Bronowski, Henri Poincare, Harlow Shapley, A. S. Eddington, H. Reichenbach, R. E. Peirls, Douglas Johnson, W. I. B. Beveridge, Charles Slichter, and W. B. Cannon were surveyed by Vitrogan for comments on attitude toward science.

From his research Vitrogan developed the following hypotheses:[8]

> A positive generalized attitude toward science is characterized by:
>
> (1) a predisposition to discern the degree in which one person or thing differs from another; a tendency to emphasize differences
> (2) a tendency to challenge authority, to test traditional beliefs and customs with actual observation and experience
> (3) a readiness to change as changing conditions require; a multiple and flexible approach to people and things
> (4) an ability to differentiate between controlled and reliable observation as opposed to casual observation
> (5) a basic notion that reality is to be regarded as a process implying continuous change; no two things are exactly alike, no one thing stays the same
> (6) structure in the form of relations and equations will be stressed over function; structure, the nature of the phenomenon, the broad unifying principle is stressed rather than application

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[8]David Vitrogan, "Characteristics of a Generalized Attitude Toward Science," School Science and Mathematics, LXIX (February, 1969), 151.

(detail) in function

(7) greater concern for research rather than findings; greater emphasis on the inquiring, the questioning rather than the final answers obtained; the form of the question is considered more important than the answer observed

(8) an emphasis on probability type explanations rather than absolute solutions.

A non-positive generalized attitude toward science is characterized by:

(1) a tendency to emphasize similarities and overlook and minimize differences; a predisposition to expect different things to be the same

(2) a predisposition to accept authority and suggestion

(3) a tendency to maintain established beliefs regardless of changing conditions; a singular and rigid approach to people and things

(4) an inability to distinguish between casual and controlled observation

(5) a static orientation where reality is viewed as having an unchanging character, a stability and constancy

(6) emphasis of the relations in the form of equations, experimental design and logic are minimized; function utility and application are stressed

(7) a preference for final answers obtained from basic questions minimizing the methods used in inquiring; the answer is considered more important than the way in which the questions are asked

(8) an acceptance of absolute solutions.

In an attempt to verify these eight hypotheses, a questionnaire was devised and administered to two groups of students. The two student groups in the 13-15 age group were selected on the basis of four criteria:

> One group . . . demonstrated a high motivational involvement with objects and ideas generally associated with science, possessed a high degree of educational development in science, obtained high achievement in science courses in secondary school, and had a high interest in science.[9]

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[9] Ibid., 154.

The other group had the opposite characteristics. As a result of the questionnaire four of the hypothetical criteria of a generalized attitude toward science (hypotheses 4, 5, 6, and 7) were substantiated. Vitrogan developed a 40-item scale, which reflected these four hypotheses, and which was expressed in the language used by students.

Vitrogan then administered the attitude scale to two other groups selected on the same basis as the original groups. From their response the null hypothesis ("No difference between the scores of the groups") was rejected at the 0.01 level of significance. Internal consistency was determined by means of item analysis.

Using the Spearman-Brown formula and the split-half method, the reliability of the attitude scale was estimated to be 0.88. Vitrogan discusses the correlations between his attitude scale and other measures of students' performance in the following:

> Low positive but statistically significant correlations were found between the attitude scale and educational development in science, the attitude scale and motivational involvement with science, and the attitude scale and achievement in science courses. The attitude scale was found to have practically a zero correlation coefficient with the Kuder Preference Record which was used as a criterion measure for identifying interest in science.[10]

"No significant correlations were found between critical thinking instruments (a highly cognitive instrument) . . . and the Vitrogan Scale."[11]

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[10] Ibid., 158.

[11] Personal Correspondence.

The VAS consists of forty statements, twenty positive, and twenty negative. This investigator arranged the order of the statements by suing a table of random numbers. In the VAS one idea is expressed in several different ways, as illustrated by the following two statements:

7. The major discoveries in the world were the result of careful observations.

12. Most discoveries could not have been made except by a lucky accident.

The students were instructed to rate the statements in the VAS either plus 1, 2, or 3, or negative 1, 2, or 3. The numbers indicate the degree of support (1 -- slight, 2 -- moderate, 3 -- strong), and the signs indicate support (+) or disagreement (-). This scaling provides for a test range of -120 to +120.

Two scoring stencils were constructed, one for the positive statements, the other for the negative statements. To determine a student's score, the sign of the negative answers was changed; then the negative score was added to the positive score.

Research Procedures and Design

From January to May, 1969, the investigator and an associate[12] evaluated student behavior using the list of 18 behaviors. The raters observed laboratories a minimum of 120 minutes and a maximum of 200 minutes; additional time

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[12]Mark Waltz, who conducted a parallel study in chemistry, cooperated in surveying the literature, identifying the behaviors, and observing and rating class performances.

was spent in classroom observation. Notes were taken on student behavior during and at the end of each session. The observers compared their notes before indicating which behaviors had been practiced in each class. Disagreement between the raters on student behaviors was resolved by further observation. Thus, the final criteria evaluation represents a composite appraisal of the two raters.

The TOUS and VAS were administered during March and April, 1969. To ensure adherence to a pre-arranged format for test administration, all tests were given under the supervision of either the investigator or his associate. Each student was supplied with a test booklet and a pencil to record his responses on the answer sheet enclosed in the test booklet. The examiners read aloud to the students the specific directions for the tests and showed the students how to respond to the sample question on the test booklet. The students were allowed exactly forty minutes uninterrupted working time for the TOUS. There was no time limitation for the VAS.

Student motivation could have been a factor in test results. If the students assumed that the test was going to contribute toward their class grade, they perhaps performed more conscientious work than if they thought the test was administered for some other reason. In addition, the format of both tests, which asked for their opinions and attitudes rather than for "right answers," was contrary to most of the students' past experience. This seemed to frustrate some students and probably lessened their motivation.

The primary statistical technique was a one-way analysis of variance F test, which is described in Dixon and Massey.[13] For each behavior the unit of analysis was the class; class scores were grouped according to those practicing and those not practicing a particular behavior. A statistically significant difference in the means of those two groups resulted in the rejection of the null hypothesis. When this occurred, the behavior stated in the null hypothesis was then concluded to promote either an understanding of science or a positive attitude toward science.

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[13] Wilfrid J. Dixon and Frank J. Massey, Jr., *Introduction to Statistical Analysis* (New York: McGraw-Hill Company, Inc., 1957), p. 145.

> If matter evades us, such as the air and light, because of its extreme thinness, if objects are located far from us in the immensity of space, if man wishes to understand the performance of the heavens for the successive periods which separate a large number of centuries, if the forces of gravity and of heat be at work in the interior of a solid globe at depths which will be forever inaccessible, mathematical analysis can still grasp the laws of these phenomena. It renders them present and measurable and seems to be a faculty of the human reason destined to make up for the brevity of life and for the imperfection of the senses.[1]
>
> Jean Baptiste Fourier 1822

CHAPTER V

PRESENTATION AND ANALYSIS OF DATA

One purpose of this study was to determine which behaviors are related to an understanding of science and a positive attitude toward science. To accomplish this purpose the evaluative criteria were restated as hypotheses. In an attempt to test the hypotheses, two instruments were administered to students in 10 physics classes from 10 schools. The tests were _Test on Understanding Science_ and _Vitrogan's Attitude Toward Science Scale_.

TOUS consists of three areas: understandings about the scientific enterprise; understandings about scientists; and understandings about the methods and aims of science. A student's understanding of the methods and aims of science may affect his behavior more than his understanding of the

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[1]Jean Baptiste Fourier, _Theorie analytique de la chaleur_, 1822, quoted in _Scientific American_, CCI (December, 1959), 54.

scientific enterprise and the scientist. Consequently, for the purposes of this study subscores for Area III as well as the total scores were considered.

The scores on each test were grouped according to whether the classes did or did not practice each behavior. A one-way analysis of variance technique was employed to ascertain if a significant difference existed between the mean scores of the groups. The size of the F value determined whether the null hypothesis of no difference between the groups was accepted or rejected. This technique, which is also described in Dixon and Massey,[2] has been incorporated in the Biomedical Computer Programs BMD01V, Analysis of Variance for One-Way Design, version of June 11, 1964, written at the UCLA Health Sciences Computer Facility.

Each mean class score was punched on a standard IBM card. The cards for each criterion were manually sorted according to the classes performing or not performing a particular behavior. The data was subsequently treated statistically using the catalog program (BMD01V) with the University of Massachusetts CDC 3600 computer.

The mean scores for the 10 classes on TOUS (part III), TOUS (total score), and VAS are presented in Tables A, B, and C. The class size, range, mean, and standard deviation are also listed.

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[2]Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis (New York: McGraw-Hill Company, Inc., 1957), p. 145.

In Tables A1 -- A18, B1 -- B18, and C1 -- C18, each hypothesis is stated and the treatment of data which was used in accepting or rejecting each of the hypotheses is presented. The numbers in each of the table headings refer to the particular hypothesis being tested. At the end of each section of tables, a summary is given of the hypotheses accepted or rejected.

Evaluation of Class Achievement on <u>TOUS</u> (part III)
for the Study Population

TABLE A

Class	Class Size	Range	Mean	Standard Deviation
1	8	8-13	10,00	1.77
2	16	7-23	13.63	4.11
3	17	9-17	11.88	2.44
4	22	8-19	14.59	3.05
5	9	12-18	15.11	1.96
6	12	9-16	11.83	2.44
7	17	7-19	13.53	3.13
8	12	7-16	11.17	2.55
9	19	9-16	13.84	2.79
10	15	9-17	13.80	2.21

TABLE A1

Null hypothesis A1 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 1 ("The student contributes to the procedure in solving a laboratory problem.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	11.83
No (group 2)	13.84	13.53	11.17	13.80		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	12.840	13.085
Standard Deviation	1.941	1.284

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.1441	1	0.1441	0.0484
Within Groups	23.7933	8	2.9742	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A2

<u>Null hypothesis A2</u> -- No significant difference in understanding of science as measured by <u>TOUS</u> (part III) exists between students practicing behavior 2 ("The student constructs graphs and interprets them.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.84	11.83
No (group 2)	11.17	13.80	13.53				

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	12.983	12.833
Standard Deviation	1.812	1.447

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.0470	1	0.0470	0.0157
Within Groups	23.8904	8	2.9863	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A3

Null hypothesis A3 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 3 ("The student analyzes and interprets data.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.84
No (group 2)	11.17	13.53	11.83	13.80		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.175	12.582
Standard Deviation	1.905	1.283

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.8425	1	0.8425	0.2919
Within Groups	23.0948	8	2.8869	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A4

Null hypothesis A4 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 4 ("The student designs equipment.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	15.11	11.83		
No (group 2)	11.88	14.59	13.84	11.17	13.53	13.80

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	12.643	13.135
Standard Deviation	2.214	1.315

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.5821	1	0.5821	0.1994
Within Groups	23.3552	8	2.9194	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A5

Null hypothesis A5 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 5 ("The student establishes the limitations of the experimental conclusions.") and students not practicing it.

Class Means

Yes (group 1)	13.63	11.88	14.59	15.11		
No (group 2)	10.00	13.84	11.17	13.53	11.83	13.80

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.802	12.362
Standard Deviation	1.421	1.606

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	4.9824	1	4.9824	2.1028
Within Groups	18.9550	8	2.3694	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A6

Null hypothesis A6 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 6 ("The student uses unassigned reference material (excluding textbook).") and students not practicing it.

Class Means

Yes (group 1)	11.88	15.11	11.83	14.59	
No (group 2)	10.00	13.80	13.84	11.17	13.53

Treatment Group	1	2
Sample Size	4	5
Mean (Group)	13.352	12.468
Standard Deviation	1.742	1.772

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	1.7385	1	1.7385	0.5617
Within Groups	21.6668	7	3.0953	
Total	23.4053	8		

The application of analysis of variance technique to the scores gives an F ratio wchih indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.59 is necessary for 1 and 7 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A7

Null hypothesis A7 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 7 ("The student develops ways of testing his proposed conclusions.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	15.11	14.59
No (group 2)	13.84	11.17	13.53	11.83	13.80

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	13.042	12.834
Standard Deviation	2.099	1.246

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.1082	1	0.1082	0.0363
Within Groups	23.8292	8	2.9787	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A8

Null hypothesis A8 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 8 ("The student constructs conceptual models.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	15.11	11.83		
No (group 2)	11.88	1.459	13.84	11.17	13.53	13.80

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	12.643	13.135
Standard Deviation	2.214	1.315

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.5821	1	0.5821	0.1994
Within Groups	23.3552	8	2.9194	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A9

Null hypothesis A9 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 9 ("The student criticizes his results.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.80
No (group 2)	13.84	11.17	13.53	11.83		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.168	12.593
Standard Deviation	1.903	1.296

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.7958	1	0.7958	0.2751
Within Groups	23.1416	8	2.8927	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A10

Null hypothesis A10 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 10 ("The student relates principles from one subject area to another.") and students not practicing it.

Class Means

Yes (group 1)	14.59	15.11	13.84	13.80	13.63
No (group 2)	10.00	11.88	11.17	13.53	11.83

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	14.194	11.682
Standard Deviation	0.631	1.281

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	15.7754	1	15.7754	15.4622
Within Groups	8.1620	8	1.0203	
Total	23.0374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE A11

Null hypothesis A11 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 11 ("The student selects the mathematical operations to be performed on quantitative information.") and students not practicing it.

Class Means

Yes (group 1)	13.63	11.88	14.59	15.11	11.83
No (group 2)	10.00	13.84	11.17	13.53	13.80

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	13.408	12.468
Standard Deviation	1.514	1.772

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	2.2090	1	2.2090	0.8133
Within Groups	21.7284	8	2.7160	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A12

Null hypothesis A12 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 12 ("The student writes an essay report.") and students not practicing it.

Class Means

Yes (group 1)	13.63	11.88	14.59	15.11	11.17
No (group 2)	10.00	13.84	13.53	11.83	13.80

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	13.276	12.600
Standard Deviation	1.703	1.673

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	1.1424	1	1.1424	0.4009
Within Groups	22.7949	8	2.8494	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A13

Null hypothesis A13 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 13 ("The student observes and records accurately.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.84
No (group 2)	11.17	13.53	11.83	13.80		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.175	12.582
Standard Deviation	1.905	1.283

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.8425	1	0.8425	0.2919
Within Groups	23.0948	8	2.8869	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A14

Null hypothesis A14 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 14 ("The student realizes the limitations of the instrument he is using.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.80
No (group 2)	13.84	11.17	13.53	11.83		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.168	12.593
Standard Deviation	1.903	1.296

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.7958	1	0.7958	0.2751
Within Groups	23.1416	8	2.8927	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F or 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A15

Null hypothesis A15 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 15 ("The student re-evaluates his ideas and opinions.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11	13.84
No (group 2)	11.17	13.53	11.83	13.80		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	13.175	12.582
Standard Deviation	1.905	1.283

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.8425	1	0.8425	0.2919
Within Groups	23.0948	8	2.8869	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A16

Null hypothesis A16 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 16 ("The student suspends final judgment on experimental outcomes until the data has been analyzed.") and students not practicing it.

Class Means

Yes (group 1)	10.00	13.63	11.88	14.59	15.11
No (group 2)	13.84	11.17	13.53	11.83	13.80

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	13.042	12.834
Standard Deviation	2.099	1.246

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.1082	1	0.1082	0.0363
Within Groups	23.8292	8	2.9787	
Total	23.9374	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A17

Null hypothesis A17 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 17 ("The student proposes additional problems as a result of laboratory activities.") and students not practicing it.

Class Means

Yes (group 1)	13.63	15.11	11.83	13.80		
No (group 2)	10.00	11.88	14.59	13.84	11.17	13.53

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	13.592	12.502
Standard Deviation	1.348	1.768

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	2.8558	1	2.8558	1.0837
Within Groups	21.0816	8	2.6352	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE A18

Null hypothesis A18 -- No significant difference in understanding of science as measured by TOUS (part III) exists between students practicing behavior 18 ("The students work on different problems at the same time.") and students not practicing it.

Class Means

Yes (group 1)	10.00	11.88	15.11	11.83	13.80
No (group 2)	13.63	14.59	13.84	11.17	13.53

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	12.524	13.352
Standard Deviation	1.974	1.288

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	1.7140	1	1.7140	0.6170
Within Groups	23.2234	8	2.7779	
Total	23.9374	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

Summary of the Analysis of Scores on the Test on Understanding Science (part III -- Methods and Aims of Science)

From the results of these analyses, evidence was provided to indicate that a significant difference in understandings about the methods and aims of science as measured by TOUS (part III) exists between those classes practicing and not practicing behavior 10 ("The student relates principles from one subject area to another."). The difference favored the class which practiced behavior 10.

The significant difference for behavior 10 could have been due to chance. Since the level of confidence was selected as .05, one in twenty hypotheses might have been accepted as true, when in reality it was false.

No evidence was provided to indicate that a significant difference in understandings about the methods and aims of science as measured by TOUS (part III) exists between the classes practicing and not practicing behaviors 1 -- 9, 11 -- 18.

Evaluation of Class Achievement on TOUS (total score)

for the Study Population

TABLE B

Class	Class Size	Range	Mean	Standard Deviation
1	8	22-51	31.38	8.83
2	16	31-53	38.13	5.94
3	17	22-46	34.12	6.13
4	22	28-49	39.32	5.50
5	9	34-48	40.56	5.03
6	12	30-44	34.50	3.92
7	17	29-45	37.41	4.94
8	12	25-40	32.25	4.65
9	19	28-49	39.37	5.91
10	15	27-46	38.13	5.63

TABLE B1

Null hypothesis B1 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 1 ("The student contributes to the procedure in solving a laboratory problem.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	34.50
No (group 2)	39.37	37.41	34.35	38.13		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	36.502	36.790
Standard Deviation	3.667	3.133

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.1995	1	0.1995	0.0165
Within Groups	96.6797	8	12.0850	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B2

Null hypothesis B2 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 2 ("The student constructs graphs and interprets them.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	39.37	34.50
No (group 2)	32.25	38.13	37.41				

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	36.911	35.930
Standard Deviation	3.519	3.207

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	2.0227	1	2.0227	0.1706
Within Groups	94.8565	8	11.8571	
Total	96.8792			

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B3

Null hypothesis B3 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 3 ("The student analyzes and interprets data.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	39.37
No (group 2)	32.25	37.41	34.50	38.13		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	37.313	35.572
Standard Deviation	3.674	2.715

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	7.2732	1	7.2732	0.6493
Within Groups	89.6060	8	11.2008	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B4

Null hypothesis B4 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 4 ("The student designs equipment.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	40.56	34.50		
No (group 2)	34.12	39.32	39.37	32.25	37.41	38.13

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	36.393	36.767
Standard Deviation	4.226	2.932

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.3360	1	0.3360	0.0278
Within Groups	96.5432	8	12.0679	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B5

Null hypothesis B5 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 5 ("The student establishes the limitations of the experimental conclusions.") and students not practicing it.

Class Means

Yes (group 1)	39.13	34.12	39.32	40.56		
No (group 2)	31.38	39.37	32.25	37.41	34.50	38.13

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	38.282	35.507
Standard Deviation	2.847	3.289

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	18.4926	1	18.4926	1.8873
Within Groups	78.3866	8	9.7983	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B6

Null hypothesis B6 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 6 ("The student uses unassigned reference material (excluding textbook).") and students not practicing it.

Class Means

Yes (group 1)	34.12	40.56	34.50	39.32	
No (group 2)	31.38	38.13	39.37	32.25	37.41

Treatment Group	1	2
Sample Size	4	5
Mean (Group)	37.125	35.708
Standard Deviation	3.293	3.635

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	4.4620	1	4.4620	0.3657
Within Groups	85.4004	7	12.2001	
Total	89.8624	8		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.59 is necessary for 1 and 7 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B7

Null hypothesis B7 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 7 ("The student develops ways of testing his proposed conclusions.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	40.56	39.32
No (group 2)	39.37	32.25	37.41	34.50	38.13

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	36.902	36.332
Standard Deviation	3.950	2.900

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.8123	1	0.8123	0.0676
Within Groups	96.0670	8	12.0084	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B8

Null hypothesis B8 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 8 ("The student constructs conceptual models.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	40.56	34.50		
No (group 2)	34.12	39.32	39.37	32.25	37.41	38.13

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	36.393	36.767
Standard Deviation	4.226	2.932

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.3360	1	0.3360	0.0278
Within Groups	96.5432	8	12.0679	
Total	96.8792			

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B9

Null hypothesis B9 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 9 ("The student criticizes his results.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	38.13
No (group 2)	39.37	32.25	37.41	34.50		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	37.107	35.882
Standard Deviation	3.569	3.141

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	3.5966	1	3.5966	0.3084
Within Groups	93.2826	8	11.6603	
Total	96.8792	9		

The application of analysis of variance of technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B10

Null hypothesis B10 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 10 ("The student relates principles from one subject area to another.") and students not practicing it.

Class Means

Yes (group 1)	39.32	40.56	39.37	38.13	39.13
No (group 2)	31.38	34.12	32.25	37.41	34.50

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	39.302	33.932
Standard Deviation	0.865	2.334

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	72.0922	1	72.0922	23.2678
Within Groups	24.7870	8	3.0984	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE B11

Null hypothesis B11 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 11 ("The student selects the mathematical operations to be performed on quantitative information.") and students not practicing it.

Class Means

Yes (group 1)	39.13	34.12	39.32	40.56	34.50
No (group 2)	31.38	39.37	32.25	37.41	38.13

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	37.526	35.708
Standard Deviation	2.990	3.635

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	8.2628	1	8.2628	0.7459
Within Groups	88.6164	8	11.0770	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B12

Null hypothesis B12 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 12 ("The student writes an essay report.") and students not practicing it.

Class Means

Yes (group 1)	39.13	34.12	39.32	40.56	32.25
No (group 2)	31.38	39.37	37.41	34.50	38.13

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	37.076	36.158
Standard Deviation	3.654	3.215

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	2.1068	1	2.1068	0.1778
Within Groups	94.7724	8	11.8465	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B13

Null hypothesis B13 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 13 ("The student observes and records accurately.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	39.37
No (group 2)	32.25	37.41	34.50	38.13		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	37.313	35,572
Standard Deviation	3.674	2.715

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	7.2732	1	7.2732	0.6493
Within Groups	89.6060	8	11.2008	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F or 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B14

Null hypothesis B14 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 14 ("The student realizes the limitations of the instrument he is using.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	38.13
No (group 2)	39.37	32.25	37.41	34.50		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	37.107	35.882
Standard Deviation	3.569	3.141

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	3.5966	1	3.5966	0.3084
Within Groups	93.2826	8	11.6603	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B15

<u>Null hypothesis B15</u> -- No significant difference in understanding of science as measured by <u>TOUS</u> (total score) exists between students practicing behavior 15 ("The student re-evaluates his ideas and opinions.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56	39.37
No (group 2)	32.25	37.41	34.50	38.13		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	37.313	35.572
Standard Deviation	3.674	2.715

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	7.2732	1	7.2732	0.6493
Within Groups	89.6060	8	11.2008	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B16

Null hypothesis B16 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 16 ("The student suspends final judgment on experimental outcomes until the data has been analyzed.") and students not practicing it.

Class Means

Yes (group 1)	31.38	39.13	34.12	39.32	40.56
No (group 2)	39.37	32.25	37.41	34.50	38.13

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	36.902	36.332
Standard Deviation	3.950	2.900

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	0.8123	1	0.8123	0.0676
Within Groups	96.0670	8	12.0084	
Total	96.8792	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B17

Null hypothesis B17 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 17 ("The student proposes additional problems as a result of laboratory activities.") and students not practicing it.

Class Means

Yes (group 1)	39.13	40.56	34.50	38.12		
No (group 2)	31.38	34.12	39.32	39.37	32.25	37.41

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	38.077	35.642
Standard Deviation	2.587	3.537

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	14.2399	1	14.2399	1.3790
Within Groups	82.6092	8	10.3261	
Total	96.8490	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE B18

Null hypothesis B18 -- No significant difference in understanding of science as measured by TOUS (total score) exists between students practicing behavior 18 ("The students work on different problems at the same time.") and students not practicing it.

Class Means

Yes (group 1)	39.13	39.32	39.37	32.25	37.41
No (group 2)	31.38	34.12	40.56	34.50	38.13

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	37.496	35.738
Standard Deviation	3.043	3.610

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	7.7264	1	7.7264	0.6933
Within Groups	89.1528	8	11.1441	
Total	96.8792			

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

Summary for the Analysis of Scores on the Test on Understanding Science (total score)

From the results of these analyses, evidence was provided to indicate that a significant difference in understanding of science as measured by TOUS (total score) exists between those classes practicing and those not practicing behavior 10 ("The student relates principles from one subject area to another."). The difference favored the class which practiced behavior 10.

The significant difference for behavior 10 could have been due to chance. Since the level of confidence was selected as .05, one in twenty hypotheses might have been accepted as true, when in reality it was false. Two indications that the significant difference between the classes was not due to chance are: (1) A significant difference on this item occurred for both part III and the total score of TOUS; and (2) A significant difference on this item occurred for both part III and the total score of TOUS in a chemistry study[3] parallel to this investigation.

No evidence was provided to indicate that a significant difference in understanding of science as measured by TOUS (total score) exists between those classes practicing and those not practicing behaviors 1 -- 9, 11 -- 18.

The absence of results using TOUS (part III) and TOUS (total score) could be due to several factors:

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[3]Mark Waltz, uncompleted doctoral dissertation at the University of Massachusetts.

1. The Test on Understanding Science may not validly measure understanding of science. The attributes of a scientist may be developed only after considerable experience.

2. The Test on Understanding Science may not be sensitive enough to measure the effect of one behavior on understanding science.

3. The observed behaviors may have occurred by chance rather than as a result of an understanding of science and a positive attitude toward science.

4. The teacher may not have formulated definite objectives. As a result, the class' behavior may not have been representative of the year's performance.

5. Our culture may be the factor that produces high scores on Test on Understanding Science rather than the physics curriculum.

Evaluation of Class Achievement on VAS

for the Study Population

TABLE C

Class	Class Size	Range	Mean	Standard Deviation
1	8	-22--+63	29.13	29.41
2	16	-7--+84	40.07	23.39
3	17	5--61	31.35	15.26
4	22	-14--+72	29.50	19.59
5	9	5--56	36.22	18.23
6	12	5--78	31.33	19.22
7	17	-40--+71	14.31	25.93
8	12	17--58	31.47	12.99
9	19	-20--+40	17.63	16.93
10	15	-22--+41	24.07	19.38

TABLE C1

Null hypothesis C1 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 1 ("The student contributes to the procedure in solving a laboratory problem.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	31.33
No (group 2)	17.63	14.31	31.47	24.07		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	32.933	21.870
Standard Deviation	4.314	7.575

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	293.7536	1	293.7536	8.8615
Within Groups	265.1961	8	33.1495	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE C2

<u>Null hypothesis C2</u> -- No significant difference in attitude toward science as measured by <u>VAS</u> exists between students practicing behavior 2 ("The student constructs graphs and interprets them.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	17.63	31.33
No (group 2)	31.47	24.07	14.31				

Treatment Group	1	2
Sample Size	7	3
Mean (Group)	30.747	23.283
Standard Deviation	6.998	8.607

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	116.9878	1	116.9878	2.1176
Within Groups	441.9620	8	55.2453	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C3

Null hypothesis C3 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 3 ("The student analyzes and interprets data.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	17.63
No (group 2)	31.47	14.31	31.33	24.07		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	30.650	25.295
Standard Deviation	7.660	8.098

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	68.8225	1	68.8225	1.1233
Within Groups	490.1273	8	61.2659	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C4

Null hypothesis C4 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 4 ("The student designs equipment.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	36.22	31.33		
No (group 2)	31.35	29.50	17.63	31.47	14.31	24.07

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	34.188	24.722
Standard Deviation	4.915	7.368

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	215.0448	1	215.0448	5.0024
Within Groups	343.9050	8	42.9881	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C5

Null hypothesis C5 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 5 ("The student establishes the limitations of the experimental conclusions.") and students not practicing it.

Class Means

Yes (group 1)	40.07	31.35	29.50	36.22		
No (group 2)	29.13	17.63	31.47	14.31	31.33	24.07

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	34.285	24.657
Standard Deviation	4.786	7.318

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	222.4915	1	222.4915	5.2902
Within Groups	336.4582	8	42.0573	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C6

Null hypothesis C6 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 6 ("The student uses unassigned reference material (excluding textbook).") and students not practicing it.

Class Means

Yes (group 1)	31.35	36.22	31.33	29.50	
No (group 2)	29.13	24.07	17.63	31.47	14.31

Treatment Group	1	2
Sample Size	4	5
Mean (Group)	32.100	23.322
Standard Deviation	2.880	7.319

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	171.2295	1	171.2295	5.0112
Within Groups	239.1871	7	34.1696	
Total	410.4166	8		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.59 is necessary for 1 and 7 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C7

Null hypothesis C7 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 7 ("The student develops ways of testing his proposed conclusions.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	36.22	29.50
No (group 2)	17.63	31.47	14.31	31.33	24.07

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	33.254	23.762
Standard Deviation	4.743	7.806

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	225.2452	1	225.2452	5.3999
Within Groups	333.7946	8	41.7131	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE C8

Null hypothesis C8 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 8 ("The student constructs conceptual models.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	36.22	31.33		
No (group 2)	31.35	29.50	17.63	31.47	14.31	24.07

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	34.188	24.722
Standard Deviation	4.915	7.368

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	215.0448	1	215.0448	5.0024
Within Groups	343.9050	8	42.9881	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C9

Null hypothesis C9 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 9 ("The student criticizes his results.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	24.07
No (group 2)	17.63	31.47	14.31	31.33		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	31.723	23.685
Standard Deviation	5.662	9.011

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	155.0755	1	155.0755	3.0718
Within Groups	403.8742	8	50.4843	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C10

Null hypothesis C10 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 10 ("The student relates principles from one subject area to another.") and students not practicing it.

Class Means

Yes (group 1)	29.50	36.22	17.63	24.07	40.07
No (group 2)	29.13	31.35	31.47	14.31	31.33

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	29.498	27.518
Standard Deviation	9.045	7.448

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	9.8010	1	9.8010	0.1428
Within Groups	549.1488	8	68.6436	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C11

Null hypothesis C11 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 11 ("The student selects the mathematical operations to be performed on quantitative information.") and students not practicing it.

Class Means

Yes (group 1)	40.07	31.35	29.50	36.22	31.33
No (group 2)	29.13	17.63	31.47	14.31	24.07

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	33.694	23.322
Standard Deviation	4.350	7.319

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	268.9460	1	268.9460	7.4191
Within Groups	290.0038	8	36.2505	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE C12

Null hypothesis C12 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 12 ("The student writes an essay report.") and students not practicing it.

Class Means

Yes (group 1)	40.07	31.35	29.50	36.22	31.47
No (group 2)	29.13	17.63	14.31	31.33	24.07

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	33.722	23.294
Standard Deviation	4.332	7.281

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	271.8580	1	271.8580	7.5755
Within Groups	287.0918	8	35.8865	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE C13

Null hypothesis C13 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 13 ("The student observes and records accurately.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	17.63
No (group 2)	31.47	14.31	31.33	24.07		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	30.650	25.295
Standard Deviation	7.660	8.098

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	68.8225	1	68.8225	1.1233
Within Groups	490.1273	8	61.2659	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C14

Null hypothesis C14 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 14 ("The student realizes the limitations of the instrument he is using.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	24.07
No (group 2)	17.63	31.47	14.31	31.33		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	31.723	23.685
Standard Deviation	5.662	9.011

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	155.0755	1	155.0755	3.0718
Within Groups	403.8742	8	50.4843	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C15

Null hypothesis C15 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 15 ("The student re-evaluates his ideas and opinions.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	29.50	36.22	17.63
No (group 2)	31.47	14.31	31.33	24.07		

Treatment Group	1	2
Sample Size	6	4
Mean (Group)	30.650	25.295
Standard Deviation	7.660	8.098

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	68.8225	1	68.8225	1.1233
Within Groups	490.1273	8	61.2659	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

TABLE C16

Null hypothesis C16 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 16 ("The student suspends final judgment on experimental outcomes until the data has been analyzed.") and students not practicing it.

Class Means

Yes (group 1)	29.13	40.07	31.35	39.50	36.22
No (group 2)	17.63	31.47	14.31	31.33	24.07

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	33.254	23.762
Standard Deviation	4.743	7.806

Analysis of Variance

	Sum of Squares	df	Mean Sqaure	F Ratio
Between Groups	225.2452	1	225.2452	5.3999
Within Groups	333.7046	8	41.7131	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that a significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is rejected.

TABLE C17

Null hypothesis C17 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 17 ("The student proposes additional problems as a result of laboratory activities.") and students not practicing it.

Class Means

Yes (group 1)	40.07	36.22	31.33	24.07		
No (group 2)	29.13	31.35	29.50	17.63	31.47	14.31

Treatment Group	1	2
Sample Size	4	6
Mean (Group)	32.922	25.565
Standard Deviation	6.901	7.565

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	129.9187	1	129.9187	2.4226
Within Groups	429.0310	8	53.6289	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypotheses is accepted.

TABLE C18

Null hypothesis C18 -- No significant difference in attitude toward science as measured by VAS exists between students practicing behavior 18 ("The students work on different problems at the same time.") and students not practicing it.

Class Means

Yes (group 1)	29.13	31.35	36.22	31.33	24.07
No (group 2)	40.07	29.50	17.63	31.47	14.31

Treatment Group	1	2
Sample Size	5	5
Mean (Group)	30.420	26.596
Standard Deviation	4.397	2.521

Analysis of Variance

	Sum of Squares	df	Mean Square	F Ratio
Between Groups	36.5574	1	36.5574	0.5598
Within Groups	522.3923	8	65.2990	
Total	558.9498	9		

The application of analysis of variance technique to the scores gives an F ratio which indicates that no significant difference exists between the groups. In order to be significant at the .05 confidence level an F of 5.32 is necessary for 1 and 8 degrees of freedom. Therefore the hypothesis is accepted.

Summary for the Analysis of Scores on Vitrogan's Attitude Toward Science Scale

From the results of the analyses, evidence was secured which indicated that a significant difference in positive attitude toward science as measured by VAS exists between those classes practicing and those not practicing behaviors (1) The student contributes to the procedure in solving a laboratory problem; (7) The student develops ways of testing his proposed conclusions; (11) The student selects the mathematical operations to be performed on quantitative information; (12) The student writes an essay report; (16) The student suspends final judgment on experimental outcomes until the data has been analyzed. The difference favored the classes which practiced the behaviors.

There was some indication that classes practicing behaviors (4) The student designs equipment; (5) The student establishes the limitations of the experimental conclusions; (6) The student uses unassigned reference material (excluding textbook); and (8) The student constructs conceptual models, exhibited a more positive attitude toward science as measured by VAS than those not practicing these behaviors.

No evidence was provided to indicate that a significant difference in positive attitude toward science as measured by VAS exists between those classes practicing and those not practicing behaviors (2) The student constructs graphs and interprets them; (3) The student analyzes and interprets data; (9) The student criticizes his results; (10) The student relates principles from one subject area to another; (13) The student observes and records accurately; (14) The student realizes the limitations of the instrument he is using; (15) The student re-evaluates his ideas and opinions; (17) The student proposes additional problems as a result of laboratory activities; and (18) The students work on different problems at the same time.

. . . Experience never errs; what alone may err is our judgment, which predicts effects that cannot be produced in our experiments.

Leonardo da Vinci 1500[1]

CHAPTER VI

SUMMARY AND CONCLUSIONS

Statement of the Problem

The purposes of this study were: (1) to identify and state those behaviors which, in the opinion of various scientists and science educators as expressed in their written statements, might foster an understanding of science and a positive attitude toward science; and (2) to determine which scientific behaviors as exhibited by students in selected high school physics classes are related to an understanding of science and a positive attitude toward science.

Procedure

The writings of prominent scientists and science educators since 1900 were systematically surveyed[2] for statements suggesting behaviors relating to an understanding of science and an attitude toward science. Initially

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[1]Leonardo da Vinci, Notebooks, circa 1500, quoted in Scientific American, CXCIX (October, 1958), 1.

[2]An associate, who conducted a parallel study in chemistry, cooperated in surveying the literature, identifying the behaviors, and observing and rating class performances.

there appeared 82 such statements, obtained from approximately 200 articles and books. After duplications were omitted, the list was reduced to 42 behaviors practiced by both teachers and students. Those statements suggesting student behaviors were rephrased into behavioral terms. Through combinations, and the elimination of those behaviors difficult to observe, a list of 19 overt student behaviors was devised.

The list of behaviors was analyzed in actual classroom situations to assure that they were readily observable. By this procedure, one item was omitted, and three others were modified. As a result the final list consisted of 18 behaviors theorized by scientists and science educators to promote an understanding of science and a positive attitude toward science.

Since it is a recognized statistical procedure to operate with the ends of a continuum, the investigator selected classes that exhibited either a majority of the behaviors, or those that exhibited few. Ten classes were utilized in the study.

During the period from January to May, 1969, the investigator and an associate evaluated student behavior using an instrument developed from the list of behaviors. Note was taken during class observation of the number of students performing or not performing each behavior or whether the behavior applied to the laboratory problem.

When all the classes had been observed, a percentage was selected to establish a dichotomy. Since it is not possible to make a distinction within a few percentage points, either 25%, 50%, or 75% were used to determine whether a behavior was checked as "yes" (it was practiced by the students) or "no" (it was not practiced by the students). The observers compared their notes before indicating which behaviors had been practiced in each class. Disagreement between the raters on student behaviors was resolved by further observation. Thus, the final evaluation represents a composite appraisal of the two raters.

During March and April, 1969, two tests, Test on Understanding Science and Vitrogan's Attitude Toward Science Scale, were administered to the classes.

TOUS consists of three areas: understandings about the scientific enterprise; understandings about scientists; and understandings about the methods and aims of science. A student's understanding of the methods and aims of science, however, may affect his behavior more than his understanding of the scientific enterprise and the scientist. Consequently, for the purposes of this study subscores for Area III, understandings about the methods and aims of science, as well as the total scores of TOUS were considered.

The primary statistical technique was a one-way analysis of variance F test. Class scores were grouped according to those practicing or not practicing a particular behavior. A statistically significant difference in the means of the two groups resulted in the rejection of the null hypothesis. When this occurred, the behavior stated in the null hypothesis was then concluded to promote either an understanding of science or a positive attitude toward science.

Conclusions

1. Evidence was provided to indicate that a significant difference in understanding science as measured by TOUS (part III) and TOUS (total score) exists between those classes practicing and not practicing behavior 10 ("The student relates principles from one subject to another."). The difference favored those classes which practiced the behavior.

2. No evidence was provided to indicate that a significant difference in understanding of science as measured by TOUS (part III) and TOUS (total score) exists between those classes practicing and not practicing behaviors 1 -- 9, 11 -- 18.

3. Evidence was provided to indicate that a significant difference in positive attitude toward science as measured by VAS exists between those classes practicing and not practicing behaviors (1) The student contributes to the procedure in solving a laboratory problem; (7) The student develops ways of testing his proposed conclusions; (11) The student selects the mathematical operations to be performed

on quantitative information; (12) The student writes an essay report; (16) The student suspends final judgment on experimental outcomes until the data has been analyzed. The difference favored the classes which practiced the behaviors.

4. There was some indication that classes practicing behaviors (4) The student designs equipment; (5) The student establishes the limitations of the experimental conclusions; (6) The student uses unassigned reference material (excluding textbook); and (8) The student constructs conceptual models, exhibited a more positive attitude toward science as measured by VAS than those not practicing these behaviors.

5. No evidence was provided to indicate that a significant difference in positive attitude toward science as measured by VAS exists between those classes practicing and those not practicing behaviors (2) The student constructs graphs and interprets them; (3) The student analyzes and interprets data; (9) The student criticizes his results; (10) The student relates principles from one subject area to another; (13) The student observes and records accurately; (14) The student realizes the limitations of the instrument he is using; (15) The student re-evaluates his ideas and opinions; (17) The student proposes additional problems as a result of laboratory activities; and (18) The students work on different problems at the same time.

Recommendations

1. Since considerable variation existed between the classes in understanding science as measured by TOUS, studies are needed which investigate the behavioral characteristics of those classes that score high on TOUS as compared with those that score low.

2. Since college preparatory physics classes usually consist of above-average students, studies are needed to determine if the same relationship exists for lower-ability students between the behaviors and an understanding of science and a positive attitude toward science.

3. Since the population of this study was restricted to 10 classes in a limited geographical area, studies utilizing a larger population in a wider geographical area need to be conducted to determine if the relationships obtained in this study were a result of class selection.

4. Studies are needed to determine how the behaviors relate to an understanding of science and a positive attitude toward science when practiced by classes in other science areas.

5. Investigations are needed in which the observation time is of longer duration to ensure that the behaviors observed were representative of a class' performance throughout the year.

6. Since students learn attitudes by identification and imitation, studies are needed to investigate the behaviors of teachers and their relationship to student behaviors.

7. Studies are needed to investigate which behaviors could promote other important objectives of science teaching such as problem-solving skills and an awareness of the social aspects of science.

8. Studies are needed to investigate understanding of science and a positive attitude toward science using other criteria measures since the Test on Understanding Science and Vitrogan's Attitude Scale may not be reliable in measuring these goals of science education. These instruments may not be sensitive enough to measure the effect of a behavior. Moreover, a scientist's understanding of science and his positive attitude toward science may be developed only after considerable experience.

9. Studies are needed to investigate whether the objectives formulated by the teacher have been transmitted to the students.

10. Studies are needed in which the effect of our culture on an understanding of science and a positive attitude toward science is controlled.

Implications

1. Behaviors related to an understanding of science and a positive attitude toward science were identified. A teacher who accepts these behaviors as goals of science teaching could develop a course that will stimulate the fostering of the identified behaviors by his students.

2. Behaviors related to an understanding of science

and a positive attitude toward science that could form the basis for a more effective measuring instrument than achievement tests measuring factual information were identified.

3. A research procedure was developed that could be used in other disciplines to identify behaviors that promote understandings and attitudes essential to those disciplines.

The test scores of both TOUS and VAS could have been affected by the following factors:

1. TOUS may not validly measure understanding of science. The attributes of a scientist may be developed only after considerable experience.

2. TOUS may not be sensitive enough to measure the effect of one behavior on understanding science.

3. The observed behaviors may have occurred by chance rather than as a result of an understanding of science and a positive attitude toward science.

4. The teacher may not have formulated definite objectives. As a result, the class' behavior may not have been representative of the year's performance.

5. Our culture may be the factor that produces high scores on TOUS rather than the physics curriculum.

6. Student motivation could have been a factor in test results. If the students felt that the test was going to count toward their class grade, they perhaps performed more conscientious work than if they were taking the test for the investigators.

7. The format of both tests, which asked for the students' opinions and attitudes rather than for "right answers," was contrary to most of their past experience. This may have frustrated some students and probably lessened their motivation.

A P P E N D I C E S

APPENDIX I

OBSERVED BEHAVIORS*

50% (1) The student contributes to the procedure in solving a laboratory problem.

Yes ______ No ______ Unobserved ______

75% (2) The student constructs graphs and interprets them.

Yes ______ No ______ Unobserved ______

50% (3) The student analyzes and interprets data.

Yes ______ No ______ Unobserved ______

25% (4) The student designs equipment.

Yes ______ No ______ Unobserved ______

50% (5) The student establishes the limitations of the experimental conclusions.

Yes ______ No ______ Unobserved ______

25% (6) The student uses unassigned reference material (excluding textbook).

Yes ______ No ______ Unobserved ______

25% (7) The student develops ways of testing his proposed conclusions.

Yes ______ No ______ Unobserved ______

25% (8) The student constructs conceptual models.

Yes ______ No ______ Unobserved ______

50% (9) The student criticizes his results.

Yes ______ No ______ Unobserved ______

*Percentages indicate the required number of students practicing a behavior before it was checked as "yes".

25% (10) The student relates principles from one subject area to another.

Yes ______ No ______ Unobserved ______

75% (11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No ______ Unobserved ______

75% (12) The student writes an essay report.

Yes ______ No ______ Unobserved ______

75% (13) The student observes and records accurately.

Yes ______ No ______ Unobserved ______

75% (14) The student realizes the limitations of the instrument he is using.

Yes ______ No ______ Unobserved ______

75% (15) The student re-evaluates his ideas and opinions.

Yes ______ No ______ Unobserved ______

75% (16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No ______ Unobserved ______

25% (17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No ______ Unobserved ______

25% (18) The students work on different problems at the same time.

Yes ______ No ______ Unobserved ______

APPENDIX II

Class 1

(1) The student contributes to the procedure in solving a laboratory problem.

Yes __x__ No ______ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes __x__ No ______ Unobserved ______

(3) The student analyzes and interprets data.

Yes __x__ No ______ Unobserved ______

(4) The student designs equipment.

Yes __x__ No ______ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes ______ No __x__ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes __x__ No ______ Unobserved ______

(8) The student constructs conceptual models.

Yes __x__ No ______ Unobserved ______

(9) The student criticizes his results.

Yes __x__ No ______ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No __x__ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No __x___ Unobserved ______

(12) The student writes an essay report.

Yes ______ No __x___ Unobserved ______

(13) The student observes and records accurately.

Yes __x___ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes __x___ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x___ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes __x___ No ______ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x___ Unobserved ______

(18) The students work on different problems at the same time.

Yes __x___ No ______ Unobserved ______

APPENDIX II (continued)

Class 2

(1) The student contributes to the procedure in solving a laboratory problem.

Yes __x__ No _____ Unobserved _____

(2) The student constructs graphs and interprets them.

Yes __x__ No _____ Unobserved _____

(3) The student analyzes and interprets data.

Yes __x__ No _____ Unobserved _____

(4) The student designs equipment.

Yes __x__ No _____ Unobserved _____

(5) The student establishes the limitations of the experimental conclusions.

Yes __x__ No _____ Unobserved _____

(6) The student uses unassigned reference material (excluding textbook).

Yes _____ No _____ Unobserved __x__

(7) The student develops ways of testing his proposed conclusions.

Yes __x__ No _____ Unobserved _____

(8) The student constructs conceptual models.

Yes __x__ No _____ Unobserved _____

(9) The student criticizes his results.

Yes __x__ No _____ Unobserved _____

(10) The student relates principles from one subject area to another.

Yes __x__ No _____ Unobserved _____

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes __x__ No ______ Unobserved ______

(12) The student writes an essay report.

Yes __x__ No ______ Unobserved ______

(13) The student observes and records accurately.

Yes __x__ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes ______ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x__ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes __x__ No ______ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes __x__ No ______ Unobserved ______

(18) The students work on different problems at the same time.

Yes ______ No __x__ Unobserved ______

APPENDIX II (continued)

Class 3

(1) The student contributes to the procedure in solving a laboratory problem.

Yes __x__ No ______ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes __x__ No ______ Unobserved ______

(3) The student analyzes and interprets data.

Yes __x__ No ______ Unobserved ______

(4) The student designs equipment.

Yes ______ No __x__ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes __x__ No ______ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes __x__ No ______ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes __x__ No ______ Unobserved ______

(8) The student constructs conceptual models.

Yes ______ No __x__ Unobserved ______

(9) The student criticizes his results.

Yes __x__ No ______ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No __x__ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes __x___ No ______ Unobserved ______

(12) The student writes an essay report.

Yes x_____ No ______ Unobserved ______

(13) The student observes and records accurately.

Yes __x___ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes __x___ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x___ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes __x___ No ______ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x___ Unobserved ______

(18) The students work on different problems at the same time.

Yes __x___ No ______ Unobserved ______

APPENDIX II (continued)

Class 4

(1) The student contributes to the procedure in solving a laboratory problem.

Yes _x_ No ___ Unobserved ___

(2) The student constructs graphs and interprets them.

Yes _x_ No ___ Unobserved ___

(3) The student analyzes and interprets data.

Yes _x_ No ___ Unobserved ___

(4) The student designs equipment.

Yes ___ No _x_ Unobserved ___

(5) The student establishes the limitations of the experimental conclusions.

Yes _x_ No ___ Unobserved ___

(6) The student uses unassigned reference material (excluding textbook).

Yes _x_ No ___ Unobserved ___

(7) The student develops ways of testing his proposed conclusions.

Yes _x_ No ___ Unobserved ___

(8) The student constructs conceptual models.

Yes ___ No _x_ Unobserved ___

(9) The student criticizes his results.

Yes _x_ No ___ Unobserved ___

(10) The student relates principles from one subject area to another.

Yes _x_ No ___ Unobserved ___

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes __x__ No ______ Unobserved ______

(12) The student writes an essay report.

Yes __x__ No ______ Unobserved ______

(13) The student observes and records accurately.

Yes __x__ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes __x__ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x__ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes __x__ No ______ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x__ Unobserved ______

(18) The students work on different problems at the same time.

Yes ______ No __x__ Unobserved ______

APPENDIX II (continued)

Class 5

(1) The student contributes to the procedure in solving a laboratory problem.

Yes __x__ No ______ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes __x__ No ______ Unobserved ______

(3) The student analyzes and interprets data.

Yes __x__ No ______ Unobserved ______

(4) The student designs equipment.

Yes __x__ No ______ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes __x__ No ______ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes __x__ No ______ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes __x__ No ______ Unobserved ______

(8) The student constructs conceptual models.

Yes __x__ No ______ Unobserved ______

(9) The student criticizes his results.

Yes __x__ No ______ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No ______ Unobserved __x__

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes __x__ No ______ Unobserved ______

(12) The student writes an essay report.

Yes __x__ No ______ Unobserved ______

(13) The student observes and records accurately.

Yes __x__ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes __x__ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x__ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes __x__ No ______ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes __x__ No ______ Unobserved ______

(18) The students work on different problems at the same time.

Yes __x__ No ______ Unobserved ______

APPENDIX II (continued)

Class 6

(1) The student contributes to the procedure in solving a laboratory problem.

Yes __x__ No ______ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes __x__ No ______ Unobserved ______

(3) The student analyzes and interprets data.

Yes ______ No __x__ Unobserved ______

(4) The student designs equipment.

Yes __x__ No ______ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes __x__ No ______ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes ______ No __x__ Unobserved ______

(8) The student constructs conceptual models.

Yes __x__ No ______ Unobserved ______

(9) The student criticizes his results.

Yes ______ No __x__ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No __x__ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes __x__ No ______ Unobserved ______

(12) The student writes an essay report.

Yes ______ No __x__ Unobserved ______

(13) The student observes and records accurately.

Yes ______ No __x__ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes ______ No __x__ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes ______ No __x__ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No __x__ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes __x__ No ______ Unobserved ______

(18) The students work on different problems at the same time.

Yes __x__ No ______ Unobserved ______

APPENDIX II (continued)

Class 7

(1) The student contributes to the procedure in solving a laboratory problem.

Yes ______ No __x__ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes ______ No __x__ Unobserved ______

(3) The student analyzes and interprets data.

Yes ______ No __x__ Unobserved ______

(4) The student designs equipment.

Yes ______ No __x__ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes ______ No __x__ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes ______ No __x__ Unobserved ______

(8) The student constructs conceptual models.

Yes ______ No __x__ Unobserved ______

(9) The student criticizes his results.

Yes ______ No __x__ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No __x__ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No __x___ Unobserved ______

(12) The student writes an essay report.

Yes ______ No __x___ Unobserved ______

(13) The student observes and records accurately.

Yes ______ No __x___ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes ______ No __x___ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes ______ No __x___ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No __x___ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x___ Unobserved ______

(18) The students work on different problems at the same time.

Yes ______ No __x___ Unobserved ______

APPENDIX II (continued)

Class 8

(1) The student contributes to the procedure in solving a laboratory problem.

Yes ______ No __x__ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes ______ No __x__ Unobserved ______

(3) The student analyzes and interprets data.

Yes ______ No __x__ Unobserved ______

(4) The student designs equipment.

Yes ______ No __x__ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes ______ No __x__ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes ______ No __x__ Unobserved ______

(8) The student constructs conceptual models.

Yes ______ No __x__ Unobserved ______

(9) The student criticizes his results.

Yes ______ No __x__ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes ______ No __x__ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No __x___ Unobserved ______

(12) The student writes an essay report.

Yes __x___ No ______ Unobserved ______

(13) The student observes and records accurately.

Yes ______ No __x___ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes ______ No __x___ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes ______ No __x___ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No __x___ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x___ Unobserved ______

(18) The students work on different problems at the same time.

Yes ______ No __x___ Unobserved ______

APPENDIX II (continued)

Class 9

(1) The student contributes to the procedure in solving a laboratory problem.

Yes ______ No __x__ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes __x__ No ______ Unobserved ______

(3) The student analyzes and interprets data.

Yes __x__ No ______ Unobserved ______

(4) The student designs equipment.

Yes ______ No __x__ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes ______ No __x__ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes ______ No __x__ Unobserved ______

(8) The student constructs conceptual models.

Yes ______ No __x__ Unobserved ______

(9) The student criticizes his results.

Yes __x__ No ______ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes __x__ No ______ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No __x___ Unobserved ______

(12) The student writes an essay report.

Yes ______ No __x___ Unobserved ______

(13) The student observes and records accurately.

Yes __x___ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes ______ No __x___ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes __x___ No ______ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No __x___ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes ______ No __x___ Unobserved ______

(18) The students work on different problems at the same time.

Yes ______ No __x___ Unobserved ______

APPENDIX II (continued)

Class 10

(1) The student contributes to the procedure in solving a laboratory problem.

Yes ______ No __x__ Unobserved ______

(2) The student constructs graphs and interprets them.

Yes ______ No __x__ Unobserved ______

(3) The student analyzes and interprets data.

Yes __x__ No ______ Unobserved ______

(4) The student designs equipment.

Yes ______ No __x__ Unobserved ______

(5) The student establishes the limitations of the experimental conclusions.

Yes ______ No __x__ Unobserved ______

(6) The student uses unassigned reference material (excluding textbook).

Yes ______ No __x__ Unobserved ______

(7) The student develops ways of testing his proposed conclusions.

Yes ______ No __x__ Unobserved ______

(8) The student constructs conceptual models.

Yes ______ No __x__ Unobserved ______

(9) The student criticizes his results.

Yes __x__ No ______ Unobserved ______

(10) The student relates principles from one subject area to another.

Yes __x__ No ______ Unobserved ______

(11) The student selects the mathematical operations to be performed on quantitative information.

Yes ______ No __x__ Unobserved ______

(12) The student writes an essay report.

Yes ______ No __x__ Unobserved ______

(13) The student observes and records accurately.

Yes __x__ No ______ Unobserved ______

(14) The student realizes the limitations of the instrument he is using.

Yes __x__ No ______ Unobserved ______

(15) The student re-evaluates his ideas and opinions.

Yes ______ No __x__ Unobserved ______

(16) The student suspends final judgment on experimental outcomes until the data has been analyzed.

Yes ______ No __x__ Unobserved ______

(17) The student proposes additional problems as a result of laboratory activities.

Yes __x__ No ______ Unobserved ______

(18) The students work on different problems at the same time.

Yes __x__ No ______ Unobserved ______

APPENDIX III

Vitrogan's Attitude Toward Science Scale

INSTRUCTIONS:

This is a study of how some students feel about some important questions. On the following pages there are 40 statements with which some students agree and other disagree. It is desirable to find out to what extent you agree or disagree with these statements, in order to compare your feelings with other students of other schools.

Please mark each statement on the answer sheet according to the amount of your agreement or disagreement, by using the following scale:

+1 : Slight support, agreement	-1 : Slight opposition, disagreement
+2 : Moderate support, agreement	-2 : Moderate opposition, disagreement
+3 : Strong support, agreement	-3 : Strong opposition, disagreement

It is important that you do this as carefully as you can. Rate every statement.

There is no time limit but work rapidly.

Read carefully the sample below; then, turn the page and begin.

Sample Statement

__+1__ 1. If an opportunity for dishonesty is presented, most students will not cheat.

__-3__ 2. If an opportunity for dishonesty is presented, most students will cheat.

If you agree slightly with statement (1) you would mark +1 in the left margin next to statement (1).

If you disagree strongly with statement (2) you would place a -3 in the blank space provided in the margin next to statement (2).

The rating key has been reproduced on a separate page and distributed to you for ready reference.

_______ 1. Basic things can not change or they would not be basic.

_______ 2. The structure of an object is less important than its function because structure without a knowledge of function makes the object useless.

_______ 3. Essentially there is only physical change taking place in the world, the most basic things remain static.

_______ 4. It is more important to know how to use an object than how it is built.

_______ 5. Often there is a question of language involved in many of the questions that are asked about nature, hence the way in which the question is asked is often more important than the answer.

_______ 6. The most important thing to know about anything or any object is to know how to use it. Only if you are going to build something, should you know about its structure.

_______ 7. The major discoveries in the world were the result of careful observations.

_______ 8. Even though the earth itself and the things upon it seem to be changing, this change is only on the surface.

_______ 9. Although answers give us information, old questions asked in a new way, have brought about new discoveries.

_______ 10. Everything in the world is changing, no one situation can exist forever.

_______ 11. Every particle of matter in the world is constantly changing.

_______ 12. Most discoveries could not have been made except by a lucky accident.

_______ 13. Only by knowing how an object is built can its true use by discovered.

_______ 14. It is very rare to make a discovery by accident.

_______ 15. The real significant discoveries have been accidental, while some minor discoveries may have been the result of careful planning and observation.

______16. Knowledge can be extended more through an understanding of the function of objects rather than of how they are put together.

______17. Although things around us seem to be stable they are constantly in motion and changing.

______18. The more and better formulated questions we are confronted with, the greater our understanding will be.

______19. Everything in the world is changing even though externally it may appear to remain static.

______20. Everything in the world undergoes change.

______21. Most great discoveries of the world were made by men who observed carefully, even though they may have appeared sometimes casual in their observations.

______22. An object is useful to mankind only if its function is known; the object is only as valuable as its uses.

______23. Despite all the careful and controlled observations which have provided some important discoveries, it has been shown over and over and over again that most great discoveries are stumbled upon.

______24. Although we hear of discoveries being found by accident, for the most part most discoveries are made after careful study.

______25. Discoveries are more often stumbled upon than found through controlled observation.

______26. Most great discoveries have been stumbled upon.

______27. Basically the questions one asks do not change, though the attitude with which they are asked may change; what is important is definitely the answer.

______28. If you know how something is built you will also be able to understand its function.

______29. Once the proper question is asked, any one can discover the answer.

______30. New ideas and new observations are the results of the way in which the qeustions are asked.

______31. In order to discover something very close observation is needed.

______32. Most scientific discoveries were stumbled upon despite careful and controlled observations.

______33. Some discoveries may seem accidental, but they are only discovered because of the patience and knowledge of the observer.

______34. The way a question is asked is more important than the answer obtained because without a properly phrased question there can be no meaningful answer.

______35. Only if you want to build things should you be more interested in their structure than in how they are to be used.

______36. What we need are basic truths or facts rather than clearly stated questions.

______37. Through research and hard work, rather than by accident, scientists figure out and plan their discoveries.

______38. Understanding comes from the answer to the question rather than from the way in which the question is asked.

______39. It doesn't matter what the question is, the right answer is the most important thing.

______40. Knowledge can be gained only from the solution to problems and not from the questions which are asked.

APPENDIX IV

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APPENDIX V

PHYSICAL CHARACTERISTICS OF SCHOOLS AND COMMUNITIES

School	Enrollment	Grade Levels	Number of Physics Sections	Number of Physics Students	Population of Community	Description of Community
1	755	9-12	1	8	5800	Middle-class community
2	840	9-12	3	60	18,000	Middle-class community; also a vocational school
3	1100	9-12	3	45	8000	College community
4	2800	9-12	4	84	39,000	High-class sub. community
5	600	7-12	1	9	4500	Regional school, rural
6	1200	10-12	2	45	52,000	Factory com., two parochial schools
7	1250	9-12	4	60	20,000	Regional school, middle class
8	530	9-12	1	12	4000	Regional school, rural
9	1000	9-12	2	35	15,000	College community
10	500	9-12	1	15	7400	Industrial community, isolated

APPENDIX VI

BRIEF DESCRIPTION OF CLASS ENVIRONMENT

Class No 1: The students, who spent about 35% or their time in the laboratory, had some choice of which experiments they carried out, and the procedure to be followed. Because of the very small laboratories, the students worked in groups of two almost in isolation from the rest of the class. The groups did not interchange data; each group discussed its results directly with the teacher. The teacher's presence in the classroom had little effect on the conduct of the laboratory, since the students generated their own enthusiasm. Industrial and technical applications of the principles were emphasized in class.

Class No. 2: The students spent 70% of their time in the laboratory. The teacher usually presented them with a phenomenon that needed explaining. As the students attempted to explain it, the teacher would question their understanding. As a result of the discussion, a question arose that was necessary to solve by laboratory work. The students carried out the laboratory experiment after deciding their own procedure. An attempt was made to discover the unifying concepts or principles as the result of the year's work. Most of the time spent in the classroom was either in pre-laboratory or post-laboratory sessions. According to the teacher, his primary purpose was to generate enthusiasm.

Class No. 3: During the period of investigation, laboratory sessions occurred twice in three weeks. In the laboratory, a problem was presented to the students. They were expected to develop part of the procedure and to decide which equipment to use. During class time, problems were solved on the board by the teacher as the students offered suggestions on the direction to take. Wrong suggestions were not initially corrected by the teacher. The students were given difficult problems to take home as an examination. After the problems were completed, the student discussed them with the teacher during an individual conference.

Class No. 4: The students spent 80% of their time in the laboratory. Experiments were selected by the teacher, but the students were encouraged to vary the procedure. The students were encouraged to understand relationships. Often the teacher was absent from the laboratory. The laboratories and classes had large enrollments compared to the other classes in this study with as many as 25 students in one laboratory. PSSC apparatus and equipment were used. Some of the experiments were adapted from the advanced PSSC curriculum materials. PSSC tests were employed.

Class No. 5: Physics class met once a week for two continuous hours; 50% of that time was spent in the laboratory. The students selected the areas they wished to study. In the absence of a standard textbook, the library served as a reference. Much use was made of the students' past experience. Students often presented the information in class. The teacher frequently would leave the laboratory for half hour periods, but his absence did not affect the conduct of the laboratory. The students determined their own grades in conference with the teacher.

Class No. 6: Laboratory sessions occurred twice during the three-week period of observation. In regular class sessions the teacher followed the traditional high school physics textbook quite closely. In the laboratory, experiments were usually designed to illustrate some principle discussed in the textbook. The experiment sometimes preceded and sometimes followed the class discussion of the principle. Considerable use was made of films -- between 15% and 20% of class time.

Class No. 7: Laboratory sessions occurred once every two weeks during the period of observation. The inexperienced teacher, who was the only beginning teacher cooperating in this study, was quite authoritarian. The procedure was prescribed for the students in advance, and the teacher reviewed the procedure thoroughly before the students performed the experiment. Students were required not to deviate from the prescribed procedure. Workbooks were filled out from the laboratory reports. There were no post-laboratories, and very few demonstrations. The textbook was followed rigidly. Discipline was very poor.

Class No. 8: Laboratory sessions occurred about once every three weeks during the period of observation. The teacher presented in class material covered in the textbook. The experiments, which illustrated some principle covered in the book, were usually well-planned by the teacher. Perhaps once a term, the students designed their own laboratory experiment based on material in the book. The school was poorly-equipped for laboratory sessions. Traditional multiple-choice type questions were used for examinations.

Class No. 9: Laboratory was given on Wednesday of each week. The teacher used overlays to explain the laboratory procedure. The students devised their own format for laboratory reports. Most laboratory sessions observed consisted of the students' collecting data to be analyzed by them. The students performed the experiments in small, voluntary groups. The main emphasis in the class was on solving problems. The students were organized into five groups; one or two students dominated each group. The teacher circulated, asking questions or providing information for the solution of the problems. The answers to the problems were on the board.

Class No. 10: Laboratory sessions, which occurred at a fixed time each week, were scheduled the first period in the morning. Experiments were simple, and the students were allowed ample time to complete them. It appeared to the investigator that the students spent much time thinking about the experiments. The main emphasis was upon discovering information to support the principles discussed in the textbook. Sometimes the students had to hunt for the equipment for a particular phase of the experiment by themselves. The teacher waited for the students to come to him with questions before he offered any advice on the experiments. Discipline was unusually good with little apparent direction from the teacher. The classrom was unusually neat, and the equipment was very well cared for. Perhaps 20% of class time was taught using overlays designed by the teacher. This was the only class with a significant (45%) of girls.

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