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COURSE IN PHYSICAL SCIENCE FOR NONSCIENCE
STUDENTS (ADAPTED PSNS).

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A STUDY OF THREE OUTCOMES OF A COLLEGE LEVEL
COURSE IN PHYSICAL SCIENCE FOR NONSCIENCE
STUDENTS (ADAPTED PSNS)

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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* * * * *

The Ohio State University
1971

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CHAPTER I

INTRODUCTION

General education is not a new term or concept, as the earliest use noted is in 1837, yet it has come into common use much more recently. The origins of the theory underlying the general education movement and the techniques for achieving its objectives can almost be inferred from the criticisms of education made by educators, social theorists, and laymen.¹

The expansion of knowledge that had come about in the twentieth century, coupled with an increasingly industrial society demanding many and varied skills from its people, made it impossible for any student to study even a fraction of the available curriculum in most colleges and universities. With the rise of the free election system, which allowed students to select courses as their individual interests dictated, there was little assurance that students would even elect samples from each of the major subdivisions of the curriculum.²

¹Lewis B. Mayhew, General Education (New York: Harper and Brothers, 1960), p. 1.

²Ibid., pp. 1-2.

Another criticism of American colleges dealt with the caliber of college teaching. In the nineteenth century, liberal arts college teachers were an important part of the total lives of their students. Collegiate education was revolutionized when the German conception of the university, as a center for scholarly research, was transplanted to the American scene in the form of the graduate school. The graduate schools directly influenced the institutions of which they became a part, and indirectly influenced other colleges through the professors they educated. Research became very satisfying, respectable, and rewarding while teaching undergraduates was not. Personal contacts between teachers and students were rare and the lecture technique was used to communicate the results of research to relatively passive undergraduates.³

Early American education was based on the psychological theory of transfer of training, where it was thought that the mind could be toughened in one set of exercises in preparation for actual work in other completely different activities. Experimental psychology disproved this belief; and curriculum builders went too far in providing separate courses for different skills. It was later found that transfer was possible so long as it was directly taught for, and

³Ibid., pp. 2-3.

so long as there were perceivable common elements in the areas considered.⁴

The American college in the twentieth century failed in its important responsibility of transmitting the cultural heritage from one generation to the other. This resulted in doctors who could scarcely communicate with their patients, engineers who had no feeling for the arts-training of their wives, scientists who could not communicate with nonscientists, and even psychologists who could not understand sociologists in common conversation.⁵

The changing technological and social world of America revealed another weakness of American colleges and universities. Labor-saving devices were freeing people from the burden of long hours of work, which resulted in more leisure time. The educational system was still training people to do specific kinds of work, with no attention to educating man to do those things which command most of his time--being a member of a family, a citizen, and a leisure-using human being.⁶

These and other conditions put graduates of colleges and universities in the 1920s and 1930s in poor light. Colleges and universities were losing large numbers of students who enrolled, many

⁴Ibid., pp. 3-4.

⁵Ibid., pp. 4-5.

⁶Ibid., p. 5.

of whom dropped out of college because it did not seem to meet their expectations. Those who did finish college did not seem to be appreciably different from those persons who never entered college, in terms of their reading habits, citizenship practices, and use of leisure time. College graduates did, however, earn more money. The new kind of education, to which the name general education was given, was applied to rectify these and other conditions.⁷

There are two assumptions on which most programs of general education are based. First, undergraduate education has the responsibility of being relevant to the individual and to the society in which he will live. This assumption is often stated as a lessened emphasis on knowledge, information, and facts. This does not mean that the accumulation of knowledge in itself is not important. It does mean that there is a recognition that what is not used immediately is soon forgotten, and that a pleasant learning process that is significant may be a more important outcome of education than any body of knowledge. A second important assumption commonly underlying programs of general education is that there are desirable outcomes of education in addition to skills, facts, and information. These outcomes have often been considered "pervasive and enduring outcomes" and as "affective outcomes." There is little hope that

⁷Ibid., pp. 4-5.

these outcomes will ensue automatically from the mastery of subject matter.⁸

The literature of general education science emphasizes the need for scientific literacy for citizenship. Over twenty years ago Eric Rogers pointed out the importance of educated people understanding science in this scientific age. Rogers said that the results of science affect our everyday lives and that scientists hold controlling knowledge and skill in industry, in warfare, and in matters that affect the whole policy of commerce and government. When there is a lack of understanding between scientists and administrators, difficulties and dangers arise. Even persons in the higher echelons of business and government must meet scientists and formulate policies and make decisions based on scientific judgments. Often, they are not prepared to understand the point of view of the scientist or to assess his statements. The old claim that the educated man should know some science does not seem as important as a new claim that every educated man should understand science well enough to work with scientists and to take something of science into his own life.⁹

⁸James G. Rice, General Education (Washington, D. C.: National Education Association, 1964), pp. 4-5.

⁹Eric M. Rogers, "The Good Name of Science: A Discussion of Science Courses for General Education in College," Science, CX (December 9, 1949), p. 599.

When President Richard M. Nixon announced the appointment of Dr. Lee Alvin DuBridge as his science adviser, he talked about this problem. He admitted that science was not one of his best subjects in school, but he realized the need to have an understanding of science. So, he said, he would try to discover ways to bridge the gap between his office and people in the scientific community.¹⁰

The dangers of such a gap in communication and understanding only tend to accentuate the problems of progress and survival in our modern society, since their solution ultimately depends upon an understanding and control of technology. This is reason enough to expect each citizen to have some measure of scientific literacy. Western intellectual leadership has become dangerously divided between the scientist and the nonscientist in their lack of communication and understanding. This was the point made by C. P. Snow over ten years ago.¹¹

Verne H. Booth summarized the need for scientific literacy well.

One of the outstanding differences between the science of today and that before World War II is its relation to the public. Science no longer can be considered the business of scientists only. It has become everybody's business.

¹⁰John Lear, "Mr. Nixon and the New Era of Science," Saturday Review, LII (January 4, 1969), p. 101.

¹¹C. P. Snow, The Two Cultures and the Scientific Revolution (New York: Cambridge University Press, 1959).

Let us forget for a moment about bombs. What the scientists do in the next few decades will have an important influence on the lives of us all, for science has become a great natural resource which will probably change the lives of many of us. Can an intelligent citizen afford to be ignorant of science? Can he afford to leave the use that is to be made of scientific discoveries to men who are ignorant of science and its methods? Can he afford to leave such use to scientists alone? The only alternative is for every intelligent citizen to become familiar with science and its methods.¹²

There is today a well-established recognition of the need for science courses specifically designed for the nonscience student. There is not, however, complete agreement on the nature of such courses.

There are some trends in science courses for the non-science student in college that are now quite evident. Survey courses, which have been used to cover large blocks of information, have been blacklisted and the term "survey course" has become taboo. Departmental lines are being dissolved and broad integrating topics, principles, and laws or conceptual schemes are being used. Interrelationships are being stressed in many cases. Much more emphasis is placed upon the student acquiring an understanding of science processes and the scientific enterprise. The desirability of laboratory work is accepted by practically everyone teaching general education science courses, but there is a shift away from the

¹²Verne H. Booth, Physical Science: A Study of Matter and Energy (New York: The Macmillan Company, 1967), p. 716.

"cook-book" experiments to those which give a greater understanding of the scientific endeavor.¹³

In an attempt to continue the above positive trends, the Commission on College Physics and the Advisory Council for College Chemistry held a series of conferences in 1963 and 1964 to encourage the initiation of a project to design a new course in physical science for the nonscience student. As a result of these conferences, the Physical Science for Nonscience Students Project (PSNS) was started in April of 1965. The project headquarters are at Rensselaer Polytechnic Institute, Troy, New York, and the project is financed by the National Science Foundation.¹⁴ A list of the members of the PSNS Staff is found in Appendix F.

The project was initiated to fill the need for a college-level course in physical science for the nonscience student, and was designed especially for those with low aptitude for and/or interest in science and mathematics. The objectives of the course are to introduce the nonscience student to the nature of scientific inquiry and experimentation and to change his attitude toward science from one

¹³Robert Ray Haun, "Changes Within the Decade," Science in General Education (Dubuque, Iowa: William C. Brown Company, 1960), p. 15.

¹⁴Paul Westmeyer, "A New College Level Physical Science Course," A paper presented at NARST, February, 1966, p. 1.

of anxiety or disinterest to one of confidence and interest.¹⁵

The ability to approach new problem situations with a scientific attitude, confidence and interest in performing simple experiments and observing phenomena, and the ability to answer substantive questions on the material covered in the course, are the behavioral objectives stated by the course designers.¹⁶

To achieve these objectives the student must have time to investigate and be enticed into wanting to investigate. It takes time to do this, thus the subject matter must be drastically limited.¹⁷ Attention is focused on a narrow range of subjects, including solid matter and the techniques for its investigation. Other areas of physical science are studied only when necessary to understand the above.¹⁸

Problem

Does the Adapted Physical Science for Nonscience Students (PSNS) Course significantly contribute to an understanding of the

¹⁵J. David Lockard, compiler, Report of the International Clearinghouse on Science and Mathematics Curriculum Developments (College Park, Maryland: AAAS and Science Teaching Center, University of Maryland, 1967), p. 303.

¹⁶Ibid., p. 304.

¹⁷Westmeyer, op. cit., p. 2.

¹⁸Lockard, op. cit., p. 303.

scientific enterprise, positive attitudes toward science and scientists, and an understanding of solid matter and the techniques for its investigation?

Definitions

1. PSNS Course: For the purpose of this study, this term will refer to a general education physical science course in which the textbook and associated materials were prepared by the Physical Science for Nonscience Students Project.¹⁹

2. Adapted PSNS Course: For the purpose of this study, this term will refer to a general education physical science course developed at California State College (Pennsylvania) and based primarily on the PSNS Course.²⁰

3. Scientific Enterprise: For the purpose of this study, this term will refer to the assumptions, activities, objectives, and products of science, as measured by The Wisconsin Inventory of Science Processes.²¹

4. General Education: For the purpose of this study, this term will refer to those phases of learning which should be the common

¹⁹This course is outlined in Appendix A.

²⁰This course is outlined in Appendix B.

²¹The Wisconsin Inventory of Science Processes, The Scientific Literacy Research Center (Madison: The University of Wisconsin, 1967).

experience of all men and women. Purposes and programs of general education are often described with reference to different and often opposing philosophical foundations.²²

Hypotheses

The null hypotheses tested were:

1. There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a test of knowledge of the scientific enterprise, as measured by The Wisconsin Inventory of Science Processes, when initial differences in pretest scores have been adjusted.

2. There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a scale of attitudes toward science and scientists, as measured by "Attitudes Toward Science and Scientists" developed by Cummings, when initial differences in pretest scores have been adjusted.²³

²²Carter V. Good, ed., Dictionary of Education (2 ed.; McGraw-Hill Book Company, Inc., 1959), p. 245.

²³John Rosswell Cummings, "Development of an Instrument to Measure Attitudes Toward Science and the Scientist" (unpublished Ph. D. dissertation, The Ohio State University, 1969).

3. There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a test of knowledge of solid matter and the techniques for its investigation, as measured by an instrument developed by the researcher and known as the "APSNS Instrument," when initial differences in pretest scores have been adjusted.

Delimitations

The study was delimited to the first trimester freshmen at California State College (Pennsylvania) in the School of Education, who were not majoring in science or industrial arts, for the Fall Trimester, 1969-70.

Limitations

1. The present study is limited to the effect, if any, that the subjects will know that they are participating in an experiment. The subjects thus may respond to the treatment in a manner unlike that of subjects not knowing that they are participating in an experiment.

2. The study is limited in that only one teacher taught the groups having the experimental treatment. The effects of teacher personality, preparation, experience, as well as other relevant factors, thus cannot be determined.

3. The study is limited in that during the analysis of data some subjects' scores were deleted in order to equalize the size of the various groups involved. Some power was sacrificed in order to avoid the computational labor necessary for the analysis of a disproportional design.

Assumptions

1. It was assumed that the sample was sufficiently large and drawn in a manner to represent the characteristics of the population.

2. It was assumed that the testing instruments possessed the reliability and the validity required for the present research purposes.

Need for the Study

Indications that the objectives of the PSNS Course have been achieved were based primarily on expressions of enthusiasm by the teachers for this approach in comparison to other approaches they have used. Essays from students indicate that this was the first science course they have ever enjoyed and really understood.²⁴

Research on the outcomes of the PSNS Course was planned for the academic year 1967-68; however, assurance of continued

²⁴Lockard, op. cit., pp. 304-305.

support from the National Science Foundation was not received in time to contract for such services.²⁵

The director of the PSNS Project, Professor Lewis G. Bassett, informed the researcher in November of 1968 that there were no plans for further evaluation or research and expressed a keen interest in the research study. In April of 1969, Professor Bassett informed the researcher that funds were available for an evaluation, the details of which were not known to him. The PSNS Course was designed as a one-year course, while out of necessity many colleges and universities must teach their general education physical science course in a much shorter period of time. Professor Bassett recognized this as a limitation of the PSNS Course and encouraged the researcher to adapt the course for use during a shorter period of time and conduct research on the outcomes of this adapted version.²⁶

There are several shortcomings in the work of the PSNS Project that this research study attempted to correct. First, the course was designed as a one-year course, while many colleges and universities teach their general education physical science course in a much shorter period of time. Any research done with PSNS Course

²⁵The PSNS Project Newsletter No. 2, PSNS Project, Rensselaer Polytechnic Institute, Troy, New York, November 1966, p. 16.

²⁶Telephone conversations with Professor Lewis G. Bassett.

materials offered over a period of one year will not prove their efficacy during half that period of time. Secondly, indications that the PSNS Course would achieve the desired outcomes, were based primarily on testimonials by students and teachers. Even the shortened Adapted PSNS Course should provide some significant insights into the efficacy of this approach.

On January 28, 1971, when the present study was completed and the report was being written, the researcher was given a copy of the Physical Science for Nonscience Students Final Report. This report included the procedure and results of an evaluation study that was done by Dr. Wayne Welch for the PSNS Project.²⁷ This study is presented in Chapter II. It is the opinion of this researcher that the present study, although limited in some ways when compared to Dr. Welch's study, provides some significant insights into the efficacy of the PSNS materials for use in general education physical science courses.

Procedure

The population in this study included those entering freshmen at California State College (Pennsylvania) in the School of Education, and not majoring in science or industrial arts, during the Fall

²⁷Lewis G. Bassett, ed., Physical Science for Nonscience Students Final Report (Troy, New York: Rensselaer Polytechnic Institute, January, 1971).

Trimester of the 1969-70 academic year. Four groups, of twenty-three subjects each, made up the sample.

Three instruments were employed to test the hypotheses stated above. The two developed by others were The Wisconsin Inventory of Science Processes, and "Attitudes Toward Science and Scientists." The "APSNS Instrument" was developed by the researcher by selecting items from a pool developed by the PSNS Project Staff. The validity was determined, and some items were deleted to make the reliability suitable for the present research purposes.

The Solomon Four-Group design was used, and it will be helpful in understanding the testing and treatment in this study. An X represents the exposure of a group to the experimental treatment, the effects of which are to be measured; O refers to an observation which will be a test score; the Xs and Os in a given row are applied to the same specific subjects. The left-to-right dimension indicates the temporal order, and Xs and Os vertical to one another are simultaneous. The symbol R indicates random assignment to separate treatment groups. The design is as follows:

R	O ₁	X	O ₂	(Experimental Group)
R	O ₃		O ₄	(Control 1 Group)
R		X	O ₅	(Control 2 Group)
R			O ₆	(Control 3 Group)

The above three mentioned instruments were administered as pretests and posttests to the subjects in the Experimental Group. Between these tests, they received the treatment which will be described later. This took place during the fourteen-week Fall Trimester of the 1969-70 academic year at California State College in California, Pennsylvania. The Control 1 Group subjects were tested likewise, except they did not receive any treatment. Subjects in the Control 2 Group were given the treatment and were tested only at the end of the fourteen-week period, while those in the Control 3 Group received no treatment but were tested in the same way. Only those subjects in the Experimental and Control 2 groups had any formal instruction in science, and no group had any mathematics course during this period of time.

The treatment in this study consisted of the Adapted PSNS Course. Mastery of the subject matter is considered only one of the objectives of this course. Subject matter coverage has been drastically limited and centers on the theme "solid matter and the techniques for its investigation." A premise on which the course is based is that more real science can be taught, in the limited time available, if less broad coverage of subject matter is attempted. Subject matter is really "uncovered," as students are encouraged and invited to observe carefully the nature of the physical world, wonder about it, then suggest hypotheses to explain it. Another

characteristic of the course is the place reserved for laboratory experiences. Experimentation is central to the course, and the classroom work is supportive. The open-ended experiments with which the students become involved require them to ask new questions and suggest procedures for answering these questions. The classwork is designed to help students ask these questions and work toward answering them, rather than learning the answers to old questions. The treatment also helps students with poor backgrounds in mathematics, as this is a characteristic of many college students which precludes their developing an interest in, and ability to do scientific work, even on an elementary level. In short, students learn to do science, rather than just learn about science.

The design described above permits a determination of the main effects of treatment and pretesting, the interactive effect of pretesting with treatment, and the combined effect of maturation and history. Appropriate statistical techniques were employed to make use of the six sets of observations that were collected in this study. These observations consisted of test scores designated as O_1 to O_6 in the design presented above. Data from student records were also used to investigate for possible sources of bias among the four groups that may have occurred when subjects were randomly assigned to these groups. Based on available data in student records, the following variables were investigated: intelligence, high school rank,

and verbal and nonverbal S. A. T. scores.

Overview of the Study

Chapter I has included a rationale for the study, a statement of the problem, definitions, hypotheses, delimitations, limitations, assumptions, need for the study, and a brief description of the procedure. Chapter II presents a review of the related literature. A detailed description of the procedure for the study is presented in Chapter III. A detailed analysis of data of the study is presented in Chapter IV. Chapter V contains a summary of the study, a discussion of the results and their implications for general education physical science courses.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

The review of the related literature and studies presented in this chapter will be developed in four parts. Part one will be devoted to a brief history of the teaching of general education science in colleges and universities. Part two will present the literature pertaining to the PSNS Course which was not presented in Chapter I. The third part will deal with research studies related to the problem. Part four deals with the two instruments, developed by others, that are used in this research study.

History of General Education Science

American colleges and universities have offered instruction in the natural sciences almost since their founding. Harvard offered "Astronomy" and the "Nature of Plants" as early as 1690.¹

The period from the latter part of the eighteenth century was one in which instruction in the natural sciences became a very

¹Victor H. Noll, "Science Teaching on the College Level," A Program for Teaching Science, Thirty-first Yearbook of the National Society for the Study of Education, Part I (Bloomington, Illinois: Public School Publishing Company, 1932), p. 306.

definite portion of the college curriculum. The separate subject approach was used to teach the various sciences, and the method was almost always lecture and demonstration. Very few laboratories were in existence, and they were used by instructors. When Rensselaer Polytechnic Institute was founded in 1825, an attempt was made to include student laboratory work in the natural sciences. The students were required to lecture and perform demonstration experiments before the class, as a part of the required work in the courses.²

In the latter part of the nineteenth century and the early part of the twentieth, individual laboratory work by the student became common in science courses. During this period, students were urged and required to take courses in science for many reasons. Some of these reasons were narrowly practical, some strictly disciplinarian, and others broadly cultural. Practical reasons given for urging students to take science courses centered on the increasing importance of science in industry and everyday life. Disciplinarian reasons focused on the idea of transfer of training that was quite popular at that time, while the cultural reasons for taking science became apparent with the introduction of the elective system which released students from the iron-clad classical curriculum.³

²Ibid., p. 307.

³Ibid., p. 308.

Science courses in colleges and universities reached their peak of popularity early in the twentieth century. At the time the Thirty-first Yearbook of the National Society for the Study of Education was published, in 1932, there was a questioning attitude about the place of science courses in colleges and universities. This resulted, in part, from the results of many experiments on transfer of training, which threw the disciplinary outcomes of science courses into serious question.⁴

The existing elementary courses were designed primarily for those students who intended to take advanced courses, and thus they necessarily dealt intensively with the detailed subject matter basic to further study in a particular discipline. Students completing these courses, even under the most favorable conditions, had considerable knowledge of a single subject with only limited understanding of science as an intellectual method or of its impact on modern life.⁵

Although colleges and universities had identified different functions for science courses, there is little evidence to show that courses had been developed with any difference of function or aims

⁴Ibid., p. 309.

⁵Earl J. McGrath, "Trends in Science Courses in General Education," Science in General Education, ed. Earl J. McGrath (Dubuque, Iowa: William C. Brown and Company, 1948), p. 381.

in mind. It was very unusual to find two different courses offered in the same subject. Attempts were made to offer two types of courses in elementary botany at the University of Minnesota during the period of 1877-1928. These attempts failed.⁶

College faculties were shocked by the narrow specialized knowledge which college graduates possessed after World War I, and set about to reorganize the curriculum with the purpose of increasing the breadth of students' knowledge and the diversity of their intellectual skills. Their efforts resulted in the survey course, which became popular in the late twenties and thirties.⁷ Survey courses, in general, are designed to give a general view of an area of study, often as a means of introducing an unfamiliar field to students before they undertake specialized work or as a means of acquiring broad general concepts about an area in which they may or may not plan to specialize.⁸ These survey courses were designed for the nonscience student, stressed breadth rather than depth, and drew their subject matter from several of the more established science fields.⁹

⁶Noll, op. cit., p. 310.

⁷McGrath, loc. cit.

⁸Carter V. Good, ed., Dictionary of Education (New York: McGraw-Hill Book Company, Inc., 1959), p. 143.

⁹W. C. Van Deventer et. al., "Science for General Education in the Colleges," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education. Part I (Chicago, Illinois: NSSE, 1960), p. 97.

The early efforts to improve science courses for nonscience majors were not successful. The major reason for their failure was the superficiality of the new survey courses. They covered so much ground, that students resorted to memorizing a vast array of facts. Educators then realized that even superior students could not cover any significant portion of the subject matter of three, four, or more sciences, in the allotted time. They also realized that it was not necessary to cover so large a body of material to reach the principal goals of science education. Therefore, it was not only possible, but desirable, to shift the emphasis in science instruction from the learning of detailed facts to the understanding of laws or principles of general applicability.¹⁰

Victor H. Noll, in 1932, called for the improvement of science courses for the nonscience student. The survey course that he recommended would include the following aims: (1) information, (2) development of interest in science, (3) understanding of the relationship of science to environment and everyday life (application), (4) understanding of the relationship of the particular science studied to other sciences, and (5) culture. He also saw a need for a preparatory course in science, whose aims should be the same as those of the survey course plus preparation for further study and specialization

¹⁰McGrath, op. cit., p. 382.

in science. A third type of course for teachers, he recommended, should include some combination of the above aims or, better still, all of the above aims. For this reason, future teachers should be enrolled in the preparatory course, if a choice is made.¹¹

Later efforts to improve the survey courses in science resulted in extensive experimentation in the late 1930s and early 1940s. The new courses that evolved were generally of three types: (1) survey courses of an improved type, (2) problem courses, and (3) cultural heritage courses. The new survey type courses took the form of integrated principles courses, based on concepts, processes, and procedures that act as unifying themes running through one or more science fields. The problems courses were based on selected problems of human living, while the cultural heritage courses either utilized a chronological-historical approach or used case studies selected from the history of science.¹²

By 1948 there were some discernable changes or new emphases in general education science courses in colleges and universities. Following are some observations identified by Earl J. McGrath.

1. There was dissatisfaction, on the part of many

¹¹Noll, op. cit., pp. 311-312.

¹²Van Deventer, op. cit., pp. 97-98.

professors, with the first attempts to provide better courses for nonscience students. They were not willing, however, to return to having the student elect an introductory course in one of the sciences to meet his general education requirement in science.

2. These professors were developing new general education science courses, with considerable variation from institution to institution, but with some similarities.
3. The new courses treated a few selected topics, laws or problems intensively, without including all of the facts that could be considered "connecting tissue."
4. The new courses usually consisted of two or three lecture-demonstration sessions, a discussion session, and usually several hours of laboratory work.
5. Emphasis was placed on the methodology of science, and the impact of science on modern life.
6. An increasing number of faculties believed that their goals could only be realized if students were required to study both physical science and biological science for at least one semester each.

7. Examinations were being used to an increasing extent to relieve students of requirements, when they were able to demonstrate that they had the necessary knowledge and skills.
8. The most common objective of these courses dealt with the development of an appreciation of the "scientific method," and the ability to use it.
9. Another common objective was that only a representative selection of leading principles and laws was contemplated, when aims referred to the student's becoming acquainted with facts in the various sciences.
10. A third common objective dealt with an understanding of the impact of science on modern life.
11. An increasing number of institutions had as a fourth objective, acquainting students with the historical development of science.¹³

As a result of various reports, in the late 1940s and early 1950s, Louis M. Heil made the following generalizations about experiences in general education science courses. They are not unlike those made by McGrath, several years before.

1. A knowledge of specific facts, laws, and principles
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¹³McGrath, op. cit., pp. 382-389.

of science was considered less important for general education students than for professional or preprofessional students.

2. Statements of objectives and statements about objectives of science for purposes of general education were more common in descriptions and discussions of general education science courses, than in science courses for professional and preprofessional education.
3. A major objective of general education science courses was a knowledge of the "scientific method."
4. There was little agreement concerning the major topics or content of science courses for general education purposes. Some courses centered on topics selected from the standard structure of science, others dealt with topics in which many principles or concepts in one or several fields of science were exemplified. Still other courses centered on topics illustrating human needs.
5. Much emphasis was placed on practical applications of scientific knowledge, in terms of a happy and useful life. Although this was recognized as desirable by many instructors in all areas of science,

a better job was done in the biological sciences.

6. There was a growing conviction that the way topics were dealt with was at least as important as the topics themselves. The topics were to be dealt with in such a way that students could recognize other examples and applications of the ideas and procedures illustrated by these topics.
7. More opportunities were provided for student analysis and discussion with fewer lectures.¹⁴

The further evolution of general education science courses can be seen with an identification of some evident trends made in 1960 by Van Deventer.

1. There was a trend toward agreement on the objectives of general education courses in science. The objectives mentioned most often stressed the necessity for developing in students an understanding of the nature of science and the methods used by scientists.
2. General education science courses were for non-science students only. Preprofessional and science

¹⁴Louis M. Heil, "The Natural Sciences in General Education," General Education, Fifty-first Yearbook of the National Society for the Study of Education. Part I (Chicago, Illinois: NSSE, 1952), pp. 138-140.

major students were required to take courses called introductory courses in the various sciences. This was a necessary expedient, in many cases, because introductory courses provided the necessary background for more advanced courses in science. It was felt that preprofessional and science major students would acquire the understandings, which are included in general education courses, as a result of a greater exposure to science in the many required courses.

3. Related to the above trend was a trend to administer comprehensive examinations to entering college freshmen, in an attempt to determine their need for a general education science course.
4. There was no definite trend in the use of the laboratory or demonstrations in the teaching of these courses. If there was a trend, it was toward the adoption of a multiple method including lecture, discussion, and demonstration, with individual and group laboratory.
5. There seemed to be three general approaches to the organization of general education science courses. They were: (1) the logic-of-science approach, (2) the

problem-area approach, and (3) the case study approach. Each of these was an outgrowth of a type of general education science course prevalent over a decade before. Courses emphasizing the logic of science were examples of the integrated-principles courses that grew out of the older survey courses. The problem-area approach was an outgrowth of the problem course, while the case study approach carried the viewpoint of the cultural heritage courses. There were certain similarities among these three types of courses, as they all utilized the block-and-gap type of organization and gave some attention to scientific methodology.¹⁵ In the block-and-gap organization, the blocks represent the topics chosen for study; they are extensive and studied thoroughly with the interrelationships among the blocks in a given course discovered, explored, and discussed. The gaps serve the purpose of reducing the content of the course so that there may be more time for ideas to mature and

¹⁵Van Deventer, op. cit., pp. 99-103.

for students to reflect and consider what they are studying.¹⁶

In 1960 another observer of the general education science scene identified some trends, brief mention of which was made in Chapter I. Following are some of the trends identified by Robert Ray Haun.

1. There was a well-established recognition of the need for two kinds of courses, one for the students specializing in science and the other for the nonscience or general student. Traditional courses for the major were taking on more breadth, and the general courses more depth.
2. Survey courses were black-listed, and the term "survey course" had become taboo. This had come about, in part, by the realization that it was impossible to cover all of the sciences, even all of the physical sciences, within the allotted time.
3. The block-and-gap course appeared in place of the survey course. There was no agreement, however, among the various people offering these courses as to which topics were to be included. Comments

¹⁶Good, op. cit., p. 141.

from those involved, texts, and course outlines indicate that some coverage of the various sciences was considered highly desirable. For this purpose, departmental lines were dissolved and broad integrating topics, principles, and laws or conceptual schemes were used with interrelationships stressed in many cases.

4. For many years, one of the objectives of general education science courses was to teach the "scientific method." With the denial of a single, simple scientific method, objectives changed. To reflect this fact efforts were made to have students understand some specific processes the scientist uses in his work.
5. Another older objective of science education had undergone extensive metamorphosis. "Understanding of scientific applications," no longer meant a knowledge of how the pump, fire extinguisher or automobile worked, but the impact of scientific knowledge and developments upon society and the life of the individual. Applications of the former type were still discussed, as illustrations of principles, and not as attempts to

explain how gadgets operate.

6. Laboratory work was accepted by practically everyone teaching these courses, but there was a shift away from the cook-book type experiments to those which give greater understanding of the scientific endeavor.¹⁷

The PSNS Project

Although seven articles have been written about PSNS by staff members, a more comprehensive presentation of the PSNS Project is found in the Physical Science for Nonscience Students Final Report. Six of these articles are included in the Final Report.¹⁸ Each article will not be presented separately, as they are repetitive. Parts of the Final Report, that will help the reader understand the work of the PSNS Project will be presented.

History of Organizational Activities

The Commission on College Physics (CCP) and the Advisory Council on College Chemistry (ACCC), in their early meetings, often

¹⁷Robert Ray Haun, "Changes Within the Decade," Science in General Education, ed. Robert Ray Haun (Dubuque, Iowa: William C. Brown Company, 1960), pp. 4-15.

¹⁸Lewis G. Bassett, ed., Physical Science for Nonscience Students Final Report (Troy, New York: Rensselaer Polytechnic Institute, January, 1971), p. 86.

discussed the need for better college science courses for the preparation of elementary school teachers. On September 5-7, 1963, these two organizations sponsored a conference in Chicago designed to explore the need for and interest in the development of materials for a laboratory-oriented physical science course for elementary education majors. There was agreement at this conference that there was a need for, and interest in, developing such a course.¹⁹

Another meeting was sponsored by these two organizations on October 18-19, 1963, in Rosemont, Pennsylvania. Twenty-six persons were invited to this conference. Included were persons who were thought to be insightful and experienced in teaching science to nonscience majors or because they had special qualifications for roles it was hoped they would play in future activities. In addition to talented teachers and curriculum developers, the participants included designers, film makers, and apparatus developers. The conference developed a feeling for the "tone" and "style" appropriate to a successful course for nonscience students. Another accomplishment was the identification of Rensselaer Polytechnic Institute as a suitable development site, and Lewis Bassett, Professor of Chemistry there, as the administrative director.²⁰

¹⁹Ibid., p. 1.

²⁰Ibid., p. 2.

Discussions aimed at describing a desirable course continued during the 1963-64 academic year. Prospective project staff members were contacted and arrangements were made for providing facilities and services for the materials developers. Preliminary drafts of a proposal requesting financial support were prepared. The principal participants in these activities were Lewis Bassett, Harold Faigenbaum, and Robert Resnick of Rensselaer Polytechnic Institute and Walter Michels, Edward Lambe, and Arnold Strassenburg of the Commission on College Physics. In April of 1964 Dr. Elizabeth Wood, then a crystallographer at Bell Telephone Laboratories, agreed to serve as leader of the materials development staff.²¹

While discussions about a physical science course for prospective elementary school teachers were occurring, the Commission on College Physics was promoting a conference on physics courses for nonscience majors, to be held on July 20-29, 1964 at the University of Colorado. The persons planning the conference on physics courses for the nonscience majors saw an opportunity to prepare course descriptions for suitable physical science courses that would be helpful to the Rensselaer group, in their efforts to prepare a proposal for course development. Descriptions of physical science

²¹Ibid., p. 3.

courses, taught during the 1963-64 academic year, by Walter Knight at the University of California at Berkeley, by Melba Phillips at the University of Chicago, and by Edwin Uehling at the University of Washington were presented in detail by the instructors and analyzed by the conference participants. Dr. Elizabeth Wood contributed an early conception of the PSNS Course. This course was enthusiastically accepted by the participants, giving the Rensselaer group confidence in their ideas.²²

On September 9-11, 1964, the PSNS leaders met in Latham (near Troy), New York to prepare a final version of a proposal for project support. A completed proposal was submitted to the National Science Foundation in November, 1964. The foundation made a grant to Rensselaer Polytechnic Institute in April, 1965.²³ The total amount received from the National Science Foundation from 1965-71 was \$684,365.²⁴

Administration

During the course of negotiations with the National Science Foundation, leading to the grant, it was decided that the administrative staff would consist of a Director, Professor Lewis G. Bassett

²²Ibid., pp. 3-5.

²³Ibid., pp. 5-6.

²⁴Ibid., p. 10.

of the Chemistry Department of Rensselaer Polytechnic Institute, who would be the principal administrative officer of the project, and two Associate Directors. The Associate Directors were Professor Robert L. Sells of the Physics Department of the State University of New York at Geneseo and Dr. Elizabeth A. Wood of the Bell Telephone Laboratories. Dr. Wood was in charge of the development of the course itself, including the procurement of staff and materials to implement the development and operation of the course.²⁵ In May 1968, Professor Walter E. Eppenstein of the Physics Department at Rensselaer Polytechnic Institute became a codirector of the project.²⁶

An Advisory Board was organized, with Dr. Wood as Chairman, to advise and assist the administrative officers in the discharge of their duties.²⁷ In the spring of 1967, Dr. Wood retired as Chairman of the Advisory Board. She was replaced by Dr. Arnold A. Strassenburg, Professor at the State University of New York at Stony Brook and the Director of the Education and Manpower Division of the American Institute of Physics.²⁸

²⁵Ibid., p. 7.

²⁶Ibid., p. 23.

²⁷Ibid., p. 7.

²⁸Ibid., p. 23.

A list of the PSNS Project Staff members, along with their field of specialization and dates of service to the project is found in Appendix F.

Materials Development

When it seemed probable that favorable action would be taken on the project proposal by the National Science Foundation, a meeting was held at the American Institute of Physics on February 15-16, 1965. The meeting was designed to plan for the work that would be done during the summer. The name Physical Science for Nonscience Students (PSNS) Project was selected as the name of the project. The participants, which included the members of the materials-development staff as well as members of the Advisory Board and a few other interested persons, agreed to distribute questionnaires to about 2,000 students who were currently enrolled in college physical science courses. The questionnaire was designed to determine backgrounds and attitudes of these students in science and mathematics. It was felt that the results of these questionnaires would be useful in preparing the materials for the proposed course.²⁹

During the summer of 1965, the staff began to prepare the written materials. Two or three members of the staff were assigned to each of the eighteen proposed chapters. One person was assigned

²⁹Ibid. , pp. 27-29.

primary responsibility. First draft material was prepared and given to every member of the staff. As the volume of written and re-written materials increased, late in the summer, much of the material was not read and criticized by every member of the staff. An editorial board, however, consisting of the Director, the Associate Directors, Professor Lois Smith, and sometimes various other members of the staff, read all of the completed chapters.³⁰

During the 1965-66 academic year, eight trial teachers used the materials that had been prepared during the previous summer in their respective colleges. The text was the first preliminary edition, and was printed in five papercovered volumes. The necessary laboratory equipment was collected, assembled, and supplied by Earl Carlyon and Elizabeth Wood. The project received feed-back from these trial teachers in the form of personal letters and at a one-day meeting held in January of 1966.³¹

Revision of the written materials, which resulted in the second preliminary edition, took place during the summer of 1966. This revision was based primarily on the feedback received from the eight trial teachers. A looseleaf Teachers' Resource Book was produced. Work was started on two supplementary chapters to the text.

³⁰Ibid., pp. 30-31.

³¹Ibid., pp. 32-33.

The chapter on Acids and Bases was written by Professor Lois Smith and the chapter on Magnetism was written by Professor Donald F. Holcomb. During the last two weeks of August, 1966, Dr. Arnold A. Strassenburg conducted a briefing session for the twenty-three teachers who planned to teach the PSNS Course during the 1966-67 academic year.³²

On the basis of feedback from the twenty-three trial teachers the third preliminary edition was prepared and published by John Wiley and Sons. This edition was used during the 1967-68 and 1968-69 academic years. The course was used in approximately forty colleges during 1967-68, and about fifty colleges in 1968-69.³³

The final hard-cover text, An Approach to Physical Science, was published by John Wiley and Sons in January of 1969. Publication of the revised edition of the Teachers' Resource Book followed shortly thereafter. In 1970 Wiley published the final edition of the Teachers' Resource Book and a book of Supplementary Chapters.³⁴ Wiley reported sales for 1969-70 at 13,000 copies of the text; 153 different colleges placed orders ranging from ten to 612 copies.³⁵

³²Ibid., pp. 34-35.

³³Ibid., pp. 37-38.

³⁴Ibid., p. 38.

³⁵Ibid., pp. 94-95.

Goals and Content

The following goals and guidelines were not explicitly stated when the course was originally outlined. The PSNS Staff felt that they did, however, form the basis for the conception of the course and influenced the choice of content.

1. Attitude Goals

- (a) To change the attitude of the students toward science from one of confusion, anxiety and dislike to one of confidence and interest; hopefully, to convince the students that science is fun.
- (b) To convince the students that science is observation and wondering; asking questions about the world around us and designing ways of discovering answers to them, not just memorizing facts.
- (c) To convince the students of the self consistency of science, the fact that it all fits together to make sense; that the Universe is not a capricious Universe in which the Earth may suddenly stop rotating or gravitational forces cease to act.
- (d) To have the students experience experimental (laboratory) investigations and gain confidence in their own observations and their ability to analyze them. They should get a sense of how we know what we know.

2. Substantive Goals

(a) To encourage the observation of natural phenomena among college students who are nonscience majors.

(b) To teach nonscience students how to formulate questions about physical situations.

(c) To teach nonscience students how to propose models and hypotheses consistent with their observations.

(d) To teach nonscience students how to design simple, controlled experiments to test their hypotheses.

(e) To teach nonscience students how to analyze experimental results.

(f) To provide for nonscience students a basis for recognizing the limitations of science.

3. Subject-Matter Guidelines

(a) In order to give time for achievement of the important goals listed above, much of the subject matter that is commonly packed into the science course for nonscience students must be omitted: the goal is not to teach the students as many facts as possible. A choice of subject matter must be made which best serves the goals listed above.

(b) In keeping with the title Physical Science, the subject matter chosen should lie mostly in the overlap area shared by physics and chemistry and should, insofar as possible be

unidentifiable as belonging to either field.

(c) For logical coherence a major focus of study should be chosen, to which all subject matter of the course contributes in a demonstrable way.

(d) The focus of study should be one rich in opportunities for first-hand experiences (laboratory) with familiar materials where possible and with simple equipment.³⁶

The central focus of the course was solid matter, how it gets the way it is, how it behaves when you do things to it, and how we find out about it. This focus is not so sharp as to exclude subject matter that is important in learning about solids.³⁷

The organization of subject matter is vertical or spiral. This means that at the beginning, students make tangible investigations of familiar substances in simple ways, gradually increasing in sophistication through the course as the students gain confidence in their work. This is based on the idea that we may gain only superficial understanding of a process or concept on first acquaintance with it. When there is an encounter again, there is the pleasure of familiarity to enhance interest and understanding. This is not the block-and-gap approach of most survey courses.³⁸

³⁶Ibid. , pp. 39-40.

³⁷Ibid. , p. 42.

³⁸Ibid. , pp. 42-44.

Certain themes or "threads," which run through all of science, were identified by the PSNS Staff and called to the attention of the students in the PSNS materials. These were:

- (a) The beauty of the orderliness and self-consistency of the Universe.
- (b) Symmetry, its beauty and its power as a tool.
- (c) The Conservation Laws.
- (d) The uses of mathematical expression.
- (e) The power of the technique of making models, both physical and mental.³⁹

Related Research Studies

Some organized research studies have been found that are concerned with the teaching of general education physical science. Only two research studies, in addition to the present study, deal with the PSNS Course or an adapted version. They will be presented in this section.

Tennieson Diehl at Miami University, Oxford, Ohio, used PSNS Course materials in a one-trimester course to find if students in this course were more open-minded toward science and had a better understanding of the role of science in contemporary society. The control group encountered rigid lectures and laboratory

³⁹Ibid., pp. 42-43.

experiences, while the experimental group used a pervasive laboratory approach accompanied by a nondirective teaching technique. He found no significant difference between groups in their open-mindedness toward science, as measured by a dogmatism scale designed by Milton Rokeach. There was no significant difference between groups in their understanding of science, as measured by the Facts About Science Test.⁴⁰

The PSNS Course and the Adapted PSNS Course use take-home experiments. Research was conducted to study the cognitive effects of such experiments on student achievement in college-level physical science classes by Appleman. As a secondary feature, data were collected pertaining to the students' attitude toward the physical science course. There was no significant difference between the achievement of the experimental group and the control group on the total test of laboratory achievement. The experimental group used take-home experiments, while the control group used the same experiments in a traditional weekly two-hour physical science laboratory. Significant differences on the subtest scores indicated that the types of groups, experimental and control, and the kinds of experiments are determining factors in the selection of the most effective

⁴⁰Tennieson Handley Thomas Diehl, "A Study of Attitude and Thought Pattern Changes Resulting from the Use of a Physical Science Course for Nonscience Majors" (unpublished Ph. D. dissertation, The Ohio State University, 1967).

laboratory approach, as experimental students did better on some experiments and control students did better on others. Difference of attitude variations were greater between the various experiments than they were between the experimental and control groups. This indicates that attitudes toward the physical science course were affected more by the experiment than the place where the experiment was performed; that is, at home or in the school laboratory.⁴¹

An investigation by Joseph Zingaro was conducted to determine if an inductive laboratory method of teaching physical science would result in significantly greater achievement than a traditional laboratory method, for sophomores in college physical science. He was concerned with achievement in respect to learning facts and principles, understanding the methods and nature of science, ability to think critically in physical science, and the ability to think critically in nonscience areas. The inductive laboratory method was found to be superior with respect to critical thinking in physical science, yet no significant relationship was found between a student's ability to think critically in physical science and his ability to think critically in nonscience areas. There was no

⁴¹Ronald Eugene Appleman, "A Comparative Study of the Cognitive Effects of the Use of Take Home Laboratory Materials on Student Achievement in College Level Physical Science Classes" (unpublished Ed. D. dissertation, Oklahoma State University, 1967).

significant difference between the inductive and traditional laboratory groups in the other areas of the study.⁴²

A study by Faril Simpson was an effort to determine if the laboratory portion of a course contributes to the achievement of general education objectives, and if so, if one type of laboratory experience is more effective than another. The general education physical science course was one semester in length, with three lectures and one laboratory per week. The general education objectives were taken to be: acquiring a degree of subject matter competence in physical science, understanding the methods of science, understanding the aims and limitations of science, developing scientific attitudes, and developing favorable attitudes toward science. The method used to test these objectives is not known.

Three different groups of general education physical science students were given three different treatments. In the traditional group, the students were asked to do a workbook-type experiment. In the second group, the students were given a choice of doing a prepared experiment or designing their own experiment. Students in the third group did no laboratory experiments, and laboratory time was

⁴²Joseph Samuel Zingaro, "An Experimental Comparison Between Two Methods of Teaching College Sophomores the Inter-relationship of Physicochemical Principles in Physical Science" (unpublished Ph. D. dissertation, Syracuse University, 1966).

devoted to reading and discussion.

The three treatment groups were not found to be significantly different in any respect at the end of the semester. Laboratory work was not found to aid in achieving general education objectives, and the treatments were judged to be equally effective.⁴³

Katherine Jones, at the University of Tulsa, in Tulsa, Oklahoma, studied the achievement of eighty-seven students in an experimental, integrated, general education physical science course as compared to fifty-five students in professionally-oriented courses of chemistry, general physics, and engineering physics. The study attempted to measure any changes in student understanding of science and scientists, to determine if students who study in the general education course achieve a higher level of understanding than do those who study in the professionally-oriented courses. The Test on Understanding Science (TOUS), Form W, was the criterion.

No empirical data on emphases in the various courses was collected, however, differences in the objectives were indicated in discussions with the various instructors and in the items which were used in the examinations. The professionally-oriented courses were concerned with particular disciplines of science, with attention given

⁴³Faril Simpson, Jr., "The Effect of the Laboratory in Achieving General Education Objectives in a College Physical Science Course" (unpublished Ed. D. dissertation, University of Arkansas, 1969).

to vocabulary, results of discoveries, factual information, quantitative procedures, and the working of problems. Although the general education course was also concerned with some facts and principles from the areas of astronomy, chemistry, physics and geology, it dealt to a greater extent with historical development, philosophy of science, and with the interaction of science with society.

The results of the analysis of data indicate that the general education physical science course is more effective in increasing student understanding of science and scientists than are the professionally-oriented courses of chemistry and physics. Although the students enrolled in the general education physical science course made greater gains in understanding science, their posttest achievement level was not as high as the pretest level of students in the professionally-oriented courses.⁴⁴

Although the above studies provide some insights into the teaching of general education physical science, the next study to be reported is much more closely related to the present research effort. The PSNS Project contracted for evaluation services with Dr. Wayne Welch, formerly with Harvard Project Physics and now at the

⁴⁴Katherine Maurice Jones, "The Attainment of Understandings About the Scientific Enterprise, Scientists, and the Aims and Methods of Science by Students in a College Physical Science Course," Journal of Research in Science Teaching, VI, Issue 1, 1969, pp. 47-49.

University of Minnesota. The procedures and results of his study were made known in January, 1971, and are briefly described here.

Dr. Welch selected a control group comparison for evaluating the PSNS Course. The primary objectives of the course were identified, and a determination was made to find if the experimental program achieved those objectives more effectively than other alternatives. The design was:

$$\begin{array}{cccc} R & O_1 & X & O_2 \\ R & O_3 & & O_4 \end{array}$$

The Os represent several different tests, given both as pretests and posttests. The X represents the experimental treatment, the PSNS Course. The Rs indicate that subjects were assigned to the two groups randomly.

Twelve professors from ten different colleges in eight states agreed to teach at least one section of PSNS and another physical science course, to randomly assign their students to either the experimental or control course, and to administer a series of pretests and posttests during the year. Approximately 1,000 students were involved in this evaluation.

Instruments were developed and selected to measure the PSNS objectives listed earlier in this chapter. To measure the substantive course objectives, often identified as process objectives, two

existing process instruments were used. They were the Test on Understanding Science and the Welch Science Process Inventory.

Three PSNS Project staff members were given these two instruments with instructions to select those items that they thought could be answered correctly by a student completing the PSNS Course. Using this method of selection, a total of 114 items were chosen; 24 from the Test on Understanding Science and 90 from the Welch Science Process Inventory. An instrument was developed to measure attitudinal objectives in a similar way. Again the course authors were presented with a series of semantic differential concepts and were asked to select those items that appeared to measure the attitudinal objectives considered important in PSNS. An example is the concept science, where students were asked to rate it on a seven-point scale between Fun and Boring.

Two other instruments, not adapted for the study, were used. The Physical Science scale of the Academic Interest Measure was used to provide data on the type of student that enrolled in the PSNS Course as well as what changes in interest took place as a result of the course. The second instrument was the Scientific Attitude Inventory, and was used to measure intellectual and emotional scientific attitudes.

All of the above instruments were combined into two booklets and mailed to the participating professors for administration during

the first two weeks of the 1969-70 academic year. Posttests were administered in May, 1970. A total of 430 PSNS students and 571 control students completed the pretests, while 305 PSNS students and 362 control students completed the posttests.

As a check on the experiment and for additional information the evaluation director, Dr. Wayne Welch, visited seven of the participating colleges during the year. The results of the Welch Study were grouped into four general categories: Characteristics of Physical Science Students, Impact of the PSNS Course on Selected Variables, Effects of Duration of Treatment, and Impressions from Site Visits.

A summary of the characteristics of the students participating in this study shows that a majority were freshmen from the following areas: Elementary Education, 20 per cent; Business, 20 per cent; Education, 15 per cent; Humanities, 11 per cent; Fine Arts, 7 per cent; Social Studies, 6 per cent; Secondary Education, 4 per cent; Science, 3 per cent; Law, 1 per cent; other, 13 per cent. Nearly all of these students had completed a biology course in high school. Approximately half of the students had completed high school chemistry, and approximately one in five had taken high school physics. Nearly 90 per cent had completed at least two years of high school mathematics. The students involved in the study were compared to the college juniors involved in determining the normative

data of the Academic Interest Measure and the Science Attitude Inventory. This comparison revealed that the students in this study expressed a greater interest in the areas of social sciences, physical sciences, and biology. The students were less interested in mathematics.

The results of the course effects were based on an analysis of fourteen dependent variables. The PSNS students and the control students were considered significantly different on those variables marked with an asterisk. The level of significance was the .10 level. Following are those variables:

1. Test on Understanding Science
2. Science Process Inventory
- *3. Academic Interest Measure-Physical Science
- *4. Science Attitude Inventory

Doing Laboratory Experiments

5. Fun
6. Useful
7. Interesting
- *8. Safe
9. Easy

Me Teaching Science

- *10. Fun
11. Useful

12. Interesting

*13. Safe

*14. Easy

An overall treatment effect on the fourteen variables existed, in favor of the PSNS students, when posttest scores were analyzed. Significant differences existed on six of the twelve attitudinal measures of the course effects. Although differences on the two process variables favored the PSNS Course, these differences were not statistically significant. The researcher thus concluded that the PSNS Course was successful in its stated goal to change students' attitudes toward science, but not successful in providing students with a greater understanding of the processes of science. It is interesting to note, that later in the research report, the researcher states that the overall change related to attitude changes for both groups, from pretest to posttest, was negative. Students' attitudes toward science declined between pretest and posttest. Since there was a significant difference on posttest attitude scores, perhaps one should conclude that students' attitudes became less negative with the PSNS Course.

The duration effects of this study were determined by looking at two process instruments; the Test on Understanding Science and the Welch Science Process Inventory, and the two attitude instruments; the Academic Interest Measure and the Science Attitude

Inventory. It was found that students learn more about the processes of science and have more positive attitudes when studying physical science for one year rather than for one semester, regardless of the course studied, PSNS or some other physical science course. As stated above, attitude changes, for PSNS and Control students, from pretest to posttest were negative. The decline was found greater for one semester than for one year.

Dr. Welch visited seven of the twelve professors participating in this evaluation study. Several of his observations are worth noting. Following are those observations:

1. Six of the seven professors teaching the PSNS Course, as well as a conventional course, were very enthusiastic about the PSNS Course. One professor was considering returning to a more conventional approach.

2. The PSNS Course seemed to be best received when it was taught in a self-contained classroom, with twenty to thirty students, with laboratory work as part of the normal daily routine.

3. Students in each of the two courses defended the course they were studying. PSNS students talked about their great interest in science, while students in the conventional courses expressed satisfaction over knowing what was expected of them. The conventional students also felt that a survey course was better suited for their intended occupation.

Although the Welch Study is the largest scale and most comprehensive study of PSNS Course materials, it leaves much to be desired. Strict controls were not employed, and the presentation of the data and results is somewhat nebulous. Perhaps the two doctoral students, who have access to the data collected in this study, will present reports that will shed more light upon the effectiveness of the PSNS Course.⁴⁵

The review of the literature in this chapter and the related research studies presented thus far in this section deal with the teaching of general education physical science on the college level. It should be remembered that physical science courses are only one part of the general education program in American colleges and universities. There have been few studies that have attempted to survey the effects of total general education programs on students. Several efforts have been made to study characteristics of students that are often identified as desirable outcomes of general education programs. The following are some of the prominent studies in this area.

A study conducted by C. Robert Pace sampled the men and women who entered the University of Minnesota in 1924, 1925, 1928, and 1929 by means of a fifty-two-page questionnaire in 1937. The type of educational experience they had was typical of that in most

⁴⁵Lewis G. Bassett, ed., op. cit., pp. 371-410.

American colleges and universities of that period. Curricula were largely fragmented and sequential; but most students didn't stay in school long enough to take the sequential courses, leaving school with only unrelated fragments of knowledge in different fields. Other students took highly specialized vocational and professional training courses and learned little outside these special fields.

The results indicated that the general adjustment, morale, participation in and enjoyment of leisure-time activities, and even economic and cultural status of these former students bore little relation to the fact that they did or did not graduate from the university. These characteristics were more closely associated with marital status, place of residence, kind of job, or academic ability. The major difference between the graduates and nongraduates was in the kind of jobs they had and the amount of money they earned.

Generalizations about the personal life of these young adults was made in two overlapping categories. The first were those showing evidence of apathy and complacency; and the second, those showing failure to appreciate interrelationships among problems. Some of the examples of complacency were self-centered goals, lack of concern with philosophy and religion, emotional tendencies toward introversion, passive use of leisure time, resignation in the face of complex family situations, inefficient practices in home management, and lack of participation in local civic affairs. Failure to appreciate

interrelationships among problems was evidenced in the many discrepancies among their activities, interests, and attitudes. Two examples of these discrepancies were in their desire for home economy coupled with their persistence in uneconomical practices and in the coupling of their concern about the government with their failure to participate in political processes.⁴⁶

A book by Ernest Havemann and Patricia Salter West, They Went to College, reported on questionnaire returns from 9,064 respondents from 1,037 colleges. The data were obtained in 1947 in a study designed to shed light on readers of Time magazine, most of whom were college educated. Ninety-eight per cent of the respondents would choose to go to college again, if they could relive their lives, and 84 per cent would select the same college. In the matter of general versus more specific kinds of educational experiences, 44 per cent were satisfied with what they had, 35 per cent wished they had a more specific kind of education, and 21 per cent wished they had a more general educational experience. Those persons in the professions, who had a more general type of undergraduate education, tended to be more active and interested citizens.

⁴⁶C. Robert Pace, They Went to College (Minneapolis: The University of Minnesota Press, 1941).

Those persons most dissatisfied with general education were in the field of business.⁴⁷

C. Robert Pace reported on studies of alumni carried out as part of a general education evaluation at Syracuse University. A questionnaire was completed by 2,500 Syracuse graduates from the classes of 1907, 1917, 1927, 1932, 1937, 1942, and 1947. Pace reported the following results. The Liberal Arts graduates exhibited a more balanced picture of interest and attitudes and were also more active participants in a larger number of fields than the graduates of the professional and technical schools. Pace did not feel he could say that a particular pattern of adult behavior was caused by the particular pattern of an academic curriculum, but he was certain that adult behavior was influenced by the curriculum. He felt that college does make a difference, and the particular kind of college education also makes a difference.⁴⁸

In a book edited by Dr. Paul L. Dressel, many studies and speculations were reported that were carried on at the Basic College of Michigan State University during the period 1944-1955. The Basic College was organized in 1944 as an administrative unit providing a

⁴⁷Mervin B. Freedman, "Studies of College Alumni," The American College, ed. by Nevitt Sanford (New York: John Wiley and Sons, Inc., 1962), pp. 849-850.

⁴⁸Ibid., pp. 866-867.

program of general education for all the students at Michigan State University. Seven courses made up the original program: Written and Spoken English, required of all students; Physical Science and Biological Science, one required; Social Science and Effective Living, one required; History of Civilization and Literature and Fine Arts, one required. Each student was also required to take one Basic course beyond the four specified; making a total of forty-five quarter hours. These requirements made up approximately one-fourth of the student's total college program, and approximately one-half of his first two years' work. In the fall of 1953, a revised program was instituted. Four courses, Communication Skills, Natural Science, Social Science, and Humanities, replaced the original seven courses and were required of all students.⁴⁹

An interesting survey was conducted, in 1956, of student reactions to their general education experience. A questionnaire was sent to graduates of the classes of 1954, 1955, and 1956 within a few weeks after they received their degrees. Graduates of the classes of 1954 and 1955 completed the Basic College requirements under the seven-course program, while those graduating with the class of 1956 completed requirements under the four-course program.

⁴⁹Paul L. Dressel, "So Little We Know," Evaluation in the Basic College at Michigan State University, ed. Paul L. Dressel (New York: Harper and Brothers, 1958), pp. 4-6.

The reactions of the graduates to their general education experience were generally positive. Eighty per cent of the graduates endorsed the forty-five credit general education requirement. The value of the Basic courses most frequently noted was the provision for a general cultural background. This value was noted by 90 per cent of the graduates. The second most frequently rated value was that of developing some new interests. This value was checked by over half of the graduates. Very closely behind were the values of practical information and improved thinking ability. Five to 10 per cent of the graduates indicated that the Basic courses provided them with help in selecting their major field.

Most of the graduates, 85 per cent, were opposed to a reduction in the forty-five required hours. Many students remarked that the change from seven to four courses would result in the elimination of the most significant parts of the program. There was concern about the probable de-emphasis on the areas of art, literature, and music. Regret was expressed by the former students at the elimination of all choice in the program. Graduates who felt that the requirement of forty-five hours should not be continued were concerned only with some reduction in hours which would permit more electives or more time for the major.⁵⁰

⁵⁰Paul L. Dressel, ed. "And Some Graduate," Evaluation in the Basic College at Michigan State University, ed. Paul L. Dressel (New York: Harper and Brothers, 1958), pp. 88-94.

The Instruments

The Wisconsin Inventory of Science Processes

Since scientists, science teachers, and science educators agree that science teaching must develop more than the memorization of science knowledge, additional objectives have been formulated. One of these objectives is a need to develop understanding of the methods and processes by which scientific knowledge evolves. This has been an objective of science instruction for more than forty years, yet little progress has been made in measuring the degree to which this objective is being achieved.

An attempt was made, by the Scientific Literacy Research Center at the University of Wisconsin, to develop a valid, reliable, and usable instrument to inventory the knowledge of the processes of science possessed by secondary school students.

A list of congruous elements which appeared in three or more of six reference books by Beveridge, Conant, Kemeny, Lachman, Nash, and Wilson was presented to fourteen research scientists for validity judgment. The list was revised on the basis of their suggestions. The resulting descriptive outline was the basis for developing the instrument. Accepted procedures of test

construction were employed in writing items and in the development of the instrument.⁵¹

The Scientific Literacy Research Center, at the University of Wisconsin, granted the researcher permission to use the instrument on August 2, 1968.⁵² Accompanying literature indicates that the instrument is designed to inventory the assumptions, products, motives and procedures of science. For this particular version, the reliability was found to be 0.82 for 12th grade students, and 0.823 for teachers. The mean score for the students was 54.2, and for the teachers 66.9. Following is an outline of the areas the instrument was developed to measure:

I. THE SCIENTIST ASSUMES THAT:

A. THE UNIVERSE AND NATURAL PHENOMENA ARE:

1. Real
2. Intelligible
3. Consistent
4. Causal

⁵¹Wayne W. Welch and Milton O. Pella, "The Development of an Instrument for Inventorying Knowledge of the Processes of Science," Journal of Research in Science Teaching, V (March, 1967), pp. 64-68.

⁵²The Wisconsin Inventory of Science Processes, The Scientific Literacy Research Center (Madison: The University of Wisconsin, 1967).

B. THE PRODUCTS (RESULTS) OF SCIENCE ARE:

1. Amoral
2. Repeatable
3. Parsimonious
4. Tentative
5. Probabilistic

C. HE AND HIS FELLOW SCIENTISTS ARE:

1. Objective
2. Anti-authoritarian
3. Motivated by a desire to understand the
physical universe

II. THE ACTIONS OR OPERATIONS OF THE SCIENTIST INCLUDE:

A. OBSERVATIONS WHICH ARE:

1. Selected
2. Influenced by instrumentation and past experience
3. Described and recorded accurately
4. Sometimes unexpected

B. MEASUREMENT WHICH:

1. Has inherent error
2. Is a method of quantitative expression

C. CLASSIFICATION, WHICH IS:

1. An invention of man used for the organization of data
2. Based on observed relations between variables and

hence has inherent weaknesses

D. EXPERIMENT, WHICH IS:

1. Used to test hypotheses and theories and to expose new areas to empirical exploration
2. The identification, manipulation and control of variables

E. COMMUNICATION, WHICH IS:

1. A method of recording scientific information and adding it to the cumulative fund of "knowledge"
2. An academic obligation which makes scientific information available for independent confirmation and verification

F. PREDICTION, WHICH IS ACHIEVED BY THE UTILIZATION OF:

1. Inductive logic
2. Deductive logic
3. A multiplicity of techniques and procedures

G. THE FORMULATION OF:

1. Hypotheses
2. Theories
3. Laws
4. Models

Attitudes Toward Science and Scientists

An instrument was developed by John R. Cummings to measure the attitudes toward science and scientists of students enrolled in elementary science methods courses. The researcher obtained an item pool from other instruments designed to measure attitudes toward science and scientists. The items were modified, and 139 new items were created, with close attention to attitude item criteria and the nature of the population for which the scale was being prepared. The population was students enrolled in elementary science methods courses.

Accepted procedures of attitude scale construction were employed in writing items and in the development of the instrument. The reliability of the scale was found to be 0.9150 for the students in the elementary science methods courses and their mean score was 203.08.⁵³

Permission was granted to the researcher, by John R. Cummings, to use this unpublished instrument in August, 1969.

Summary

This chapter presented a review of the related literature and studies. It traced the history of the teaching of general education

⁵³John Rosswell Cummings, "Development of an Instrument to Measure Attitudes Toward Science and the Scientist: (unpublished Ph. D. dissertation, The Ohio State University, 1969).

science courses in the United States. The work of the PSNS Project was presented. Only two organized research studies were found that were directly related to the PSNS Course, however, several studies were found that were somewhat related. Some of these studies involved general education physical science courses similar to the PSNS and Adapted PSNS Courses, while others were concerned with the outcome of general education programs. Literature pertaining to the instruments used in this study, that were developed by others, was included in this chapter. Chapter III presents a description of the design of the present study.

CHAPTER III

DESIGN OF THE STUDY

Selection of Subjects

A roster was prepared by the Registrar of the entering freshmen, at California State College (Pennsylvania), in the various curricula that require Man and His Physical World. The students on this roster include those in the Division of Teacher Education, and not majoring in science or industrial arts. For the Fall 1969 Tri-mester there were 317 such students.

Four groups of thirty-six subjects each, were randomly selected from the above population, with the aid of a table of random numbers. Although thirty-six subjects were selected, it was felt that a smaller number of subjects would actually participate in the experiment. Some students who are accepted for admission do not come to college, for various reasons, and some students change their curriculum upon arrival. Also, the researcher was not able to require those who were selected, and not enrolled in Man and His Physical World, to participate in the study. A small number of subjects would also be randomly deleted in order to equalize the group size, for purposes of data analysis.

With the cooperation of the Registrar two groups of subjects, designated Experimental and Control 2, were assigned to two separate Man and His Physical World classes, where they received the experimental treatment. The other two groups, designated Control 1 and Control 3, were not assigned to any science or mathematics courses. Only those subjects in groups Experimental and Control 2 had any formal instruction in science, and no group had any mathematics course.

The subjects in the Control 1 Group were informed by letter to their homes, and at freshmen orientation activities, of their selection. They were instructed to report to a session for pretesting. Subjects in the Control 3 Group were informed by letter to their homes, approximately fourteen weeks later, of their selection and asked to report to a session of posttesting along with those subjects in the Control 1 Group. Those subjects in groups Experimental and Control 2 were assigned to Man and His Physical World classes and were thus tested during class sessions.

Permission to Use Prepared Instruments

Permission was granted to the researcher, by the Scientific Literacy Research Center at the University of Wisconsin, to duplicate and use The Wisconsin Inventory of Science Processes. Permission was also granted, by John R. Cummings, to use "Attitudes Toward

Science and Scientists," that he developed at The Ohio State University.

Development of the APSNS Instrument

The instrument used to measure knowledge of solid matter and the techniques for its investigation was developed by the researcher. Objective questions were selected from a pool of questions included in the Teacher's Resource Book, which was written by the PSNS Staff, and accompanies An Approach to Physical Science.¹ The questions were selected by the researcher with the advice of another member of the Physical Science Department at California State College (Pennsylvania), and they dealt with those topics that were included in the Adapted PSNS Course. At the suggestion of Dr. Lewis G. Bassett, director of the PSNS Project, the list of questions was submitted to Dr. A. A. Strassenburg, a member of the American Institute of Physics and on the faculty of the State University of New York at Stony Brook. The suggestions of Dr. Strassenburg were incorporated into the instrument. The expert judgment of the PSNS Staff and Dr. Strassenburg provided the basis for considering the instrument valid.

The reliability of the instrument was not determined previous

¹PSNS Project Staff, Teacher's Resource Book: An Approach to Physical Science (New York: John Wiley and Sons, Inc., 1969), pp. 285-304.

to its administration, as it was not possible to assemble a randomly-selected group from a population similar to the one involved in this study. Items whose point biserial coefficient was low, were deleted from the original instrument. This reduced the number of items on the instrument from thirty-nine to twenty-one. The reliability of the instrument was recomputed and found to be much higher. Since the instrument used several kinds of questions with differential weighting of item responses, most conventional methods of calculating reliability could not be employed. A method was developed for such a situation by Hoyt and Stunkard.² This method is based on the analysis of variance technique.

Administration of Pretests and Posttests

The Solomon Four-Group design was used in this study, and it will be helpful in understanding the testing and treatment in this study. An explanation of this design was presented in Chapter I.

The design is as follows:

R	O ₁	X	O ₂	(Experimental Group)
R	O ₃		O ₄	(Control 1 Group)
R		X	O ₅	(Control 2 Group)
R			O ₆	(Control 3 Group)

²Cyril J. Hoyt and Clayton L. Stunkard, "Estimation of Test Reliability for Unrestricted Item Scoring Methods," Educational and Psychological Measurement, XII (Winter, 1952) pp. 756-758.

The three instruments mentioned above were administered as pretests and posttests to the subjects in the Experimental Group. They received the treatment, which consisted of the Adapted PSNS Course, during the fourteen-week interval between these tests. Control 1 Group subjects were tested likewise, except they did not receive any treatment. Subjects in the Control 2 Group were given the treatment and were tested only at the end of the fourteen-week period, while those in the Control 3 Group received no treatment but were tested in the same way. Only those subjects in groups Experimental and Control 2 had any formal instruction in science, and no group had any mathematics course during this period of time.

The Treatment

In short, the treatment consisted of the Adapted PSNS Course. The length of the course was fourteen weeks, during the Fall Trimester of the 1969-70 academic year. The instructor for both the Experimental and the Control 2 groups, who had taught five sections of this course previously, was not the researcher. A complete outline of the Adapted PSNS Course can be found in Appendix B. For comparison, an outline of the PSNS Course is presented in Appendix A.

The major differences between the PSNS Course and the Adapted PSNS Course are length and attention to students' mathematics

backgrounds. The former was designed as a one-year course, and the latter a one-trimester course. Also, the Adapted PSNS Course is designed to help students with poor backgrounds in mathematics, as this is a characteristic of many college students which precludes their developing an interest in, and ability to do scientific work, even on an elementary level. The subject matter was selected by the researcher and a colleague at California State College (Pennsylvania), and is primarily the first part of the PSNS Course.

Just looking at the course outlines does not really provide a feeling for the "spirit" of the courses. The content outlined is used only as a vehicle, and its mastery is considered only one of the objectives. Subject matter coverage has been drastically limited and the theme "solid matter and the techniques for its investigation," was selected somewhat arbitrarily. A premise on which the courses are based is that more real science can be taught, in the limited time available, if less broad coverage of subject matter is attempted. Subject matter is really "uncovered," as students are encouraged and invited to observe carefully the nature of the physical world, wonder about it, then suggest hypotheses, just as those who engage in scientific research. This type of activity is closer to the nature of scientific investigation than is the memorizing of facts.

Another characteristic of the two courses, which makes them different from traditional general education physical science courses,

is the place reserved for laboratory experiences. Experimentation is central to the courses, and the classroom work is supportive. In the laboratory, which is sometimes at home when take-home experiments are performed, students are involved with open-ended experiments which require them to ask new questions and suggest procedures for answering these questions. The classwork is designed to help students ask these questions and work toward answering them, rather than learning the answers to old questions. It is important to know what has been done in the past, but this is not a major objective of the courses. Student learn to do science rather than just learn about science.

Statistical Treatment

With the Solomon Four-Group design, used in this research study, there is no singular statistical procedure which makes use of all six sets of observations simultaneously. The statistical analysis outlined by Campbell and Stanley in the Handbook of Research on Teaching³ was used as the basis for the procedures in this study, as follows:

1. Proportional cell frequencies were achieved from disproportional frequencies by randomly discarding

³Donald T. Campbell and Julian C. Stanley, "Experimental and Quasi-Experimental Designs for Research on Teaching," Handbook of Research on Teaching, ed. N. L. Gage (Chicago: Rand McNally Company, 1963), pp. 194-195.

a few observations. This avoids the computational labor necessary for the analysis of disproportional designs, and is worth the small reduction in power which may result.⁴ The four groups were reduced from 27, 28, 26, and 23 subjects to 23 subjects each by using this procedure.

2. Posttest scores were analyzed using a 2 X 2 analysis of variance. The data for this analysis were arranged as follows:

	No X	X
Pretested	O ₄	O ₂
Unpretested	O ₆	O ₅

The main effects of treatment and pretesting and the interaction of pretesting with treatment were investigated in this analysis of variance.

3. An analysis of covariance was performed on Control 1 Group posttest scores (O₄) versus Experimental Group posttest scores (O₂), with the pretest scores for each of those two groups (O₃ and O₁ respectively), being the covariate.

⁴Gene V. Glass and Julian Stanley, Statistical Methods in Education and Psychology (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1970), pp. 439-440.

4. A comparison, using the analysis of variance technique of Control 3 Group posttest scores (O_6), Experimental Group pretest scores (O_1), and Control 1 Group pretest scores (O_3), was used to indicate the effect of maturation and history.
5. Although accepted procedures were used for assigning subjects to the four groups in this study, data from student records were used to investigate for possible sources of bias among the groups. A one-way analysis of variance was used to compare the four groups on the variables of intelligence, high school rank, and verbal and nonverbal S. A. T. scores.

Summary

This chapter presented a detailed description of the procedure used in this study. It included selection of subjects, permission to use prepared instruments, development of the "APSNS Instrument," administration of pretests and posttests, the treatment, and the statistical treatment. Chapter IV presents a detailed description of the analysis of data in this study.

CHAPTER IV

ANALYSIS OF DATA

The Reliability of the "APSNS Instrument"

The reliability of this instrument was computed using the method developed by Hoyt and Stunkard presented in Chapter III. This method can be used with several types of questions and with differential weighting of item responses. This method is based on the analysis of variance technique. Table 1 summarizes the results of the analysis of variance. The reliability coefficient was estimated to be 0.67.

TABLE 1

ANALYSIS OF VARIANCE TABLE FOR ESTIMATING THE RELIABILITY OF THE APSNS INSTRUMENT

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Items	20	61.8240	3.0912
Individuals	91	57.9751	0.6371
Within	<u>1820</u>	<u>384.9380</u>	0.2115
Total	1931	504.7371	

Standard Error of Measurement - 2.1075

Reliability Coefficient - 0.6680

The Effect of Treatment, Pretesting and Interaction
Using the Analysis of Variance Technique

The main effects of treatment and pretesting, and the interactive effect of testing with treatment were analyzed by using a 2 X 2 analysis of variance. The arrangement of posttest scores below allows estimates of the main effect of treatment from row means, the main effect of pretesting from column means, and the interaction of testing with treatment from cell means. A discussion of the meaning of these results is presented in Chapter V. The raw data is presented in Appendix G. For this analysis, posttest scores were arranged as follows:

	No X	X
Pretested	O ₄	O ₂
Unpretested	O ₆	O ₅

The Wisconsin Inventory of Science Processes

The results of the analysis of variance, using posttest scores of The Wisconsin Inventory of Science Processes are summarized in Table 2. There was a significant difference, beyond the .01 level, between scores of those subjects having the experimental treatment and those not having it. The F-ratio was 8.80. The mean for the group having the treatment was 59.24, while the mean for the group not having the treatment was 54.61. There was an effect of pretesting on posttest scores, significant beyond the .05 level. The F-ratio was

4. 42. The mean for the pretested group was 58.57, while the mean for the non-pretested group was 55.28. There was no significant interaction between pretesting and treatment. The F-ratio was 0.01. In the estimation of the above three effects, F-ratios of 6.93 and 3.95 were necessary to consider these effects significant at the .01 and .05 levels respectively.

TABLE 2
ANALYSIS OF VARIANCE TABLE FOR POSTTEST
SCORES ON THE WISCONSIN INVENTORY
OF SCIENCE PROCESSES

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Exposure to treatment (Treatment vs no treatment)	493.1406	1	493.141	8.80 ^a
Exposure to pre-test (Pretested vs unpretested)	247.8369	1	247.837	4.42 ^b
Interaction	0.3350	1	.335	0.01
Within	<u>4931.2461</u>	<u>88</u>	56.037	
Total	5672.5625	91		

$F^a .01 (1, 88) = 6.93$

^a Sig. at .01 level

$F^b .05 (1, 88) = 3.95$

^b Sig. at .05 level

Attitudes Toward Science and Scientists

The results of the analysis of variance, using posttest scores of "Attitudes Toward Science and Scientists," are summarized in Table 3. There was a significant difference in scores, beyond the .05 level, with the group having the experimental treatment scoring higher. The F-ratio was 4.88. The mean for the group having the treatment was 172.22, while the mean for the group not having the treatment was 160.96. There was no significant effect of pretesting on posttest scores as the F-ratio was 0.00 and no significant interaction between pretesting and treatment, as the F-ratio was 1.41. F-ratios of 6.93 and 3.95 were necessary to consider these effects significant at the .01 and .05 levels respectively.

APSNS Instrument

The results of the analysis of variance, using posttest scores of the APSNS Instrument, are summarized in Table 4. There was a difference in scores, significant beyond the .01 level, with the group having the experimental treatment scoring higher. The F-ratio was 68.55. The mean for the group having the treatment was 14.72, while the mean for the group not having the treatment was 9.63. There was no significant effect of pretesting on posttest scores as the F-ratio was 0.32 and no significant interaction between pretesting and treatment, as the F-ratio was 0.61. F-ratios of 6.93 and 3.95

TABLE 3

ANALYSIS OF VARIANCE TABLE FOR POSTTEST
SCORES ON "ATTITUDES TOWARD
SCIENCE AND SCIENTISTS"

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Exposure to treatment (Treatment vs no treatment)	2916.5640	1	2916.564	4.88*
Exposure to pre-test (Pretested vs unpretested)	0.0435	1	0.043	0.00
Interaction	840.3926	1	840.393	1.41
Within	<u>52571.9920</u>	<u>88</u>	597.409	
Total	56329.0000	91		

$$F^*_{.05} (1, 88) = 3.95$$

TABLE 4

ANALYSIS OF VARIANCE TABLE FOR POSTTEST
SCORES ON THE "APSNS INSTRUMENT"

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F
Exposure to treatment (Treatment vs no treatment)	595.1738	1	595.174	68.55*
Exposure to pre-test (Pretested vs unpretested)	2.7826	1	2.783	0.32
Interaction	5.2623	1	5.262	0.61
Within	<u>763.9998</u>	<u>88</u>	8.682	
Total	1367.2188	91		

$$F^*_{.01} (1, 88) = 6.93$$

were necessary to consider these effects significant at the .01 and .05 levels respectively.

The Effect of Maturation and History

A comparison, using a one-way analysis of variance of the Control 3 Group posttest scores (O_6), the Experimental Group pretest scores (O_1), and the Control 1 Group pretest scores (O_3), indicated no significant effect of maturation and history on all three of the instruments. The results of this analysis of variance are summarized in Tables 5, 6, and 7, and the meanings of these results are discussed in Chapter V. The F-ratios for The Wisconsin Inventory of Science Processes, "Attitudes Toward Science and Scientists," and the "APSNS Instrument," were 0.96, 1.16, and 1.00 respectively. An F-ratio of 3.14 was necessary to consider a significant effect of maturation and history.

Analysis of Covariance on Posttest Scores with Pretest Scores Being the Covariate

An analysis of covariance was performed on the Control 1 Group posttest scores (O_4) versus the Experimental Group posttest scores (O_2), with pretest scores of the Control 1 Group and the Experimental Group (O_3 and O_1 respectively), being the covariate. This technique was employed to determine whether or not the difference between the adjusted mean scores of groups Experimental and

TABLE 5

ANALYSIS OF VARIANCE TABLE FOR ANALYZING THE
EFFECT OF MATURATION AND HISTORY ON THE
WISCONSIN INVENTORY OF SCIENCE PROCESSES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between Groups	2	105.69	52.84	0.96
Within Groups	<u>66</u>	<u>3640.00</u>	55.15	
Total	68	3745.69		

TABLE 6

ANALYSIS OF VARIANCE TABLE FOR ANALYZING THE
EFFECT OF MATURATION AND HISTORY ON
"ATTITUDES TOWARD SCIENCE
AND SCIENTISTS"

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between Groups	2	1020.00	510.00	1.16
Within Groups	<u>66</u>	<u>29012.00</u>	439.58	
Total	68	30032.00		

TABLE 7

ANALYSIS OF VARIANCE TABLE FOR ANALYZING THE
EFFECT OF MATURATION AND HISTORY ON THE
"APSNS INSTRUMENT"

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between Groups	2	15.86	7.93	1.00
Within Groups	<u>66</u>	<u>523.22</u>	7.93	
Total	68	539.08		

Control 1, on all three instruments, was significant. The meaning of those results is discussed in Chapter V.

The Wisconsin Inventory of Science Processes

The mean scores and the adjusted mean scores of the two groups, on The Wisconsin Inventory of Science Processes, are shown in Table 8. The difference between the mean scores was 4.53 in favor of the Experimental Group. When the means were adjusted for the differences between the two groups on the pretest, a difference of 4.29 in favor of the Experimental Group was found. This difference was significant beyond the .05 level, and the calculation for determining this significance is summarized in Table 9.

TABLE 8

CRITERION AND COVARIATE VARIABLE MEANS OF THE WISCONSIN INVENTORY OF SCIENCE PROCESSES

	n	Criterion Posttest		Covariate
		Adjusted	Unadjusted	Pretest
Experimental	23	60.71	60.83	55.70
Control 1	23	<u>56.42</u>	<u>56.30</u>	<u>55.35</u>
Difference		4.29	4.53	.35

TABLE 9

ANALYSIS OF COVARIANCE TABLE FOR COMPARING THE
EXPERIMENTAL AND CONTROL 1 GROUPS ON THE
WISCONSIN INVENTORY OF SCIENCE PROCESSES

Source of Variation	Residuals			F
	Degrees of Freedom	Sum of Squares	Mean Square	
Between	1	211.36	211.36	6.45*
Within	<u>43</u>	<u>1409.71</u>	32.78	
Total	44	1621.07		
F* .05 (1, 43) = 4.07				

Attitudes Toward Science and Scientists

The mean scores and the adjusted mean scores of the Experimental and Control 1 groups, on "Attitudes Toward Science and Scientists," are shown in Table 10. The difference between the mean scores was 17.31 in favor of the Experimental Group. When the means were adjusted for the differences between the two groups on the pretest, a difference of 10.66 in favor of the Experimental Group was found. This difference was significant beyond the .05 level, and the calculation for determining this significance is summarized in Table 11.

The APSNS Instrument

The mean scores and the adjusted mean scores of the Experimental and Control 1 groups, on the "APSNS Instrument," are

TABLE 10
CRITERION AND COVARIATE VARIABLE MEANS OF
"ATTITUDE TOWARD SCIENCE AND
SCIENTISTS" SCORES

	n	Criterion		Covariate
		Posttest		Pretest
		Adjusted	Unadjusted	
Experimental	23	172.07	175.22	172.96
Control 1	23	<u>161.41</u>	<u>157.91</u>	<u>165.96</u>
Difference		10.66	17.31	7.00

TABLE 11
ANALYSIS OF COVARIANCE TABLE FOR COMPARING THE
EXPERIMENTAL AND CONTROL 1 GROUPS ON THE
"ATTITUDES TOWARD SCIENCE AND
SCIENTISTS" INSTRUMENT

Source of Variation	Degrees of Freedom	Residuals		F
		Sum of Squares	Mean Square	
Between	1	1336.25	1336.25	4.21*
Within	<u>43</u>	<u>13656.58</u>	317.59	
Total	44	14992.83		

$F^*_{.05} (1, 43) = 4.07$

shown in Table 12. The difference between the mean scores was 5.56 in favor of the Experimental Group. When the means were adjusted for the differences between the two groups on the pretest, a difference of 5.32 in favor of the Experimental Group was found. This difference

was significant beyond the .01 level, and the calculation for determining this significance is summarized in Table 13.

TABLE 12
CRITERION AND COVARIATE VARIABLE MEANS OF
THE "APSNS INSTRUMENT" SCORES

	n	Criterion		Covariate
		Posttest		Pretest
		Adjusted	Unadjusted	
Experimental	23	14.66	14.78	11.13
Control 1	23	<u>9.34</u>	<u>9.22</u>	<u>9.96</u>
Difference		5.32	5.56	1.17

TABLE 13
ANALYSIS OF COVARIANCE TABLE FOR COMPARING THE
EXPERIMENTAL AND CONTROL 1 GROUPS ON THE
"APSNS INSTRUMENT" SCORES

Source of Variation	Degrees of Freedom	Residuals		F
		Sum of Squares	Mean Square	
Between	1	313.03	313.03	36.94*
Within	<u>43</u>	<u>364.42</u>	8.47	
Total	44	677.45		

$$F^* .01 (1, 43) = 7.28$$

A Further Look at the Sample

Although accepted procedures were employed for assigning subjects to the four groups in this study, data from student records were used to investigate for possible sources of bias among the

groups. A one-way analysis of variance was used to compare the four groups on the variables of intelligence, high school rank, and verbal and nonverbal S. A. T. scores. No differences were found among the four groups on the above four variables, except the Control 2 Group was found to be significantly different, at the .01 level, than the other groups on the variable of high school rank. High school rank was reported in fifths, and the means for the three groups that were not significantly different were 1.70, 1.96, and 1.57. The mean of the Control 2 Group was 2.57, indicating that subjects in this group had lower high school grades. S. A. T. scores were not available for two subjects in the Control 2 Group and one subject in the Control 1 Group, thus group sizes were reduced from 23 to 21 to simplify the analysis of data. The results of the analysis of data are summarized in Tables 14, 15, 16, and 17. The meaning of these results will be discussed in Chapter V.

TABLE 14
ANALYSIS OF VARIANCE TABLE OF I. Q. S IN
STANINES OF THE EXPERIMENTAL,
CONTROL 1, CONTROL 2, AND
CONTROL 3 GROUPS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	3	10.17	3.39	2.42
Within	<u>88</u>	<u>123.13</u>	1.40	
Total	91	133.30		

TABLE 15

ANALYSIS OF VARIANCE TABLE OF HIGH SCHOOL
RANK IN FIFTHS OF THE EXPERIMENTAL,
CONTROL 1, CONTROL 2, AND
CONTROL 3 GROUPS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	3	13.60	4.53	5.17*
Within	<u>88</u>	<u>77.13</u>	0.88	
Total	91	90.73		
F* .01 (3, 88) = 4.00				

TABLE 16

ANALYSIS OF VARIANCE TABLE OF VERBAL S. A. T.
SCORES OF THE EXPERIMENTAL, CONTROL 1,
CONTROL 2, CONTROL 3 GROUPS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	3	1540.00	513.33	0.15
Within	<u>80</u>	<u>275936.00</u>	3449.20	
Total	83	277476.00		

Summary

This chapter presented the analysis of data of this study. The reliability of the "APSNS Instrument" was estimated using a method developed by Hoyt and Stunkard which is based on the analysis of variance technique. The reliability of this instrument was estimated to be 0.67. There was a significant effect of the treatment on

TABLE 17

ANALYSIS OF VARIANCE TABLE OF NONVERBAL
S. A. T. SCORES OF THE EXPERIMENTAL,
CONTROL 1, CONTROL 2, AND
CONTROL 3 GROUPS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between	3	5408.00	1802.67	0.51
Within	<u>80</u>	<u>283904.00</u>	3548.80	
Total	83	289312.00		

the posttest scores of all three instruments, even when the posttest scores were adjusted with pretest scores, using the analysis of covariance technique. The significance was beyond the .05 level for The Wisconsin Inventory of Science Processes and "Attitudes Toward Science and Scientists," while the level of significance was beyond the .01 level for the "APSNS Instrument." There was no significant interactive effect of pretesting with treatment on any of the three instruments. On one of the instruments, The Wisconsin Inventory of Science Processes, there was an effect of pretesting on posttest scores, significant beyond the .05 level. A further examination of the sample revealed that all four groups were similar with respect to three of the four variables investigated. These four variables were intelligence, high school rank, verbal S. A. T. scores, and nonverbal S. A. T. scores. Control 2 Group was significantly different than the

other four groups with respect to the variable of high school rank, ranking lower than the other three groups.

Chapter V will contain a summary of this study, the researcher's interpretations of the results and their implications for general education physical science courses, an examination of the methodology employed in this study and recommendations for future studies.

CHAPTER V

SUMMARY, RESULTS, IMPLICATIONS, METHODOLOGY, AND RECOMMENDATIONS

This chapter contains a brief summary of this study, a discussion of the results, implications, methodology, and recommendations for future studies.

Summary

This study was designed to determine if an adapted version of the Physical Science for Nonscience Students (PSNS) Course significantly contributes to an understanding of the scientific enterprise, positive attitudes toward science and scientists, and knowledge of solid matter and the techniques for its investigation.

The study was delimited to the first trimester freshmen at California State College (Pennsylvania), in the School of Education, who were not majoring in science or industrial arts, for the Fall Trimester of the 1969-1970 academic year. Four groups, of twenty-three subjects each, made up the sample.

Three instruments were employed to test research hypotheses based on the problem stated above. These hypotheses will be discussed later in this chapter. The two instruments that were

employed in this study and developed by others were The Wisconsin Inventory of Science Processes and "Attitudes Toward Science and Scientists." A third instrument, the "APSNS Instrument," was developed by the researcher. Suggested items designed to measure the subject matter of the PSNS Course, solid matter and the techniques for its investigation, were developed by the PSNS Project Staff. Items were selected from this pool that related to the sections of the PSNS Course that were included in the adapted version of that course that was used in this study. The validity of the resulting instrument was determined, and some items were deleted to make the reliability suitable for the present research purposes.

The Solomon Four-Group design was used. The design is as follows:

R	O ₁	X	O ₂	(Experimental Group)
R	O ₃		O ₄	(Control 1 Group)
R		X	O ₅	(Control 2 Group)
R			O ₆	(Control 3 Group)

The above-mentioned instruments were administered as pretests and posttests to the subjects in the Experimental Group. Between these tests, they received the experimental treatment. This took place during the fourteen-week Fall Trimester of the 1969-70 academic year at California State College in California, Pennsylvania. The Control 1 Group subjects were tested likewise, except they did not

receive any treatment. Subjects in the Control 2 Group were given the experimental treatment and were tested only at the end of the fourteen-week period, while those in the Control 3 Group received no treatment but were tested in the same way. Only those subjects in the Experimental and Control 2 groups had any formal instruction in science, and no group had any mathematics course during this period of time.

The experimental treatment in this study consisted of the Adapted PSNS Course. Mastery of subject matter was considered only one of the objectives of this course. Subject matter coverage was drastically limited and centered on the theme "solid matter and the techniques for its investigation." Subject matter was really "uncovered," as students were encouraged and invited to carefully observe the nature of the physical world, wonder about it, then suggest hypotheses to explain it. Experimentation was central to the course, and the classroom work was supportive of these experiences. The open-ended experiments required the students to ask questions and suggest procedures for answering these questions; the classwork helped the students formulate these questions and work toward answering them. The course also helped students with poor backgrounds in mathematics, as this is a characteristic of many college students which precludes their developing an interest in, and ability to do scientific work, even on an elementary level. In short, students were expected to do science, rather than just learn about science.

The research design described above permits a determination of the main effects of treatment and pretesting, the interactive effect of pretesting with treatment and the combined effect of maturation and history. Appropriate statistical techniques were employed to make use of the six sets of observations collected in this study. These observations consisted of test scores designated as O_1 to O_6 in the design presented above. Data from student records were also used to investigate for possible sources of bias among the four groups that may have occurred when the subjects were randomly assigned to these groups. Based on available data in student records, the following variables were investigated: intelligence, high school rank, and verbal and nonverbal S. A. T. scores.

Discussion of the Results

The results of this study will be discussed by looking at the results of the development of the "APSNS Instrument," and an examination of the research hypotheses.

The APSNS Instrument

An instrument was needed to measure student knowledge of solid matter and the techniques for its investigation. Since no such instrument existed, the researcher developed one as a part of this study. The researcher would have preferred to develop an open-ended essay-type instrument in keeping with the spirit of the course. It was

felt that it would be impossible to have a panel of capable and willing readers each look at approximately 150 tests. Therefore, objective questions were selected from a pool of questions included in the Teacher's Resource Book, which was written by the PSNS Staff, and accompanies An Approach to Physical Science. The questions were selected by the researcher with the advice of another member of the Physical Science Department at California State College (Pennsylvania) and they dealt with those topics that were included in the Adapted PSNS Course. At the suggestion of Dr. Lewis G. Bassett, director of the PSNS Project, the list of questions was submitted to Dr. Arnold A. Strassenburg, who was also associated with the PSNS Project. Dr. Strassenburg's suggestions were incorporated into the instrument. The expert judgment of the PSNS Staff and Dr. Strassenburg provided the basis for considering the instrument valid.

The reliability of the instrument was not determined previous to its administration as it was not possible to assemble a randomly-selected group from a population similar to the one involved in this study. Items whose point biserial coefficient was low, were deleted from the instrument in order to improve its reliability. This reduced the number of items on the instrument from thirty-nine to twenty-one. The reliability of the instrument was recomputed and found to be 0.67; thus making the "APSNS Instrument" acceptable for research purposes. Although the desirability of deleting eighteen

questions may be questionable, the researcher felt that this was the only way the reliability could be made acceptable and that the validity of the instrument was probably not seriously affected by this reduction in the number of items.

Null Hypothesis 1

There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a test of knowledge of the scientific enterprise, as measured by The Wisconsin Inventory of Science Processes, when initial differences in pretest scores have been adjusted.

The difference between the mean scores of the Experimental and Control 1 groups was 4.53 in favor of the Experimental Group. Using an analysis of covariance, these posttest means were adjusted for differences between the two groups on the pretest. A difference of 4.29 in favor of the Experimental Group was found. This difference was significant at the .05 level.

The design of this study permitted, in addition to an analysis of the effect of treatment, an analysis of the effects of pretesting, interaction of pretesting and treatment, and the combined effect of maturation and history. The pretesting effect was significant at the .05 level, however, it was not as large as the treatment effect. The

F-ratio for the treatment effect was 8.80, while the same ratio for the pretesting effect was 4.42. There was no significant interaction of pretesting and treatment, or maturation and history effect.

Null Hypothesis 1 must be rejected, since there was a significant difference between the two groups, in favor of the Experimental Group. As mentioned above, part of this difference was due to the pretesting that had taken place, even though the experimental treatment effect was greater. Perhaps the effect of pretesting can be reduced or eliminated by using different versions of The Wisconsin Inventory of Science Processes. Only one version is presently available. The strength of the rejection of Null Hypothesis 1 is diminished by this pretesting effect, however, it is the opinion of the researcher that the Adapted PSNS Course, as taught, significantly contributes to students' knowledge of the scientific enterprise.

Null Hypothesis 2

There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a scale of attitudes toward science and scientists, as measured by "Attitudes Toward Science and Scientists" developed by Cummings, when initial differences in pretest scores have been adjusted.

The difference between the mean scores for the Experimental

and Control 1 groups was 17.31 in favor of the Experimental Group. When the means were adjusted for the differences between the two groups on the pretest, a difference of 10.66 in favor of the Experimental Group was found. This difference was significant at the .05 level. There was no significant effect of pretesting, interaction of pretesting and treatment, and maturation and history. Null Hypothesis 2 was thus rejected. This means that the Adapted PSNS Course, as taught, significantly contributes to a more positive attitude toward science and scientists.

Null Hypothesis 3

There is no significant difference in posttest scores of subjects assigned to the Adapted PSNS Course and those having no formal instruction in science or mathematics, on a test of knowledge of solid matter and the techniques for its investigation, as measured by an instrument developed by the researcher and known as the "APSNS Instrument," when initial differences in pretest scores have been adjusted.

The difference between the mean scores of the Experimental and Control 1 groups was 5.56 in favor of the Experimental Group. Using an analysis of covariance these posttest means were adjusted for differences between the two groups on the pretest. A difference of 5.32 in favor of the Experimental Group was found. This difference

was significant at the .01 level. There was no significant effect of pretesting, interaction of pretesting and treatment, and maturation and history. Null Hypothesis 3 was thus rejected. This means that the Adapted PSNS Course, as taught, significantly contributes to an understanding of solid matter and the techniques for its investigation.

In short, the Adapted PSNS Course, as taught, significantly contributes to an understanding of the scientific enterprise, positive attitudes toward science and scientists, and a knowledge of solid matter and the techniques for its investigation. This can only be said with certainty about the accessible population, which consisted of the entering freshmen at California State College (Pennsylvania) who were in the School of Education and not majoring in science or industrial arts in the Fall Trimester of the 1969-1970 academic year. With the use of inferential statistics it is not difficult to generalize the findings from the sample to the accessible population from which the sample was randomly selected. It is much more difficult to generalize the findings to a target population; a much larger group to whom the findings may apply. For example, would the results of this study also apply to a group of college freshmen at some other college? It seems reasonable to assume that the findings would apply if that group of students is exactly like the group of students who participated in this study. Relevant variables to describe the two groups would have to be described; only some of the variables that are probably relevant

could be investigated from student records at California State College (Pennsylvania). These variables will be presented in hopes that persons at other institutions will want to compare their students with the students involved in this study in order to make a better judgment about the relevancy of these findings to their students.

The four variables investigated were: intelligence, high school rank, verbal S. A. T. score, and nonverbal S. A. T. score. The mean intelligence of the students in the four groups of the sample was 6.91. The scores available to the researcher were in stanines. High school rank was recorded in fifths, with those at the top of their high school class identified as 1, and those at the bottom as 5. The mean for the four groups was 1.95. The mean verbal S. A. T. score was 445.87; the nonverbal S. A. T. mean was 472.80.

The Methodology

The topic of this study was selected because the researcher has a strong conviction that research needs to be conducted on the outcomes of national curriculum development projects. Large scale research projects should be carried out by the projects themselves; however, research also needs to be done on the outcomes of adapted versions of the resulting curricula. The researcher was strongly influenced by Dr. Lee Cronbach and Dr. Robert Howe in the selection of the design of this study. It seems that attempts to research and

evaluate new curricula have been remarkably uniform. These studies usually compare students taking the old curriculum with those taking the new curriculum. The results are often the same; students taking the new curriculum do rather well on the examinations designed for that curriculum and rather worse on those designed for the old curriculum, while students using the old curriculum perform in the opposite way.¹

A research design was selected that could be used to re-search the outcomes of the Adapted PSNS Course without making comparisons with traditional courses whose objectives are different; the design is also a true experimental design that controls internal and external invalidity well. Internal validity insures that the experimental treatment made the difference and not sources of internal invalidity such as history, maturation and pretesting. External validity answers the question of generalizability; and like the question of inductive inference it is never completely answerable. One important factor that it considers is the interaction of testing with treatment.²

The design used in this study was the Solomon Four-Group

¹Michael Scriven, "The Methodology of Evaluation," Perspectives of Curriculum Evaluation, ed. B. Othanel Smith (Chicago: Rand McNally and Company, 1967), pp. 62-66.

²Donald T. Campbell and Julian C. Stanley, "Experimental and Quasi-Experimental Designs for Research on Teaching," Handbook of Research on Teaching, ed. N. L. Gage (Chicago: Rand McNally Company, 1963), pp. 175-176.

design. This design can be used to estimate the main effects of treatment and testing, the interaction of testing with treatment, and the combined effect of maturation and history.³

Subjects in this design are assigned to four groups randomly. This is the best procedure for reducing possible sources of bias among the four groups. As a further precaution, however, data from student records were used to investigate for possible sources of bias among the four groups with respect to four variables. The four variables were intelligence, high school rank, verbal S. A. T. scores, and nonverbal S. A. T. scores. A one-way analysis of variance indicated no differences among the four groups on the above four variables, except Control 2 Group was found to be significantly different, at the .01 level, from the other groups on the variable of high school rank. Since only one group differed on only one of the variables investigated, it is the opinion of the researcher that for the purposes of this study, the four groups can be considered similar.

Implications

General education physical science is only a part of the total general education program at colleges and universities. It is extremely difficult to involve college faculties in significant curriculum development on their total general education program; in fact it is

³Ibid., pp. 194-195.

difficult to get natural science faculties to work together on seemingly mutual concerns. The Physical Science for Nonscience Students (PSNS) Project made an important contribution in developing a general education physical science course of the type that science educators had been advocating for many years.

In a period when critics are charging that the general education movement has "run its course," and all segments of the population are calling for accountability, it becomes increasingly important to do research on the outcomes of programs, even if these programs represent only part of the total general education program. Although the efforts of the PSNS Project have been laudable, research on the outcomes of the resulting course has not been intensive or profound.

The present research study has attempted to test three research hypotheses on the outcomes of an adapted version of the PSNS Course. It was not an evaluation study designed to determine the efficacy of one approach over others. The researcher was encouraged to undertake the present study, in part, by several of his professors at The Ohio State University, several colleagues, and Professor Lewis G. Bassett, Director of the PSNS Project.

Recommendations

As a result of this study, the researcher is of the opinion that studies of the following types could provide more significant

insights into the teaching of general education physical science.

1. A study to identify cognitive and affective behavioral objectives of the PSNS Course.
2. Studies to develop highly valid and reliable instruments, based on the behavioral objectives identified, to measure student performance.
3. Studies similar to the one undertaken by this researcher, but with more generalizability.
4. Evaluation studies to compare the efficacy of using this approach, over some other.

APPENDIX A

AN OUTLINE OF THE PSNS COURSE

CHAPTER I YOU AND PHYSICAL SCIENCE

- 1.1 About this Course
- 1.2 The Scientist as a Detective
- 1.3 Observation and Sherlock Holmes
- 1.4 Asking Answerable Questions
- 1.5 Classification of Objects
- 1.6 Summary

Experiments

- 1.1 Solution of Powders
- 1.2 Formation and Dissolving of Crystals
- 1.3 Classification of Objects

CHAPTER II WHEN, WHERE, AND HOW MUCH?

- 2.1 A Controlled Environment, the Laboratory
- 2.2 How much?
- 2.3 When?
- 2.4 How Hot?

Experiments

- 2.1 Making Measurements
- 2.2 Observations of Dissolving Solids
- 2.3 A Thermal Illusion
- 2.4 The Temperature Sensitivity of the Hand

- 2.5 Heat Transfer from Different Substances
- 2.6 A Study of Temperature Change During Cooling
- 2.7 A Closer Look at the Plateau

CHAPTER III A LOOK AT LIGHT

- 3.1 Light Information
- 3.2 Color
- 3.3 Waves on the Surface of Water
- 3.4 The Wave Model of Light

Experiments

- 3.1 Colored Objects
- 3.2 Breaking Up White Light
- 3.3 Water Waves
- 3.4 A Chemical Reaction Produced by Light

CHAPTER IV INTERFERENCE OF LIGHT

- 4.1 Interference
- 4.2 Superposition of Waves
- 4.3 Interference Revisited

Experiments

- 4.1 Young's Double-Split Experiment
- 4.2 Measuring the Wavelength of Light

CHAPTER V CRYSTALS IN AND OUT OF THE LABORATORY

- 5.1 Crystal Growth
- 5.2 Harvesting the Home-Grown Crystals
- 5.3 Harvesting Crystals Grown in Nature
- 5.4 Breaking Crystals

Experiments

- 5.1 Salt and Sugar
- 5.2 Packing of Spheres
- 5.3 Cleaving Crystals
- 5.4 Determining an Upper Limit for
Roughness of Crystal Faces

CHAPTER VI WHAT HAPPENED IN 1912?

- 6.1 The Story
- 6.2 The Nature of Diffraction
- 6.3 The Idea
- 6.4 The Experiment
- 6.5 Diffraction from a Regular Array of Objects

CHAPTER VII MATTER: A CLOSER LOOK AT DIFFERENCES

- 7.1 The Need to Question
- 7.2 Another Way to Explore Difference
- 7.3 Comparison of Solids, Liquids and Gases

7.4 Alternative Models of a Gas

7.5 Which Model Shall We Choose?

7.6 Volume Changes of a Gas

Experiments

7.1 The Distillation of Wood

7.2 Effect of Heat on Various Solids

7.3 The Vaporization of a Liquid

7.4 Effect on a Gas of a Change in Temperature

CHAPTER VIII MATTER IN MOTION

8.1 Some Simple Kinds of Motion

8.2 Forces

8.3 Force, Mass, and Acceleration

8.4 The Motion of a Falling Object

Experiments

8.1 Motion of Objects on a Horizontal Surface

8.2 Acceleration of Falling Objects

8.3 Force and Motion

CHAPTER IX ENERGY AND THE KINETIC THEORY

9.1 Work

9.2 Kinetic Energy

9.3 Potential Energy

9.4 Thermal Energy

9.5 Principle of Conservation of Energy

9.6 The Kinetic Theory of Gases

Experiments

9.1 Conservation of Mechanical Energy

9.2 The Relation Between the Temperature and Pressure of a Gas

CHAPTER X BONDING FORCES WITHIN A CRYSTAL

10.1 Strength of a Crystal

10.2 On Understanding

10.3 Requirements for the Bonding Force

10.4 Kinds of Forces

10.5 Gravitational Forces Examined

10.6 Magnetic Forces Examined

10.7 Electrical Forces Examined

10.8 Behavior of Charges in Material

10.9 A Review and Extension

Experiments

10.1 An Introduction to Electrical Forces

10.2 An Investigation of Types of Electrical Charges

10.3 An Investigation of Transfer of Electrical Charge Through Various Materials

CHAPTER XI ELECTRIC CHARGES IN MOTION

- 11.1 The Microscopic and the Macroscopic Views
of Electrical Charge
- 11.2 An Electric Circuit
- 11.3 Electric Current and Potential Difference
- 11.4 Energy and Power in an Electric Circuit
- 11.5 What Determines the Current in a Conductor?
- 11.6 The Conductivity of Materials
- 11.7 A Preliminary Microscopic Model of Conduction
in Solids

Experiments

- 11.1 Production of a Flow of Electric Charges
- 11.2 A Simple Electric Circuit
- 11.3 Using an Electric Circuit to Study Materials
- 11.4 A Mechanical Analogue to Conduction in Solids

CHAPTER XII MODELS OF ATOMS

- 12.1 The Beginnings
- 12.2 Rutherford's Scattering Experiments
- 12.3 Atomic Mass
- 12.4 Spectra and Energy Levels
- 12.5 Removing Electrons from Atoms
- 12.6 The Shell Model and Cloud Model of the Atom

Experiments

- 12.1 Determining the Size of an Object from
Collision Probabilities
- 12.2 Determination of the Atomic Mass of Magnesium
- 12.3 Observation of Various Spectra

CHAPTER XIII IONS

- 13.1 A Look Back and a Look Forward
- 13.2 Ions in Melts
- 13.3 Introduction to the Use of Chemical Equations
- 13.4 Ions in Solution
- 13.5 Electrolysis of Solutions
- 13.6 Chemical Properties of Ions and Atoms
- 13.7 Behavior of Ions
- 13.8 Replacement of Ions
- 13.9 Combination 250
- 13.10 Oxidation and Reduction
- 13.11 Cells

Experiments

- 13.1 Passing an Electric Current Through Lead Chloride
- 13.2 Migration of Ions
- 13.3 Electrolysis of Lead Nitrate and Sodium Chloride
- 13.4 Replacement of Ions

13. 5 Combining Zinc and Iodine

13. 6 An Electric Current by Electron Transfer

CHAPTER XIV THE NATURE OF AN IONIC CRYSTAL

14. 1 Preliminary Steps in Determining the Structure
of a Crystal

14. 2 Use of X-Ray Diffraction in Determining the
Structure of a Crystal

14. 3 The Structure of Cesium Chloride

14. 4 The Structure of Sodium Chloride

14. 5 Sizes of Ions

14. 6 The Mass of an Atom and Avogadro's Number

14. 7 Crystal Forces and Potential Wells

14. 8 Melting and Dissolving

Experiments

14. 1 Crystals of Sodium Chloride and Cesium Chloride

14. 2 Construction of a Model of Cesium Chloride

14. 3 Construction of a Model of Sodium Chloride

14. 4 Water in an Electric Field

14. 5 The Law of Entropy

CHAPTER XV MOLECULES

15. 1 An Attempt to Electrolyze Water

15. 2 Combining Hydrogen and Oxygen

- 15.3 Combining Volumes
- 15.4 Avogadro's Hypothesis
- 15.5 Diatomic Molecules
- 15.6 Bonds in Molecules
- 15.7 Summary

Experiments

- 15.1 Electrolysis of Water
- 15.2 Combining Hydrogen and Oxygen
- 15.3 Model for Carbon Bonding

CHAPTER XVI NONIONIC MATERIALS

- 16.1 The Structure of Diamond
- 16.2 Other Carbon Compounds
- 16.3 Graphite
- 16.4 Loosely Bonded Crystals
- 16.5 Hydrogen Bonding
- 16.6 Metals
- 16.7 Packing in Metal Crystals
- 16.8 Applying the Metal Model
- 16.9 A Comparison of Crystal Bond Types
- 16.10 Sulfur--A Solid that is Sometimes Noncrystalline
- 16.11 Glass
- 16.12 Properties of a Linear Polymer

16. 13 Rubber - Network Polymers

16. 14 Mixtures

16. 15 Conclusion

Experiments

16. 1 Electrical Properties of Two Fluids

16. 2 Mechanical Properties of Metals

16. 3 Physical Properties of Sulfur

16. 4 A Model of Sulfur

16. 5 Experiments with Glass

16. 6 Experiments with Polyethylene

16. 7 An Experiment with Rubber

APPENDIX B

AN OUTLINE OF THE ADAPTED PSNS COURSE

CHAPTER 1 INTRODUCTION AND COMPUTATIONAL METHODS

- 1.1 About this Course
- 1.2 Exponents and Decimal Points
- 1.3 Approximate Calculations
- 1.4 Dimensional Analysis
- 1.5 The Metric System
- 1.6 The Slide Rule
- 1.7 Graphing
- 1.8 Science and Curiosity
- 1.9 The Scientist as a Detective
- 1.10 Observation and Sherlock Holmes
- 1.11 Asking Answerable Questions
- 1.12 Classification

Experiments

- 1.1 The Metric System
- 1.2 Salol
- 1.3 Solution of Powders
- 1.4 Formation and Dissolving of Crystals
- 1.5 Classification of Objects
- 1.6 Indirect Evidence
- 1.7 Mental Model

CHAPTER II WHEN, WHERE, AND HOW MUCH?

- 2.1 A Controlled Environment, the Laboratory
- 2.2 How Much?
- 2.3 When?
- 2.4 How Hot?
- 2.5 Slope

Experiments

- 2.1 Making Measurements
- 2.2 Observations of Dissolving Solids
- 2.3 A Thermal Illusion
- 2.4 The Temperature Sensitivity of the Hand
- 2.5 Heat Transfer from Different Substances
- 2.6 A Study of Temperature Change During Cooling
- 2.7 A Closer Look at the Plateau
- 2.8 Sampling Techniques

CHAPTER III CRYSTALS IN AND OUT OF THE LABORATORY

- 3.1 Crystal Growth
- 3.2 Crystal Imperfections
- 3.3 Crystal Structure of Metals
- 3.4 Harvesting the Home-Grown Crystals
- 3.5 Harvesting Crystals Grown in Nature
- 3.6 Breaking Crystals

Experiments

- 3.1 Salt and Sugar
- 3.2 Packing of Spheres
- 3.3 Cleaving Crystals
- 3.4 Observation of Surroundings

CHAPTER IV MATTER: A CLOSER LOOK AT DIFFERENCES

- 4.1 The Need to Question
- 4.2 The Effect of Heat on Various Substances
- 4.3 Comparison of Solids, Liquids, and Gases
- 4.4 Alternative Models of a Gas
- 4.5 Volume Changes of a Gas

Experiments

- 4.1 The Distillation of Wood
- 4.2 The Effect of Heat on Various Substances
- 4.3 The Vaporization of a Liquid
- 4.4 The Diffusion of Ammonia Vapor and Hydrogen
Chloride in a Glass Tube, Ink and Potassium
Permanganate in Water
- 4.5 Effect on a Gas of a Change in Temperature

CHAPTER V MATTER IN MOTION

- 5.1 Some Simple Kinds of Motion

5.2 Forces

5.3 Force, Mass, and Acceleration

5.4 The Motion of a Falling Object

Experiments

5.1 Motion of Objects on a Horizontal Surface

5.2 Acceleration of Falling Objects

5.3 Force and Motion

CHAPTER VI ENERGY AND THE KINETIC THEORY

6.1 Work

6.2 Kinetic Energy

6.3 Potential Energy

6.4 Thermal Energy

6.5 Principle of Conservation of Energy

6.6 The Kinetic Theory of Gases

Experiments

6.1 Conservation of Mechanical Energy

6.2 The Relation between the Temperature and Pressure of a Gas

APPENDIX C

ATTITUDES TOWARD SCIENCE AND SCIENTISTS

ATTITUDES TOWARD SCIENCE AND SCIENTISTS¹

INSTRUCTIONS:

Please give your reactions to the following list of statements regarding science, scientists, and scientific careers. Work rapidly. Record your first impression--the feeling that comes to mind as you read the item. Feel free to express yourself because you will not be graded.

You must USE A PENCIL to make a heavy mark on your answer sheet. Be sure to erase completely if it is necessary to change your response.

ON THE ANSWER SHEET PROVIDED, PLEASE MARK:

- A if you strongly agree with the item
- B if you are in agreement
- C if you are neutral
- D if you disagree
- E if you strongly disagree

¹John Rosswell Cummings, "Development of an Instrument to Measure Attitudes Toward Science and the Scientist" (unpublished Ph. D. dissertation, The Ohio State University, 1969).

EXAMPLE:

A	B	C	D	E
//	☒	//	//	//

Scientists are apt to be more rational in solving problems outside their field than are other professionals. (Since B is marked this indicates you are in agreement.)

1. The majority of scientists are irreligious.
- *2. I am very strongly attracted to scientific activities.
- *3. More science should be taught in the elementary school
4. Science has caused chaos in our world.
5. Theories and laws of modern science are apt to remain in their present form.
- *6. Science is essential in the technological age.
7. Most scientists make few friends other than their fellow scientists.
8. Those girls who are not mechanically inclined should not contemplate becoming scientists.
- *9. I am enthusiastic about learning more scientific information.
10. Educators attach too much importance to the study of science.
- *11. Science will enable me to think more clearly in most other subject areas.
12. Science is less interesting than most other school subjects.
- *13. Scientific methods will find the solutions to our social problems such as crime.
14. Science causes our way of life to change too rapidly.

- *15. Science aids us in comprehending our surroundings.
- 16. Scientific work is boring.
- *17. I would like to be a research scientist.
- 18. People possessing creative imaginations should not pursue science as a vocation.
- 19. Most scientists are little concerned about the harmful consequences of later applications of their research findings.
- *20. Scientific research problems are intriguing.
- *21. The study of science enables one to reason more clearly in other areas such as politics.
- 22. Science has not been very beneficial to the average citizen.
- *23. Science is a very fascinating subject.
- 24. High school science ought to be compulsory only for those students who wish to become scientists.
- 25. Science is irrelevant in present-day society.
- *26. Scientists have a potent influence over the significant economic, political, and social processes.
- 27. Most scientific investigations are performed in the laboratory rather than in the everyday world.
- *28. An education in science is imperative in present-day society.
- 29. Government favoritism toward extraordinary scientific talent is undemocratic.
- 30. Most scientific research is conducted by scientists who have little concern for their own personal physical welfare.
- *31. Most scientists are very creative thinkers.
- 32. Scientific knowledge is hard for me to understand.

33. Science is related little to everyday living.
- *34. I enjoy solving science problems in the school laboratory.
35. Only students of better than average ability can be successful in school science courses.
- *36. Science helps society by using recently discovered scientific information to develop new industries.
37. I wouldn't like to pursue a science research project.
38. Scientists' attempts to solve their personal problems of everyday living are often unrealistic.
- *39. Science information which is not related to school work frequently interests me.
- *40. An education in science contributes toward good citizenship.
- *41. The study of science benefits people socially.
42. The methods of science are not applicable to understanding human behavior.
43. The methods of science will not enable the human mind to comprehend many aspects of our universe.
- *44. A comprehension of the significance of science is necessary to thoroughly appreciate present-day society.
45. Scientists are often eccentric in their personal behavior.
46. Scientific truths are normally discovered by individuals seeking financial gain.
- *47. I enjoy doing science investigations.
48. The difficulties involved in learning science often exceed its usefulness.
49. To me science classes are very interesting.
- *50. I enjoy doing science laboratory experiments.

- *51. Great improvement in all areas of human endeavor could be accomplished by the application of scientific methods.
- 52. Most of the science worth knowing can be read in books.
- 53. Most scientific discoveries were accidental.
- *54. A comprehension of science is essential for my everyday living.
- 55. The majority of scientists are not very interested in the practical value of scientific information.
- 56. The nation's top scientists are mainly interested in their own current of thought.
- 57. Science is chiefly a program of action for originating new gadgets.
- *58. An education in science frequently helps one make more logical decisions in everyday living.
- 59. Science is not as important as other school subjects such as English.
- *60. Science appears to be necessary in our present-day society.
- *61. Public interest in science is necessary for the continuance of scientific research.
- 62. In pursuit of their interests, scientists often consent to sacrifice the well-being of others.
- 63. I would not recommend high school science to beginning high school students.
- 64. The advancement of science makes possible the control of our lives by a few people.
- *65. Most great discoveries of the world were found through careful observation rather than by accident.
- 66. Scientists have shown their lack of consideration for the welfare of mankind by participating in such research as the development of nuclear weapons.

67. I would prefer not to take any college science courses.

*Positive item

All others are negative items.

SCORING OF POSITIVE ITEMS

A	B	C	D	E
//	//	//	//	//
4	3	2	1	0

SCORING OF NEGATIVE ITEMS

A	B	C	D	E
//	//	//	//	//
0	1	2	3	4

APPENDIX D

THE APSNS INSTRUMENT

APSNS INSTRUMENT

The following are simple multiple choice questions. Select the correct answer.

1. A gas is enclosed in a nonexpandable sealed container. Its temperature is initially 200°K . Later the temperature of the gas is raised to 400°K . As a result of the increase in temperature the kinetic energy of the molecules of the gas would be
 - (a) left unchanged
 - (b) halved
 - (c) doubled
 - (d) increased by a factor of $\sqrt{2}$
 - (e) increased four times

The above crystals are all of the same color and density.

2. From the above information plus observation of the crystals it is possible to say that
 - (a) all three crystals must be composed of the same material
 - (b) each of the three crystals is composed of a different material
 - (c) crystals A and B may be composed of the same material but C is composed of different material
 - (d) it is possible that all three crystals are composed of the same material
 - (e) crystals B and C are probably composed of the same material but A is composed of different material

3. Which of the following can be used as a definition of a chemical element?
- (a) the weather
 - (b) a constituent part of matter
 - (c) a pure metal, not combined with anything else
4. If a positively charged rod is brought near an object and is found to attract the object, this proves that the object
- (a) cannot be neutral
 - (b) cannot be negatively charged
 - (c) cannot be positively charged
5. The fundamental reason that the elements Li, Na, K, Rb, and Cs have been placed in the same group or family in the periodic table is that they all
- (a) are metals
 - (b) react with water
 - (c) have similar melting points
 - (d) have one electron in their outermost shell
6. If you were to watch salol growing under a microscope, the smallest particles you would observe in the liquid would be expected to be
- (a) diamond shaped
 - (b) round
 - (c) square
 - (d) irregular
7. The reason for the answer given in question number six is that
- (a) the hot liquid eats at the edges and causes irregular or round boundaries
 - (b) small things like to form compact shapes--like round raindrops
 - (c) the angles between faces of the growing crystals appear to remain constant as they grow, and larger salol crystals are diamond shaped
 - (d) salol ought to form square outlines in small crystals, as sodium chloride (salt) does

8. Weight and mass

- (a) measure the same thing
- (b) are completely unrelated
- (c) are proportional to each other

9. The reason for the answer given in question number eight is that

- (a) the system of units used (e. g., English units or metric units) must be carefully chosen
- (b) the gravitational force on an object depends on the mass of the object
- (c) things do not weigh anything far away from the earth

10. As the substance solidified in the cooling curve experiment

- (a) heat energy was absorbed into the solid
- (b) heat was continuously given off
- (c) there was a period of time during which there was no change in its heat content

11. The experimental evidence for the answer given in question number ten is that the

- (a) liquid contained more heat than the solid
- (b) temperature did not change
- (c) water or air surrounding the test tube became warmer

12. If the density of an Aluminum block is determined outdoors on a hot day in August, the result will be

- (a) larger than a room-temperature measurement
- (b) smaller than a room-temperature measurement
- (c) the same as a room-temperature measurement

13. Some crystals _____ easily in certain directions because the forces between their adjacent layers are smaller in the corresponding directions.

- (a) cleave
- (b) transmit light
- (c) bend

14. The _____ of a steel spring at the Moon's surface would differ from its value on Earth.
- (a) strength
 - (b) mass
 - (c) weight
 - (d) length
15. The reason for the answer given in question number fourteen is that
- (a) the Moon has no atmosphere
 - (b) the gravitational attraction is less there
 - (c) it is too far away from the Earth to affect it noticeably
16. A body moves with a constant acceleration. A velocity-time graph of its motion would be a
- (a) straight horizontal line
 - (b) straight sloping line
 - (c) parabola
17. The reason for the answer given in question number sixteen is that
- (a) the rate of change is always the same
 - (b) the distance traveled is a parabola
 - (c) the area under the velocity-time graph increases
 - (d) acceleration cannot be obtained from the graph

Choose the correct answer to the following questions. Choose as many answers to these questions as you think are correct for each question. Points will be subtracted for incorrect answers, so choose carefully.

18. The density of a solid is a measure of
- (a) the amount of material in a substance
 - (b) a characteristic property of a substance
 - (c) an arbitrary standard kept in France
19. Acceleration is best defined as
- (a) how much faster it goes
 - (b) the amount of energy used to go faster
 - (c) how much the velocity changes in an interval of time

20. Some of the characteristics of velocity are

- (a) magnitude
- (b) force
- (c) time
- (d) direction
- (e) frequency

21. The Rutherford experiment was the crucial test for

- (a) the fact that gold can be made in very thin sheets
- (b) the validity of X-ray diffraction
- (c) the conservation of charge
- (d) none of these

APPENDIX E

THE WISCONSIN INVENTORY OF SCIENCE PROCESSES

THE WISCONSIN INVENTORY OF SCIENCE PROCESSES¹

This instrument is designed as an inventory of knowledge of the scientific enterprise.

The statements on the following pages are concerned with the assumptions, activities, objectives, and products of science.

Some statements are accurate, some inaccurate.

MARK YOUR ANSWERS ON THE ANSWER SHEET

If the statement is always or nearly
always accurate mark space (A).

A I D
☐ () ()

If the statement is always or nearly
always inaccurate mark space (I).

A I D
() ☐ ()

If you do not know or do not understand
the statement mark space (D).

A I D
() () ☐

Make the mark a heavy black line using a lead pencil. Do not use a pen or ballpoint.

If you change an answer, erase the first mark completely.

Answer all the statements.

REMEMBER

Use Pencil

Do Not Write in This Booklet

With Permission of the Scientific Literacy Research Center, The University of Wisconsin, Madison, Wisconsin, August 2, 1968.

¹The Wisconsin Inventory of Science Processes. The Scientific Literacy Research Center (Madison: The University of Wisconsin, 1967).

THE WISCONSIN INVENTORY OF SCIENCE PROCESSES

1. If a scientist repeatedly observes that condition A is followed by state B, then he can, by observing an instance of condition A, predict the occurrence of state B. (A)
2. Unpredicted observations have played a role in a majority of scientific achievements. (I)
3. The assumptions made by scientists that space and time are real is defensible on the basis of past experience. (A)
4. Scientists look upon the existence of error in measurement as inevitable. (A)
5. One of the interests of the scientist is in finding relationships of the type, "When A occurs, then B will occur." (A)
6. Mathematical systems are used by scientists for organizing and communicating information about data. (A)
7. Classification schemes, such as the periodic table of the elements, are based on observed similarities and differences. (A)
8. A scientist prefers simple interpretations of phenomena. (A)
9. Scientists can, by following the scientific method step by step, answer almost any question concerning natural phenomena. (I)
10. Factual evidence produced by means of experimentation is the primary means of establishing the credibility of a scientific theory. (A)
11. A scientist formulates a working hypothesis after he has exhaustively examined the available facts and data. (I)
12. Science is a self-correcting enterprise. (A)
13. A scientist must have a definite idea of the kinds of observations he expects to make during an experiment. (A)
14. Prior to approaching a new problem, a scientist reviews the literature for relevant information. (A)

15. The scientist must be able to establish the credibility of the data he collects. (A)
16. Scientists use their present knowledge of events and phenomena as a means of explaining events and phenomena of the past. (A)
17. The scientist assumes a moral responsibility when he elects to do research in an area in which his findings could be destructive to society. (I)
18. Scientists attempt to keep the number of hypotheses and axioms utilized at a minimum. (A)
19. Scientists obtain and utilize data expressed in terms of statements of probability. (A)
20. A law in science is derived from a vast body of consistent experience. (A)
21. A basic objective of science is the generation of knowledge with technological application. (I)
22. A scientist publishes his research findings so that other members of the academic community may independently evaluate his work. (A)
23. A classification scheme is a useful method of organizing scientific observations. (A)
24. Scientists assume that all natural phenomena have natural causes. (A)
25. Scientific models are idealizations of reality. (A)
26. All contributions to the fund of scientific knowledge are public property, beyond the minimum credits for the achievement of discovery. (A)
27. Scientists assume that matter is an idea and is not real. (I)
28. Present scientific knowledge is tentative and in a continuous state of refinement. (A)
29. Science establishes a cumulative fund of knowledge that provides a basis for scientific advancement. (A)

30. Many presently accepted scientific theories were rejected by some scientists when the theories were first proposed. (A)
31. Classification schemes are vital to progress in science. (A)
32. A scientific theory, regardless of its credibility, always contains elements of chance. (A)
33. A scientist usually chooses to make those observations which have the highest probability of use in answering a specific question. (A)
34. Scientists rely on the outside authority of the general scientific community to guide them in the formulation of conclusions from experiments. (I)
35. A law in science is a statement with demonstrated high probability. (A)
36. Hypotheses in science seldom have their origin in "speculative ideas," "inspired guesses," or "intuitive hunches." (I)
37. If two scientists individually examine the same data, they will arrive at very similar conclusions. (I)
38. Scientific models are not intended to photographically represent reality. (A)
39. Observations and descriptions expressed in terms of numerical measurements are more accurate than observations and descriptions not expressed as numerical measurements. (A)
40. The scientist varies as many factors as possible at one time in a single experiment so that the maximum interaction of these factors may be observed. (I)
41. Experimentation includes those procedures by which errors in observation and measurement are limited or controlled. (A)
42. The formulation of theories in science is basically a deductive procedure. (I)
43. Scientific knowledge is ethically and morally neutral. (A)
44. Scientists believe that some natural phenomena are too complex

to ever be explained by science. (I)

45. Once accepted, scientific knowledge is no longer subject to change. (I)
46. The morality of a scientific discovery is determined by its use by a society. (A)
47. Scientists assume that the human mind is capable of understanding the events and materials of the physical universe. (A)
48. One of the uses of a hypothesis is the development of new or further experimentation. (A)
49. Scientific knowledge is, at best, an approximate explanation of natural phenomena. (A)
50. One phase of an experiment is the establishment of a set of conditions under which observations are made. (A)
51. Induction is the process of arriving at specific facts from generalizations. (I)
52. Providing explanations of the phenomena of the physical universe is a basic objective in science. (A)
53. The scientists and most of the nonscientists believe in the reality of the universe. (A)
54. A scientist usually reports only those observations relevant to his hypothesis. (I)
55. A scientific experiment will always yield information even though it may not yield the predicted information. (A)
56. From facts collected by means of experimentation, the scientist creates theories which are used to explain natural phenomena. (A)
57. A scientist is more likely to accept a theory on the basis of his personal opinion than on the available experimental evidence. (I)
58. Statistical inference is a form of deductive reasoning. (I)

59. Classification systems in science are in a continual state of refinement. (A)
60. Scientists reject data collected from an experiment or event if the experiment or event cannot be reproduced. (I)
61. A scientist puts a limit on the number of variables he observes at any given time. (A)
62. Scientists discover the classification schemes that are inherent in the physical universe. (I)
63. Scientists believe that certain natural phenomena will never be understood. (I)
64. A law in science can be used to predict but not to prescribe the occurrence of events in the physical universe. (A)
65. Modern scientific measurements are so refined that they contain no error. (I)
66. Conclusions in science are essentially statistical in nature. (A)
67. Scientific data and results contain an expressed or implied estimate of error. (A)
68. The scientist's motivation for studying the physical universe is mainly curiosity--the desire to know. (A)
69. Induction is the process of predicting particular occurrences from the general class of occurrences. (I)
70. Models in science are mental constructs that are used to describe phenomena in terms of familiar concepts. (A)
71. The scientist assumes that if under a given set of conditions a particular phenomenon repeatedly occurs, then a duplication or repetition of the same set of conditions should produce a similar phenomenon. (A)
72. A hypothesis is equivalent to a theory. (I)
73. Errors in measurement are due to errors in the techniques of measurement. (I)

74. Science starts with facts and ultimately ends with facts no matter what theoretical structures are built between them. (A)
75. Public presentation, publication and review of scientific information is a system of checks and balances self-imposed by science to regulate the quality of the products of science. (A)
76. If two scientists simultaneously view the same natural phenomena, both will notice the same things. (I)
77. An essential test of a scientific theory is its use in successfully predicting events and phenomena. (A)
78. Scientific observations gain significance when they are related to something previously observed or known. (A)
79. Concise and precise recording of observations is an essential activity in scientific research. (A)
80. If a choice is to be made between two different scientific theories, both of which account for the observed facts, the more complex is chosen. (I)
81. There are many different classification systems which could be used for any given set of observations. (A)
82. Objective observation is less important in modern science since the development of new instruments such as the electron microscope. (I)
83. Data requiring interpretation or judgment by the scientist is of little value because it is subject to the unconscious bias of the scientist. (I)
84. Scientists are unwilling to communicate their findings to other members of the scientific community. (I)
85. A majority of the scientific discoveries are the result of fortuitous (fortunate) observations. (I)
86. It is understandable for a scientist to record descriptions of his experiments because this information may bias another scientist who is attempting to verify the results. (I)
87. One purpose of setting up a laboratory experiment is to devise a

situation in which the observations and physical conditions can be controlled to the same degree that they are in the ordinary course of events. (I)

- 88. When a scientist makes a prediction, he is assuming that the physical universe is consistent. (A)
- 89. Inductive logic is more likely to yield valid conclusions than is deductive logic. (I)
- 90. The scientist assigns numerical values to data so that these data may be incorporated into numerical laws. (A)
- 91. The use of scientific theories is an inductive process. (I)
- 92. If two scientists use radically different procedures to attack the same problem, it is highly unlikely that both scientists will solve the problem. (I)
- 93. The activities of a scientist include the keeping of accurate records of observations and experimental conditions. (A)

APPENDIX F

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APPENDIX G

SCORES ON THE VARIOUS INSTRUMENTS

EXPERIMENTAL GROUP SCORES

Subject	APSNS		WISP		Attitudes	
	Pre	Post	Pre	Post	Pre	Post
1	13	16	66	61	207	195
2	10	15	50	61	174	179
3	11	14	42	57	152	191
4	9	13	55	55	164	151
5	10	10	61	64	184	183
6	6	15	50	47	174	181
7	10	20	55	59	183	182
8	14	18	55	60	181	154
9	10	15	59	61	195	201
10	14	19	63	70	163	174
11	16	14	58	67	163	189
12	14	18	60	68	192	175
13	14	13	66	65	187	207
14	10	14	50	55	178	174
15	11	16	66	65	180	183
16	13	15	52	57	185	200
17	9	14	56	56	174	200
18	2	13	46	59	158	152
19	12	9	41	53	171	179
20	8	17	52	57	160	162

Subject	APSNS		WISP		Attitudes	
	Pre	Post	Pre	Post	Pre	Post
21	12	13	58	73	134	141
22	13	19	70	72	149	137
23	<u>15</u>	<u>10</u>	<u>50</u>	<u>57</u>	<u>170</u>	<u>140</u>
Mean	11.13	14.78	55.70	60.83	172.96	175.22
St. Dev.	3.15	2.91	7.69	6.40	16.42	20.88

CONTROL 1 GROUP SCORES

Subject	APSNS		WISP		Attitudes	
	Pre	Post	Pre	Post	Pre	Post
1	9	6	54	55	178	171
2	11	14	52	61	182	157
3	15	8	45	47	185	190
4	10	9	54	56	146	124
5	10	13	60	56	151	117
6	11	10	59	65	156	128
7	8	5	62	64	178	173
8	9	7	52	45	161	155
9	7	6	58	49	191	161
10	6	7	54	66	156	165
11	9	10	51	51	166	183
12	10	9	51	55	193	188
13	7	6	65	64	188	161
14	7	6	63	66	132	120
15	14	9	48	41	160	146
16	12	14	59	66	204	208
17	10	15	60	67	158	177
18	9	12	47	50	162	121
19	16	9	51	46	157	177
20	7	7	62	62	172	155

Subject	APSNS		WISP		Attitudes	
	Pre	Post	Pre	Post	Pre	Post
21	12	7	49	48	127	115
22	12	11	66	52	156	156
23	<u>8</u>	<u>12</u>	<u>51</u>	<u>63</u>	<u>158</u>	<u>184</u>
Mean	9.96	9.22	55.35	56.30	165.96	157.91
St. Dev.	2.65	2.97	6.05	8.14	19.20	26.52

CONTROL 2 GROUP SCORES

Subject	APSNS Post	WISP Post	Attitudes Post
1	14	63	169
2	12	61	187
3	19	62	197
4	16	49	115
5	12	42	182
6	16	61	194
7	16	53	133
8	15	59	175
9	19	66	190
10	14	53	168
11	13	58	170
12	10	54	174
13	16	65	203
14	12	59	176
15	17	57	185
16	15	57	151
17	16	59	138
18	12	45	162
19	11	69	122
20	15	38	193

Subject	APSNS Post	WISP Post	Attitudes Post
21	15	60	165
22	14	60	189
23	<u>18</u>	<u>56</u>	<u>159</u>
Mean	14.65	57.65	169.22
St. Dev.	2.44	6.87	23.87

CONTROL 3 GROUP SCORES

Subject	APSNS Post	WISP Post	Attitudes Post
1	11	43	136
2	6	45	135
3	10	55	220
4	10	51	182
5	10	46	133
6	12	55	176
7	12	62	167
8	12	56	170
9	9	52	157
10	10	54	161
11	14	59	128
12	8	66	173
13	15	60	184
14	9	54	193
15	8	50	155
16	8	48	147
17	7	63	198
18	15	32	123
19	15	50	164
20	10	52	189

Subject	APSNS Post	WISP Post	Attitudes Post
21	8	42	163
22	13	53	126
23	<u>11</u>	<u>69</u>	<u>192</u>
Mean	10.04	52.91	164.00
St. Dev.	3.39	8.35	26.09

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