A REVIEW OF THE PHYSICAL SCIENCE STUDY COMMITTEE HIGH SCHOOL PHYSICS COURSE

by

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B.S., Baker University, 1964

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

Approved by:

Major Professor

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. Ronald Anderson, Assistant Professor of Education, Kansas State University. His suggestions in planning and completing the report have been most helpful.

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INTRODUCTION

Since the early years of the 20th century, the natural sciences have undergone two distinct and consequential changes. First, the sciences themselves have grown enormously, both in technique and in depth. Next, science has become inextricably interwoven with our daily life. Modern man whether he is aware of it or not, lives his life in constant association with methods of scientific research and consequences of scientific research.

> In business, legislation, and statesmanship, the scientist increasingly is called upon to help unravel the social and economic implication of science. But beyond its technological goods and meaning, science as a humanistic study stands on its own terms as a dynamically stable system with its own ends and procedural style. As a form of human expression, it is one of the triumphs of the intellect. It lends perspective and direction to the other aspects of life. It is a system one can ill afford to ignore if one is to become a whole man in a world of whole men.[1]

The teaching of high school physics has received considerable attention during recent years due to accelerated technological and scientific advancement and a recognition on the part of teachers, administrators, and laymen of the vital role that science will play in the future of our country. The traditional materials and methods of teaching

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[1]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:64, Spring, 1962.

high school physics have been severely criticized by some people in responsible positions. For example, Elbert P. Little stated,

> There is a powerful intellectual discontent with the present status of science teaching; the scientists, the teachers, and the educated laymen are all disturbed by the discontent that science teaching does not fairly represent science.[1]

Because of this criticism, a multimillion-dollar program for the revision of the high school physics curriculum was undertaken by the Physical Science Study Committee (PSSC) under a grant from the National Science Foundation. The Committee was organized in November of 1956 to devise a modern course in physics for the secondary school and to prepare materials for the course.

During the 1957-58 school year, the PSSC course was offered in eight schools in the United States. Since this time the number of schools teaching the course has risen sharply. "There are approximately 5,000 teachers using the PSSC program during the 1964-65 school year with around 200,000 students. This is approximately 50 per cent of the secondary school students in the U.S.A. enrolled in physics."[2]

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[1]Elbert P. Little, "From the Beginning," Science Teacher, 24:318, November, 1958.

[2]Educational Services Incorporated Newsletter, (Watertown, Massachusetts: Educational Services Incorporated, January, 1965), p. 4.

In 1964-65, fifty-three teachers in Kansas used the PSSC physics materials.[1]

There has been wide controversy over the effectiveness of the course. For example, some teachers feel the course is not teaching enough physics to give the students the background they need for college physics courses and therefore, does not prepare students for college work as well as a conventional high school physics course. There have also been opinions stated by some teachers that the PSSC course is a revolution in the teaching of science and will make physics a more meaningful course in the secondary school.

This study was designed to make an objective evaluation of the effectiveness of the PSSC course in the secondary schools.

THE PROBLEM

Statement of the problem. The purpose of this study is to answer the following questions:

1. Why and how was the PSSC course developed?

2. What are the opinions of teachers and educators concerning the course?

3. Are the objectives formulated by the Committee being achieved by the students taking the PSSC course?

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[1]Letter from Warren J. Bell, Education Consultant of Science and Mathematics, Kansas State Department of Public Instruction, Topeka, Kansas.

Importance of the study. Because of the wide diversity of opinion among teachers and educators on the PSSC program, and the fact that many schools are using the program or are considering putting the program into their curriculum, the author has undertaken this study to determine, if possible, if the objectives of the Committee have been reached.

Procedures employed in the study. The author collected his data for this report from all pertinent articles, papers, newsletters, dissertations, theses, and books that could be located. Most of the material used was located at Kansas State University library, Kansas University library, or was obtained through interlibrary loans, and correspondence with Educational Services Incorporated, Kansas State Department of Education, and the Department of Health, Education and Welfare. The materials are organized into the following categories for presentation:

1. Background and development of the PSSC course.

2. Opinions of teachers and educators on the effectiveness of the PSSC course.

3. Research studies to determine the effectiveness of the PSSC course.

4. Summaries and conclusions regarding the PSSC course for secondary school physics curriculum.

BACKGROUND AND DEVELOPMENT OF THE PHYSICAL SCIENCE STUDY COMMITTEE COURSE

A historical study of the inception and development of the PSSC was made in order to better understand the philosophy and underlying beliefs of the committee members. The following pages also point to the objectives formulated by the PSSC.

The organization of the Physical Science Study Committee. The PSSC began formal operations in November, 1956. The formation of the committee was made possible by a grant of $303,000 from the National Science Foundation to the Massachusetts Institute of Technology.[1] An additional grant of $142,000 was made by the National Science Foundation in August, 1957. In October, 1957 further grants were made by: the National Science Foundation, $300,000; the Ford Foundation, $500,000; the Fund for the Advancement of Education, $200,000; and the Alfred P. Sloan Foundation, $250,000.[2] As of January 1, 1958, the PSSC had expended $649,000. By September 30, 1958, the PSSC had spent an additional $1,045,700. The budget established for the fiscal year October 1, 1958 to October 1, 1959 was $2,600,000.[3] The total cost of revision during the

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[1] First Annual Report of the Physical Science Study Committee, (Watertown, Massachusetts: The Committee, January, 1958), p. 13.

[2] Ibid.

[3] Ibid.

period 1956-1961 was approximately six million dollars, exclusive of teacher-retraining costs which came to approximately an equal sum. Continuing costs of the PSSC are presently running at a level of $300,000 per year.[1]

The first steps in the development of the committee were informal discussion groups which were formed in and around Boston. These groups developed tentative outlines for a new physics course. The discussions were stimulated primarily by Dr. Jerrold R. Zacharias of the Massachusetts Institute of Technology.

Concurrently with these informal discussion groups, in and around Boston, some essential work was being carried on by the American Institute of Physics, the American Association of Physics Teachers, and the National Science Teachers' Association.[2] These groups were actively engaged in a study of the traditional physics textbooks being used throughout the United States.

With this kind of informal beginning, the committee's work gained impetus with the first grant from the National Science Foundation in November of 1956. The newly formed

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[1]Jerrold R. Zacharias and Stephen White, "The Requirements for Major Curriculum Revision," School and Society, 92:67, February 22, 1964.

[2]Elbert P. Little, "The Physical Science Study Committee," Harvard Educational Review, 29:1, Winter, 1959.

Physical Science Study Committee, directed by Jerrold R. Zacharias, Elbert P. Little, and Francis L. Friedman, held its first major planning conference on December 10, 11, 12, 1956.[1] This conference was held at the Massachusetts Institute of Technology in Cambridge, Massachusetts. The committee met to discuss and to plan improved and modernized courses in physical science for secondary schools. Forty-eight committee members were in attendance, representing more than twelve universities, government agencies, and commercial laboratories. Following this meeting several of the centers prepared outlines and preliminary drafts to be presented in a conference during the summer of 1957 at the Massachusetts Institute of Technology.

During this summer conference of 1957, university physicists worked with high school physics teachers from many parts of the country along with specialists in such fields as testing, film-making, educational administration, and editorial production. All parts of the program were started, but the textbook and laboratory were given priority so that enough material would be available to use in courses the coming year.[2]

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[1]"A Planning Conference Report: The Physical Science Study Committee," Physics Today, 10:28, March, 1957.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:72, Spring, 1962.

During the 1957-58 school year eight teachers used the preliminary versions with about three hundred students participating. This first year of experience with the course was well accepted by the teachers using the course. "The eight teachers who used the course in 1957-58 claimed they would never return to the conventional text again."[1] Teachers and students were enthusiastic and found the course stimulating. The results of the preliminary achievement tests used that year indicated that the students attained the desired levels.[2] However, the shopping for the laboratory equipment by the teachers, and construction of this equipment by the students was both lengthy and costly. Because of this the committee turned to the development of easily assembled kits of preformed apparatus.

In the summer of 1958 approximately three hundred high school physics teachers attended five National Science Foundation Summer Institutes at which the PSSC course was the subject of study.[3] The preliminary course materials were supplied without cost to any of these teachers who desired to use them the following year. During the 1958-59 school

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[1]Randolph Jance, "The Six New Science Curriculums," School Management, 7:63, June, 1963.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:73, Spring, 1962.

[3]Elbert P. Little, "The Physical Science Study Committee," Harvard Educational Review, 29:3, Winter, 1959.

year 12,500 students in 286 schools in the United States were taught the new physics course.[1]

The new course materials used during the 1958-59 school year included a preliminary textbook, teacher's guide, laboratory program, a few films, and a set of ten achievement tests.[2] All the feedback information from the teachers that used the materials was accumulated and used to revise the textbook and other materials. Also, during this school year a non-profit organization, Educational Services Incorporated, was created to assume the administration of the PSSC.[3]

During the summer of 1959 about seven hundred teachers studied the course in fifteen institutes. For the 1959-60 school year the course materials were provided at cost to the schools that wished to use them. About 560 teachers and 22,500 students used the materials. Of the teachers that had used the course the previous year, 96 per cent elected to continue with the PSSC.[4] Except for the films, a complete set of preliminary materials was on hand.

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[1]Frederick L. Ferris, Jr., "The Physical Science Study Committee: Will It Succeed?," Harvard Educational Review, 29:32, Winter, 1959.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:74, Spring, 1962.

[3]Annual Report of the Educational Testing Service for the Year 1958-59 (Princeton, New Jersey: Educational Testing Service), p. 15.

[4]Finlay, op. cit., p. 75.

During the 1959-60 school year, the Committee's major effort was directed to a complete revision of all printed materials and the design changes appropriate to the commercial production of kits of laboratory apparatus. By the fall of 1960 the textbooks, laboratory guidebooks, apparatus, tests, films, and teachers' guidebooks had been turned over to commercial suppliers and were available to all teachers who desired them.[1]

During 1960-61 the course was used by about eleven hundred teachers with 45,000 students. In 1962, 20 per cent of all students taking high school physics in the United States were using the PSSC materials and by 1964 this percentage had risen to 50 per cent.[2]

Why and how the Physical Science Study Committee developed its course.

> In content, the traditional (or conventional) course imitates the introductory physics course in college. Applications of physics to technology are stressed rather heavily. Problem-solving, ranging from the simple exercises in substituting data into a formula to more demanding tasks, is a part of the course. Laboratory exercises are usually of the highly organized variety called "cookbook" experiments.[3]

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[1] Gilbert C. Finlay, "The Physical Science Study Committee," *School Review*, 70:75, Spring, 1962.

[2] W. C. Kelly, *Survey of Education in Physics in Universities of the United States*, (New York: American Institute of Physics, 1964) p. 10.

[3] *Ibid.*, p. 11.

For the purpose of this paper the author will use the term traditional or conventional to refer to any physics course being taught on the secondary level other than the Physical Science Study Committee course. The conventional texts today are built around Newtonian mechanics. The course begins with statics, goes on to kinematics and dynamics, and in the light of these disciplines undertakes to explain, one after another, heat, light, and sound.[1] There was a feeling by many educators before 1955 that such an organization was beyond criticism; it had logical unity and reflected both the current state of knowledge and general attitude of the physicists.

"In the years that have passed, physics has thrust out wider roots and borne unimaginably richer fruits, like quantum theory, relativity, and nucleus and subnucleus of the atom."[2] Because Newtonian mechanics rapidly ceased to serve as a unifying concept, the subject compartmentalized and physics became several distinct and disconnected subjects such as mechanics, optics, heat, sound, and others.

Since none of these could be covered adequately in the time at the teacher's disposal, the temptation grew to shift

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[1]Elbert P. Little, "From the Beginning," Science Teacher, 24:316, November, 1957.

[2]*Ibid.*, p. 317.

the emphasis from the science, which in many cases was not being taught, to the technology. This helped students understand practical applications they could observe, as an internal combustion engine, a refrigerator, a radio, and even a space ship. More and more the teachers were teaching a subject the scientists did not even recognize as science.[1]

The informal committee of 1956 came to the following conclusions about the traditional high school physics textbook:

> 1. Textbooks in general reflected a scientific outlook that dated back half a century and was no longer representative of the views of the scientific community.
> 2. Genuine attempts to remain abreast of scientific developments had given even the best textbooks a patchwork quality in which the unity of physics disappeared.
> 3. The sheer mass of material in the textbooks had become so great that it could no longer be reasonably taught in an academic year or even in two years.
> 4. With the increasing application of science in everyday environment, physics textbooks had given over more and more of their attention to technology, thus further overloading the course and further minimizing the concepts of science itself, and its unity.[2]

Meanwhile, as the syllabus had come to be steadily less representative of the subject matter, the need had become greater. A large and constantly increasing proportion

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[1]Elbert P. Little, "From the Beginning," <u>Science Teacher</u>, 24:317, November, 1957.

[2]<u>First Annual Report of the Physical Science Study Committee</u> (Watertown, Massachusetts: The Committee, January, 1958), p. 3.

of high school students were going on to make careers of science and engineering. The rest, whether businessmen or skilled laborers, could almost certainly expect to come in contact with science. But in the face of these realities, secondary school curricula failed to make science a meaningful part of general education.[1] "Misapprehensions about science in the public mind have become one of the principal reasons why we have today, too few students studying scientific careers, and too few teachers competent to teach science."[2]

In summary the 1956 problems in science involved:

> 1. A recognition of the real significance of science in our modern world.
> 2. The need for a change in attitude toward science and the necessity for reducing the gap between the sciences and humanities.
> 3. The development of a truly new curriculum which cannot be done by accretion, but which must be done by a total and complete reorganization which will also provide for the development of a high degree of scientific literacy among the rank and file of our people.
> 4. A necessary change in attitude towards teaching at all levels with a view of recognizing its importance and its problems and with a dedicated effort toward the solution of these problems, while at the same time retaining and expanding our efforts in the creation of new knowledge.[3]

Animated by an outlook such as this, the PSSC was

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[1]Elbert P. Little, "From the Beginning," Science Teacher, 24:318, November, 1957.

[2]Ibid., p. 316.

[3]Addison E. Lee, "Current Problems in Science Education," Science Education, 49:150, March, 1965.

organized to seek ways of giving this outlook expression in the high school curriculum. Therefore, the original statement of the Committee's aims was:

> 1. To plan a course of study in which the major developments of physics, up to the present time, are presented as a logical and integrated whole;
> 2. To present physics as an intellectual and cultural pursuit which is part of present-day human activity and achievement;
> 3. To assist physics teachers by means of various teaching aids to carry out the proposed program.[1]

As an initial target, the Committee chose to design a new course to fit into the current pattern of the high school curriculum. The Committee addressed itself to the preparation of a one year physics course for the students who are currently taking physics. These students make up about one-fourth of the high school population, drawn mostly from the upper half in achievement and aptitude, and include a large number who are not seeking a career in science.[2]

The Committee decided to plan a course dealing with physics as an explanatory system, a system that extends from the domain inside the atom to distant galaxies. The course was designed to tell a unified story--one in which the successive topics are chosen and developed to lead toward

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[1]Leo E. Klopfer, "The Physics Course of the Physical Science Study Committee: A View from the Classroom," Harvard Educational Review, 29:26, Winter, 1959.

[2]Gilbert C. Finlay, "Secondary School Physics: Physical Science Study Committee," American Journal of Physics, 28:287, March, 1960.

an atomic picture of matter, its motions and interrelations. The aim was to present a view of physics that would bring a student close to the nature of modern physics and to the nature of physical inquiry.[1] The student should see physics as an unfinished and continuing activity. For example, ideas about waves and particles keep reoccurring, each time to be carried further in a higher synthesis of ideas.

> This coherent, searching character of Man's approach to building an explanatory structure of the physical world is one of the course's principle aims and chief pedagogical characteristics.[2]

It was also decided that the course would be directed toward familiarizing the student with two central notions of modern physics, the wave particle duality and the modern concept of the atom.[3] The Committee attempts to develop scientific physics from the ground up with nothing being handed down from high authority. The course is built to read like a novel, with a continuous building of physical concepts. The problem was to create enough comprehension to generate the motivation for wading through tough logical sequences

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[1] Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:64, Spring, 1962.

[2] Gilbert C. Finlay, "Secondary School Physics: Physical Science Study Committee," American Journal of Physics, 28:292, March, 1960.

[3] Jerrold R. Zacharias and Stephen White, "The Requirements for Major Curriculum Revision," School and Society, 92:67, February 22, 1964.

and develop a genuine interest in scientific ideas and concepts.[1]

The student is expected to be an active participant in this course. The student is expected to wrestle with a line of inquiry, including his own laboratory investigations, that lead to basic ideas.

> The fundamental ideas are brought out partially in the students work on end-of-chapter problems, but more importantly the ideas are brought out sequentially through using those ideas which are introduced early to illuminate other ideas in a chain that comprises an introduction of the structure of physics.[2]

No one-year course in physics can give an adequate account of both an expanding physics and the related technology. The Committee therefore, chose for its subject matter the big overarching ideas of physics; those that contribute most to contemporary physicists' views of the nature of the physical world.[3] Through its material the Committee seeks to convey those aspects of science which have the deepest meaning, the widest applicability, and the greatest power for further thought and activity. Because of this feeling, some of the long familiar topics in secondary school

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[1]Darrel W. Tomer, "New Physics Course for High Schools: Developed by the PSSC," California Journal of Secondary Education, 33:493, December, 1958.

[2]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:65, Spring, 1962.

[3]Gilbert C. Finlay, "Secondary School Physics: Physical Science Study Committee," American Journal of Physics, 28:287, March, 1960.

physics are not central to the overarching view sought in the PSSC course, and as a result, do not appear in the course. In attempting to transmit those ideas and styles of thought that have the broadest applicability, the Committee judged it wise to shift the emphasis in secondary school physics away from technology toward a deeper exploration of basic ideas and the nature of inquiries. Technological application has not been eliminated from the course, but it has been cut back sharply from its previous role. The reduced emphasis on technology does not imply disapproval any more than the reduced dependence upon trigonometry implies disapproval of mathematics. This technology was at the forefront of scientific investigation several centuries ago, but now it does not shed as much light on our present day picture of the physical world as does a study of waves and particles.[1]

Perhaps one of the text's most distinctive characteristics is its technique of attempting to build familiarity with the substructure of the concepts of physics, rather than assert principles, then show applications.[2] The course explores parts of optics, mechanics, and atomic physics more deeply than usual in order to show how a field of thought is developed.

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[1]Darrel W. Tomer, "New Physics Course for High Schools: Developed by the PSSC," California Journal of Secondary Education, 33:494, December, 1958.

[2]Gilbert C. Finlay, "Secondary School Physics: Physical Science Study Committee," American Journal of Physics, 28:292, March, 1960.

In summary, the principles underlying the PSSC course are the following:

1. The Committee seeks to present physics as an intellectual activity, rather than as a body of rules for the control or the manipulation of natural phenomena.
2. The Committee seeks to reflect in its course the spirit of inquiry.
3. The course reflects, as much as possible, the world of physics as it appears to the professional physicist, for only in this manner is it likely to have any clear relevance to the student himself.
4. The Committee's course prefers to present the traditional subdivisions of physics as various aspects of a single discipline.
5. The nature of the American school system makes it desirable to create a course which will be relatively independent of the order and content of the rest of the secondary school curriculum.
6. The most difficult decision which faced the PSSC at the outset of its work was the decision to omit from the course large areas of physics, and the selection of those areas which would be omitted.[1]

A whole battery of techniques is being used to get the story of physics across to the students. The text attempts to lay out a coherent framework. Problems and exercises lead the student into inference and interpretation as well as practice in elementary reasoning with basic concepts.[2] The text was developed simultaneously with laboratory experiments; and, although it was intended that the text should be able to

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[1]Stephen White, "The Physical Science Study Committee: The Planning and Structure of the Course," Contemporary Physics, 2:41-43, October, 1960.

[2]A. B. Arons, "The New High School Physics Course," Physics Today, 13:22, June, 1960.

stand as nearly as possible on its own, it was written with laboratory work in mind. The laboratory program includes about fifty experiments in all and ten of these experiments are done in modern physics.[1]

Since laboratory work is used as a tool contributing to the generation of ideas, the laboratory is designed to give the student an opportunity for personal discovery. The experiments are designed to supply firm rooting for the growth of ideas by providing non-verbal contact with relevant data. The experimental situations as they are presented to the students are "open ended". The basic ideas of the experiment are carefully discussed, but very few explicit instructions are given. Students are led to do as much as possible within a minimum of directing and are urged to extend the inquiry on their own initiative.[2] The experiments are both qualitative and quantitative. The most common use of the laboratory experiment is to introduce a topic or to contribute to the early stages of its development.

Because the Committee realizes that physics teachers have a budget to meet, all costs for the laboratory have been measured in dimes and dollars. "Almost all the apparatus

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[1]Gilbert C. Finlay, "Secondary School Physics: Physical Science Study Committee," American Journal of Physics, 28:292, March, 1960.

[2]A. B. Arons, "The New High School Physics Course," Physics Today, 13:22, June, 1960.

is designed to be built by the students themselves, either in the laboratory or, in rare instances, in the school's shop courses."[1] The building of apparatus is as much a part of physics as learning about different concepts. There will be little the student will use in the school laboratory that he cannot duplicate in his garage or cellar. There he can modify, elaborate, or redesign an experience, and set up "doing physics" on his own.[2] Also the time taken for construction in the laboratory is small and very rewarding. For example, in ten minutes a student can make a microbalance out of two pins, a soda straw, and a wood screw, with sensitivity down to twenty micrograms per millimeter deflection.[3]

A great deal of what might ordinarily be called demonstration is provided by the films produced by the Committee. Films are being used to bring to the classroom certain extended ideas beyond the level of the text and certain key experiments that are likely to be too difficult, too time consuming, or too costly for students to perform or for teachers to demonstrate. Because the films articulate closely with these resources and most of the film producers assume that the viewer is familiar with earlier parts of the course,

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[1]Jerrold R. Zacharias, "Into the Laboratory," Science Teacher, 24:324, November, 1957.

[2]*Ibid.*, p. 325.

[3]Harold P. Knauss, Physics for Secondary Schools," American Journal of Physics, 26:379, September, 1958.

the scheduling of the films is quite easy. The films are intended as take-off points for teachers and students.[1] As of February, 1965, sixty-five films were available.[2]

The Committee also developed a teacher's guidebook in order that teachers could outline their class procedures and as inquisitive questions. Through these questions, the students may find insight into the physical concepts. In addition to the guidebook, ten standardized tests were developed to check the progress of the students. As supplementary sources of authoritative and scientific information, the Committee developed a series of paperback books. The purpose of these books was to supply deeper meaning to the course and to cover material omitted from the course. For example, related fields like biophysics, technology, the history of physics, and biographies of noted physicists are covered in the paperback books. These books are appearing as the "Science Study Series". As of February, 1961, fifty books had been published in the series.[3]

In summary, the PSSC developed the following material for the course; textbook, laboratory guide and a set of new

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[1]Gilbert C. Finlay, "The Physical Science Study Committee," School Review, 70:68, Spring, 1962.

[2]Educational Services Incorporated Newsletter, February, 1965, (Watertown, Massachusetts: Educational Services Incorporated), p. 7.

[3]Ibid.

and inexpensive apparatus, a large number of films, standardized tests, a growing series of paperback books by leaders in related fields, and a comprehensive teacher's resource book directly related to the course.

To be retained, each item of subject matter had to meet the following criteria:

> 1. To stress major achievement in physics such as the great conservation principles.
> 2. To give insight into the way in which these powerful ideas were conceived, nurtured, and sometimes over thrown by even more powerful ideas.
> 3. To present a unified story in which the inner connections within physics were brought to light.
> 4. To show physics as a human activity comparable in significance with the humanities, the languages and the other major studies of high school students.[1]

Finally, the Committee recognized that no material could be teacher-proof. The physicists ran summer institutes, more of them every year, to train teachers. "By the end of 1962, nearly twenty-five hundred teachers, who came into contact with perhaps a quarter of a million students each year, had spent at least one summer working on the PSSC course."[2]

The Physical Science Study Committee Course. The PSSC course is divided into four major sections. The first

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[1]Elbert P. Little, "The Physical Science Study Committee," Harvard Educational Review, 29:2, Winter, 1959.

[2]Martin Mayer, "Scientists in the Classroom," Commentary, 35:314, April, 1963.

deals with the basic concepts of which the student must have some understanding before he can pursue a worthwhile study of the subject matter of science. Time, distance, motion, the nature of measurement, the atomic structure of matter, and the molecular interpretation of chemistry are the main topics covered in the first section.[1] The presentation is through general concepts rather than specific definitions, and the student makes some contact at once with most of the subject matter with which he will deal later in greater depth.

The second part of the course is a study of optics and waves.[2] Optical phenomena are described first in terms of rays and then a particle theory is developed to provide a possible picture of the nature of light. When this model fails to provide an explanation of the refraction of light, the concepts of wave action are introduced as an alternative model. By studying waves in ropes, springs, and ripple tanks, the student is guided to observe the comparison between waves and some properties of light. In this way the student should be able to predict some new principles of light through his experience with waves. The understanding of waves is general

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[1] Physical Science Study Committee, Physics, (Boston: D. C. Heath and Company, 1960) p. v.

[2] Ibid., p. vi.

enough to allow extension to other areas. "For instance, the nature and properties of sound, though not stressed in the course, can be developed by the student because of his basic understanding of waves."[1]

These two sections, constituting the first half of the course, emphasize the kinematics of our universe. The third section introduces Newton's laws of motion, showing the relationship between force and motion and leading to the extraordinary story of the discovery of universal gravitation. Conservation laws form a substantial part of this section of the course and lead naturally to a development of the kinetic theory of heat as an application of dynamics in this particular field of physics.[2]

The fourth section includes a careful introduction of electrical and magnetic phenomena, especially the interactions of charged particles with electric and magnetic fields.[3] The techniques of the electrical and electronic industries are omitted, but the major experiments of modern physics are carefully developed. The photoelectric effect, for example, requires the return to a particle concept of

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[1]Elbert P. Little, "The Physical Science Study Committee," Harvard Educational Review, 29:2, Winter, 1959.

[2]Physical Science Study Committee, Physics, (Boston: D. C. Heath and Company, 1960), p. vi.

[3]Ibid., p. vii.

light, with new insights into the nature of both matter and light.[1] "The course returns to the study of the atom; its discreteness, its structure, its charges, its nucleus, and its behavior."[2] Thus, the circle is closed and the student returns to the basic concepts of science with a new understanding.

COMMENTS AND OPINIONS ABOUT THE PHYSICAL SCIENCE STUDY COMMITTEE

Because of the difficulty of finding statistical data on the achievement of the objectives of the Committee, the author felt this section was needed to better understand the Committee's course. This section is designed to give the comments and opinions of teachers and educators both for and against parts of the Committee's program.

One question that is usually considered in reviewing a book is the language and language structure used. On this point there seems to be two opposing opinions. One teacher believes the language is inoffensively informal; "A center of mass 'sits still', charges on insulators are 'nailed down', and dark centers of contour patterns are 'globs'."[3] Another aspect of the Committee's policy, with regard to language,

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[1]Elbert P. Little, "The Physical Science Study Committee," Harvard Educational Review, 29:3, Winter, 1959.

[2]Ibid.

[3]Thomas D. Miner, "Physics: PSSC," American Journal of Physics, 29:338, May, 1961.

was the reluctance to use a key word until properly defined. "Because Newton's second law of motion is not treated until p. 307, the word 'force' is taboo before that. Consequently, we have until that point, 'pushes', 'shoves', and 'pulls' galore."[1] Another author believes some of the things that the students are assumed to know, probably are not known.

> For example, on page 18, galaxies are mentioned but they are not defined until p. 28. On p. 398 there is mention of "mesons" and "hyperons". The authors must have been dreaming to assume that the students know what these terms mean.[2]

Another complaint given regarding language was that no effort was made to get the students to learn to use the words and language they should be learning.

> In general the problems given in the text are excellent and logically conceived; but they fail to create opportunities in which students recognize and talk about definitions, describe simple physical events in the technical language they are learning, articulate lines of reasoning and logical connections between steps, recognize in words the idealization implicit in the handling of a problem.[3]

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[1]Thomas D. Miner, "Physics: PSSC," American Journal of Physics, 29:338, May, 1961.

[2]Oscar L. Brauer, "Something Dangerously New in Physics Teaching," Science Education, 47:369-70, October, 1963.

[3]A. B. Arons, "The New High School Physics Course," Physics Today, 13:25, June, 1960.

A drawback that was often found concerning the Committee's course was the lack of enough applications of principles of physics.

> I quite agree that physics, 1959, should not be merely a course in technology, but this should not rule out the teaching of life situations where a principle being taught may be applied. One of the best physics teachers I know continually stresses, "Physics is the world about us".[1]

> All of the physics that is necessary to enable the student to understand what he sees about him is avoided. For instance he wonders about the electrical refrigerator, the gas refrigerator, radio, television, and heat engines. Nothing in the PSSC text will enlighten him on any of these topics. Even alternating current and sound is not discussed in the text.[2]

However, there are some that believe the Committee's program is an answer to a long needed understanding of science.

> By trying to educate for an understanding of total perspective of science we will naturally avoid excesses of detail and the cram course that imparts no real understanding of science; that does not excite the creative imagination, and that rewards only memory and gadgeteering.[3]

One of the most common criticisms encountered was that the course was too long to be taught effectively in one year.

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[1]William Barish, "Reader's Column," Science Teacher, 26:389, October, 1959.

[2]Oscar L. Brauer, "Something Dangerously New in Physics Teaching," Science Education, 47:366, October, 1963.

[3]Addison E. Lee, "Current Problems in Science Education," Science Education, 49:149, March, 1965.

> Most of the indoctrinated teachers never finished the book and some only got half way through. To teach everything in that book would take all the school time of the student leaving no time for other studies.[1]

The Committee's textbook is the largest high school physics text ever published. It has 634 two column pages of text material on a page size 7.5 inches by 9 inches.[2]

There is a feeling by some that the concepts in the textbook are too hard even for the top twenty-five per cent of the high school population.

> My students reported that in their opinion, these volumes (PSSC text) were written by physicists to please themselves and other physicists, and not for secondary school students. The writing of the text has tended to obscure the facts, bringing them in a vast sea of explanatory words. It is too hard for the students to get at the important ideas.[3]

However, another opinion was:

> My better students (A or B) developed understanding of the subject matter much better than in previous years. However, the C and D students seemed to understand only after detailed explanation. The C and D students understanding was about as usual, but their appreciation of physics and their attention to detail seemed higher.[4]

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[1]Oscar L. Brauer, "Something Dangerously New in Physics Teaching," Science Education, 47:367, October, 1963.

[2]Richard P. Feynman, "The Relation of Physics to Other Sciences," The Physics Teacher, 3:112, March, 1964.

[3]Summary of Judgments Made by Teacher," Science Teacher, 26:581, December, 1959.

[4]Ibid., p. 580.

In view of these opinions one could draw the conclusion that it is difficult for the student who does not want to think or analyze, but not so for the student who is sincerely interested.

Another general view that goes along with the opinion that the course is hard, is the opinion that the problems are too difficult for the majority of students.

> The PSSC authors work no problems in the text and it has very few problems that could be classed as easy. Some of the problems even depend on theory developed in chapters several chapters ahead.[1]

"Many of the problems are exceedingly difficult and are insurmountable for many of our students."[2]

The most effective aspect of the course is generally given by critics as the laboratory experiments.

> The laboratory experiments may well be the most effective aspect of the work of the PSSC at this point, and continued efforts along these lines might make a major contribution to the teaching of physics. The emphasis on inexpensive equipment is, of course, very admirable, even if not actually as new as claimed. Although such emphasis is most desirable, it should not be permitted to obscure the fact that much scientific work does require sophisticated equipment.[3]

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[1]Oscar L. Brauer, "Something Dangerously New in Physics Teaching," Science Education, 47:368, October, 1963.

[2]Ibid.

[3]Alexander Calandra, "Some Observations of the Work of the PSSC," Harvard Educational Review, 29:21, Winter, 1959.

Another general criticism of the program is that it tends to stabilize the present sequence of science courses in high school, which usually start with General Science in the ninth grade, biology in the tenth, chemistry in the eleventh, and physics in the twelfth. This sequence is the order of increasing difficulty as these subjects are now taught. It would appear more sound to present the science courses in order of dependence; thus, since biology depends to a substantial extent on chemistry, and chemistry on physics, it would appear desirable to teach physics first, chemistry second, and biology last.[1]

Elmer Hutchison, director of the American Institute of Physics, believes the Committee's course has added a fourth "R" to the list of reading, writing, and arithmetic.[2] This fourth "R" is reasoning and the vehicle for finding this excellence for acquiring the skill in precise reasoning is physics. "No secondary school education can be said to be either liberal or complete without some study of this important subject."[3] The ability to reason is one of the

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[1] Alexander Calandra, "Some Observations of the Work of the PSSC," Harvard Educational Review, 29:20, Winter, 1959.

[2] Elmer Hutchison, "Physics in Our High Schools," The Physics Teacher, 2:386, November, 1964.

[3] Ibid., p. 385.

principle characteristics by which the advancement of a civilization may be measured. "A truly civilized nation is one in which the public has a measured confidence in man's ability to observe nature and to reason from these observations."[1]

Several authorities believe that the most important and most difficult phase of the Committee's course is for teachers to learn how to teach the course.[2] Because some teachers are so resistive to change and hate to alter the routine of their classrooms, the Committee's program is hard to instill in the teachers. In Indiana, a survey was taken to determine why teachers did not use the PSSC course. The reasons given were as follows:

> 1. Many teachers use parts of the program. Usually this means the laboratory exercises. A few used the PSSC course in the first part for an advanced physics course. These people have not attended an institute and for some reason do not want to identify themselves with our group.
> 2. Several have said after looking at the text, they thought it to be too difficult for their students. Some of these people were skeptical of the intent of the course since it was associated with the Massachusetts Institute of Technology.
> 3. Some teachers frankly admit they were unable to teach the course. They do not go to

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[1]Edward C. Colby, "The New Science Curriculum," <u>School Management</u>, 8:87, November, 1964.

[2]<u>Ibid</u>.

summer institutes or evening classes because they have a steady job paying them as much as their teaching job.

4. A great many feel they would like to teach PSSC physics, but they already have four or five preparations for five or six classes of thirty to thirty-five students and just do not feel they have time to prepare for such a course.

5. There are those few that are really conservative. Their reasons are obvious.[1]

Maybe the major lessons to be learned from the whole PSSC program fall in another category. The Program presents us with strong evidence that:

1. High school teachers and college teachers can work together and the experience is stimulating to both.

2. Subject matter revision should be made by practicing specialists in a field.

3. High school students will respond to an intellectual presentation of subject matter, in which retional thought and analysis are more important than brute force memory.

4. High school teachers, with proper support can teach subject matter far beyond the limits of what they studied in college.

5. Proper support consists not only of subject matter but of the specialists.

6. An exceptionally favorable method for providing this kind of support is through the use of teaching films in which these specialists are the film personalities, seen and heard by the students.[2]

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[1]Lawrence Gene Poorman, "Indiana Physics Teachers React to PSSC," Science Education, 29:171-172, March, 1965.

[2]Elbert P. Little, "PSSC," Science Educational Leadership, 17:169, December, 1959.

One final opinion should be given since this teacher may have hit at the heart of the problem of evaluation of the Committee's course, as compared to the conventional course, even if his opinion is somewhat biased.

> If one starts with the premise that the aim of a physics course is to produce students who can apply neatly boxed equations to everyday life, and in this way calculate such quantities as the final temperature of a mixture of two liquids or determine the focal length of a lens, then the conventional texts will suffice.
> The second view, if one considers it more important to stress the very basic concepts with a deeper treatment than is customarily accorded them, and to build up a view of physics as a modern quantitative science which relies on experiment, deduction, analysis, and prediction, then the Physical Science Study Committee course is the answer.[1]

A REVIEW OF RESEARCH AND EVALUATIONS CONDUCTED ON THE PHYSICAL SCIENCE STUDY COMMITTEE COURSE

Several statistical studies have been conducted since 1957 on the PSSC program. In this section the author will attempt to show what research studies have been conducted to determine if the objectives of the Committee's course have been reached.

The objectives of the PSSC course have been listed in a study by Leslie W. Trowbridge. Trowbridge proposed fifty-

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[1]M. W. Friedlander, "Book Reviews," Physics Today, 15:63, January, 1962.

five objectives of the Committee and confirmed these objectives by interviews and questionaires with the directors of the PSSC. Trowbridge has listed sixteen objectives which are particularly proposed by the PSSC course and thirty-nine objectives which are common to both the PSSC course and the traditional course.[1] Most of these objectives can be classified under several general objectives formulated by Trowbridge. From the author's wide reading about the aims and goals of the Committee, he determined that the following eight objectives of Trowbridge are the main objectives the Committee was trying to achieve in introducing the course. These objectives are:

1. To emphasize the continuity and unity of physics.
2. To encourage students to prepare for careers in the physical sciences.
3. To prepare students for advanced work in colleges and universities.
4. To emphasize the study of a few major topics at considerable depth.
5. To employ thests as a means of determining the ability of students to reason to logical conclusions when working with unfamiliar data.
6. To develop the spirit of scientific inquiry.
7. To teach physics to the typical kind of high school group which has traditionally taken high school physics in the past.
8. To help students learn techniques of experimentation in order to find the answers to all problems.[2]

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

[2]Ibid.

The report continues with a summary of the research findings. Then an analysis is made to determine if the objectives have or have not been reached.

From the very beginning, a systematic program of achievement testing was built into the development of the course itself. The achievement tests were designed to measure the kinds of learning expected of students by the authors of the course. Ten tests were given throughout the year. The achievement tests measured the extent to which the course objectives had been met, and also served as a criterion measure for a self-appraisal by the Committee.[1]

In 1958-59 the tests were given to see if the following questions could be answered:

> 1. Is the group of students enrolled in the PSSC Program during 1958-59 representative of the aptitude level for which the course was designed?
> 2. Is the course generally appropriate to the ability range of students for which the course was designed?
> 3. Is the course, as many critics had predicted, hopelessly beyond the capacity of the students in the lower aptitude ranges of those who normally take physics?[2]

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[1]Frederick L. Ferris, Jr., "An Achievement Test Report," Science Teacher, 26:577, December, 1959.

[2]*Ibid.*

No comparison of the effectiveness of the Committee's course with other methods of secondary school physics instruction was contemplated. Each school was asked to administer the School and College Ability Test (SCAT) yielding verbal, quantitative, and composite scores for all Physical Science Study Committee students and thereby establishing control on scholastic aptitude for the test group.

As the year progressed the schools administered each of the tests in the achievement-battery.

> Consistant with the aims of the course, nearly every test situation demanded not only a knowledge of the subject matter, but also an ability to use and apply this knowledge in the context of a variety of situations new to the student.[1]

The consensus of teachers giving the test seemed to be that the tests led to discussion that served to summarize and clarify the course content and its objectives.

The test reliabilities of all instruments, including the SCAT test, were satisfactorily high. The mean difficulty of the tests was a little high, but the test did an excellent job of discrimination as compared to the College Entrance Examination Board.[2]

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[1]Frederick L. Ferris, Jr., "An Achievement Test Report," Science Teacher, 26:578, December, 1959.

[2]Ibid.

> The results of the aptitude testing showed that 80 per cent of the PSSC students scored better than the 75 percentile of the national norms group of the United States twelfth grade students on SCAT.[1]

Since the Committee's course was designed for those who generally rank in the upper half of their class, Ferris's study concluded that the test group of students enrolled in the course was essentially representative of the aptitude range for which the course was designed.[2]

A special study was made of the achievement test results for students in each of three aptitude groups measured by SCAT. The three groups were: Group I, students ranking above the 90th percentile; Group II, students ranking between the 90th and 75th percentile; Group III, students below the 75th percentile.[3] One striking fact emerged in that there was a marked overlap in the score distribution of the respective groups. A high percentage of students in the lower aptitude group performed better on the achievement tests than the median score of the group ranking above the 90th percentile on SCAT.

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[1]Frederick L. Ferris, Jr., "An Achievement Test Report," Science Teacher, 26:578, December, 1959.

[2]Ibid.

[3]Ibid.

> Therefore, it is now possible to exclude the idea that the Committee's course is appropriate only for students of the highest academic aptitude. The evidence obtained from the testing program overwhelmingly points to the conclusion that, not only is the course well within the capability of the great majority of United States high school physics students, but that experience in it is also highly profitable to a sizeable percentage of relatively low-aptitude students.[1]

One of the earliest studies conducted on the evaluation of the Physical Science Study Committee course was done by Warren L. Hipsher in Tulsa, Oklahoma.[2] The investigation was designed to compare the relative effectiveness of the traditional high school physics curriculum and the PSSC physics curriculum. This was accomplished by comparing scores of two groups of students who took the Cooperative Physics Test, when the variables of scholastic aptitude, prior achievement in natural science, physical science aptitude, and socio-economic status are statistically controlled.

The experiment was carried out over a two year period at the Will Rogers High School in Tulsa, Oklahoma. All students in the school that took high school physics during the 1957-58 school were taught using the traditional physics curriculum. A total of 145 high school seniors were enrolled

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[1]Frederick L. Ferris, Jr., "An Achievement Test Report," <u>Science Teacher</u>, 26:578, December, 1959.

[2]Warren L. Hipsher, "A Comparative Study of High School Physics Achievement," (Doctoral Dissertation, University of Tulsa, Tulsa, Oklahoma, 1960).

in five classes. This group was designated as the control group. The following school year, 1958-59, five classes of 134 high school seniors completed the course developed by the Committee, which was designated as the experimental group.[1] The same teacher was used in each of the different groups.

Form Z, the latest revision of the Cooperative Physics Test, was used to measure the level of achievement in physics of the students. This test was actually based on the objectives of the traditional course. The objectives of the authors of the Committee's Program, however, were different from the objectives of those who had shaped the traditional physics course. Consequently, a test which measured achievement that was expected to result from the use of the traditional course would not be completely applicable for measuring achievement of the Committee's course.

> Nevertheless most colleges and universities were and are oriented toward traditional physics in their introductory course in college physics. Thus the preparation of high school graduates to succeed in a traditional physics curriculum at the college level might be one of the expectations and requirements that might be postulated for any high school physics program.[2]

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[1]Warren L. Hipsher, "A Comparative Study of High School Physics Achievement," (Doctoral Dissertation, University of Tulsa, Oklahoma, 1960.) p. 9.

[2]*Ibid.*, p. 4.

Thus the decision was made to use the Cooperative Physics Test.

In the statistical analysis the effect of the following four variables were taken into account when comparing scores on the Cooperative Physics Test. Scholastic aptitude was measured by the Gamma Form of the Otis Quick-Scoring Mental Ability Test. Prior achievement in natural science was tested by the General Achievement Test in Natural Science. Physical science aptitude was measured by the Engineering and Physical Science Aptitude. To establish the socio-economic level of each of the students, the North-Hatt Scale was used.

The analysis of covariances was used to test the following null-hypothesis:

> There is no difference in the achievement of the control and the experimental groups in their response to the criterion, the Cooperative Physics Test, when the variables of scholastic aptitude, prior achievement in natural science, physical science aptitude and socio-economic status are statistically controlled.[1]

The null-hypothesis was rejected and the findings of the investigation indicated that students taught physics using the traditional high school physics curriculum performed significantly better on the Cooperative Physics

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[1]Warren L. Hipsher, "A Comparative Study of High School Physics Achievement," (Doctoral Dissertation, University of Tulsa, Tulsa, Oklahoma, 1960.), p. 49.

Test, than students taught high school physics using the curriculum developed by the PSSC. In light of their investigation a question has been raised relative to the effectiveness of the Committee's course in preparing students for traditionally oriented courses in college physics.

Robert W. Heath of the Educational Testing Service developed a new test which he felt was able to test the objectives of the Committee. This test was called the Cognitive Preference Test.[1] This test presented a statement with four options designed to demonstrate different forms of cognitive preference in physics. One option was to show preference for memory of specific facts or terms. Another provided a practical application of the information given in the statement. A third choice reflected some challenging or questioning of the information given The fourth option was a statement of fundamental principle of physics underlying the data. The purpose of this test was to compare PSSC classes and conventional physics classes with a reference to the four cognitive preferences.

The population was made up of forty-nine teachers and their classes using the traditional course and thirty

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[1]Robert W. Heath, "Curriculum, Cognition, and Educational Measurement," Educational and Psychological Measurement, 24:239-53, Summer, 1964.

teachers and their classes using the PSSC course. The control group was designated as the traditional physics classes. All students in both groups took the following tests:

1. The School and College Ability Test, Part I, II, and Form 1A for scholastic aptitude.
2. The Cooperative Physics Test, Form Z for a traditionally oriented comprehensive examination.
3. The PSSC Comprehensive Final Examination.
4. The Concealed Figures Test to measure the ability to change the function or significance of structural elements of an object and to use them in a new way.[1]

Table I shows how the students scored on the different tests. The PSSC group, on the average, demonstrated less preference for menory of specific facts and for practical application options in the Cognitive Preference Test, and a stronger preference for the questioning of assumption and a statement of fundamental principles option than the control group. The PSSC groups are, on the average, superior in ability as measured by SCAT. The control group performed slightly better on the conventional achievement test but the PSSC group is much superior on the PSSC test. The PSSC

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[1]Robert W. Heath, "Curriculum, Cognition, and Educational Measurement," Educational and Psychological Measurement, 24:245-246, Summer, 1964.

TABLE I

SUMMARY STATISTICS OF PSSC AND CONTROL GROUPS

	PSSC GROUP		CONTROL GROUP	
	Mean Score	Standard Dev.	Mean Score	Standard Dev.
SCAT	42.7	3.4	39.3	4.3
Coop. Physics	39.6	7.7	41.4	6.4
PSSC Final	29.5	5.4	18.7	4.0
Concealed Figures	61.8	6.0	52.4	7.7
Cognitive Preference: Memory	5.6	.8	6.8	1.5
Cognitive Preference: Application	4.5	.7	4.7	1.1
Cognitive Preference: Question	4.5	.7	4.1	.4
Cognitive Preference: Principle	5.3	.6	4.3	.5

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[1]Robert W. Heath, "Curriculum, Cognition, and Educational Measurement," *Educational and Psychological Measurement*, 24:247, Summer, 1964.

groups were also higher on the Concealed Fingures Test. The possibility that the difference in cognitive preference can be accounted for by differences in ability was tested and discounted.[1]

Based on the proposition that the PSSC high school physics course has an objective of encouraging cognitive preferences different from the traditional course, the following hypotheses were tested, and were accepted:

1. that PSSC students demonstrate a stronger preference for fundamental principles and questioning than non-PSSC students;

2. that non-PSSC students prefer memory for facts and practical application to a greater degree than PSSC students;

3. that preference for fundamental principles and questioning is more positively related to achievement test scores for PSSC students than for the control group; and

4. that preference for facts and terms and for practical application is more negatively related to achievement test scores for PSSC students than for control group students.[2]

One of the most recent research studies concerning the PSSC was done by William W. Day to determine if a relationship exists between the amount and type of physics taken by a pupil and his critical thinking ability.[3]

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[1]Robert W. Heath, "Curriculum, Cognition, and Educational Measurement," Educational and Psychological Measurement, 24:247, Summer, 1964.

[2]Ibid., p. 251.

[3]William W. Day, "Physics and Critical Thinking: A Comparison of PSSC and Traditional Physics," (A summary of Doctoral Dissertation, University of Nebraska, June, 1964).

A test population consisting of three groups was selected from thirteen Colorado secondary schools and contained 890 individuals. The groups were divided as follows: the PSSC group comprised 25 per cent of the total population, the traditional physics group comprised 29 per cent of the total population, and the no-physics group comprised 46 per cent of the total population. "All three groups were equated on the basis of intelligence; achievement; course background in English, mathematics, social studies, and science; and mobility."[1] The evaluative instruments used as a basis of critical thinking were the Watson-Glager Critical Thinking Appraisal, form XM, and Logical Reasoning, form A.

A questionaire was given to the students whose teachers taught both the PSSC and traditional courses and this questionaire revealed a distinct difference in acceptance of the physics courses and students' attitudes toward science. On a question asked about the course being up to the students' expectations, the PSSC students answered "no" by 51 per cent; whereas, the Traditional students answered "yes" by 82 per cent. A question about the method of

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[1]William W. Day, "Physics and Critical Thinking: A Comparison of PSSC and Traditional Physics," (A summary of Doctoral Dissertation, University of Nebraska, June, 1964).

presentation indicates the 79 per cent of the PSSC group were not pleased with the presentation; while 61 per cent of the Traditional group felt the presentation was satisfactory.[1]

The students were tested for the following aspects of critical thinking; inference, deduction, interpretation, logical reasoning, total critical thinking appraisal, assumption, and argument. Inference, deduction, interpretation, logical reasoning and total critical thinking critical appraisal are all significant at the 1 per cent level, while assumption and argument are significant at the 5 per cent level.[2]

An examination of Table II reveals that the PSSC mean is higher than the traditional mean in all but one of the categories of critical thinking tested, this being the assumption category. "The difference between the PSSC group and the Traditional group, as well as the Traditional group and the no-physics group, is much less than the difference between the PSSC group and the No-Physics group."[3] By adding the differences between the PSSC and the Traditional groups and the Traditional and No-Physics group, it can be

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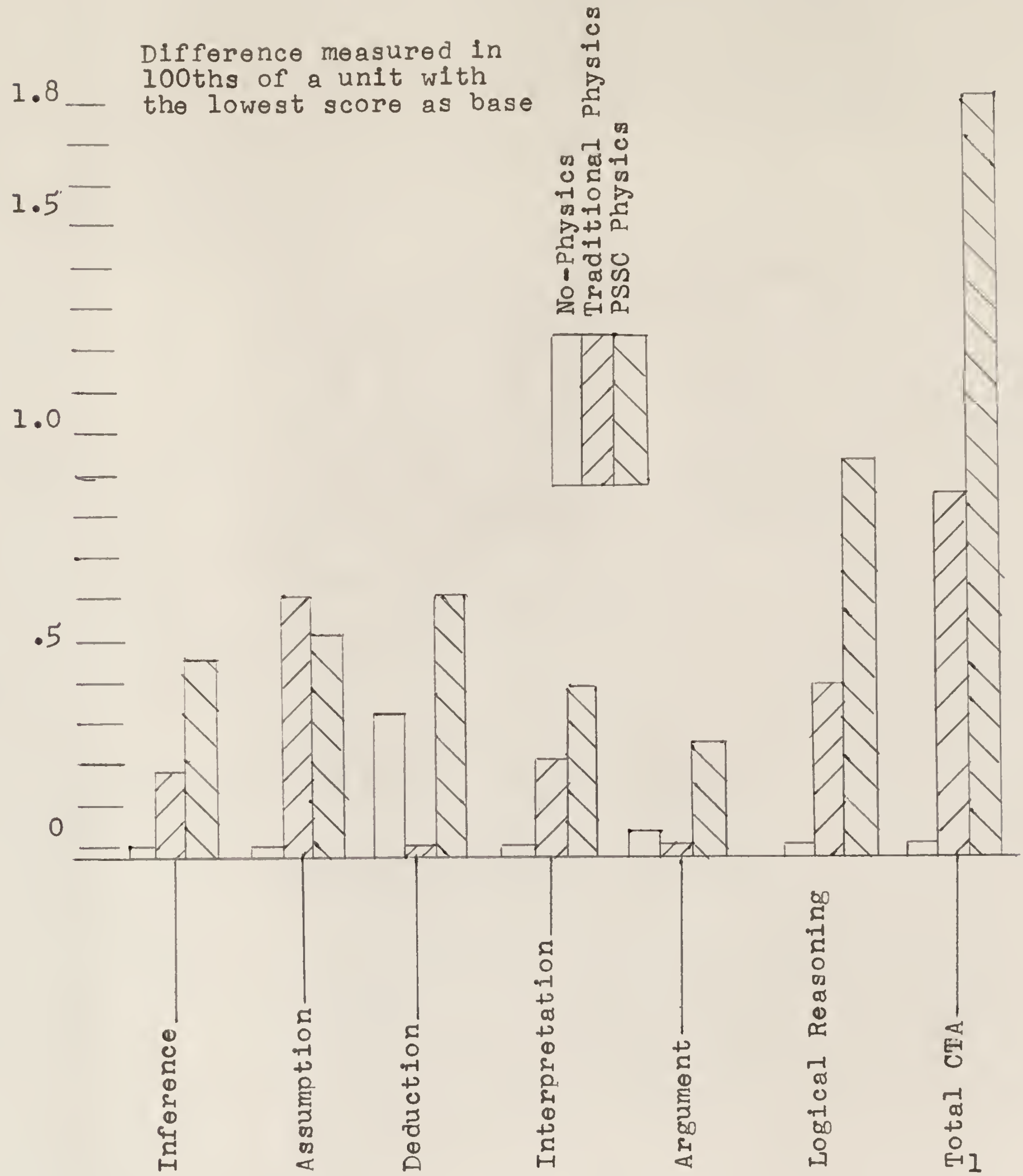
[1]William W. Day, "Physics and Critical Thinking: A Comparison of PSSC and Traditional Physics," (A summary of Doctoral Dissertation, University of Nebraska, June, 1964), p. 12.

[2]*Ibid.*, p. 13.

[3]*Ibid.*, p. 15.

TABLE II

ANALYSES OF THE NO-PHYSICS, TRADITIONAL PHYSICS, AND PSSC PHYSICS, WITH SEVEN DIFFERENT CATEGORIES



[1]William W. Day, "Physics and Critical Thinking: A Comparison of PSSC and Traditional Physics," (Summary of Unpublished Doctoral Dissertation, University of Nebraska, June, 1964) p. 14.

seen that the difference between the PSSC and Traditional groups is about one and one half times la rger than the cumulative difference between the Traditional and No-Physics group.

The following were the conclusions made by the investigator:

> 1. Students who take PSSC physics exhibit a greater ability to solve critical thinking problems than do those students who do not take physics, as measured by the evaluative instruments.
> 2. The results also suggest an advantage of PSSC physics over Traditional physics in developing critical thinking ability and an advantage of Traditional physics students over students who do not take physics is measured by the evaluative instruments. These differences were not tested statistically for significance.
> 3. The results of the study support the conclusion that of the small sub-population of PSSC and Traditional students whose instructor taught both PSSC and Traditional sections of physics, the PSSC physics students have a negative attitude toward the course, when compared to the Traditional students. The Traditional students were not only more positive in attitude toward their course but were also more positive in the areas of interest in science and science activities.
> 4. The school population is highly mobile and college bound.[1]

One of the first ideas that enters the researchers mind when considering the PSSC course, is what are the

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[1]William W. Day, "Physics and Critical Thinking: A Comparison of PSSC and Traditional Physics, (A summary of Doctoral Dissertation, University of Nebraska, June, 1964), pp. 15-16.

objectives of the Committee. Leslie W. Trowbridge did research on the comparison of the objectives of the PSSC and a Traditional physics course.[1] He developed a composite list of seventy-two objectives, some which were unique to the PSSC course, some to the traditional course, and some common to both courses. This he sent to various high school physics teachers to have them indicate what they thought were the main objectives of both courses.

Among the objectives on which the PSSC teachers and teachers of traditional courses differed significantly were the following:

> 1. To help the student become a more intelligent consumer of the products of modern technology.
> 2. To teach the application of physics principles to modern technology and to devices common in the life of the student.
> 3. To cover the requirements of standard state and local syllabi and examination.
> 4. To use a textbook which helps students retain learned information by use of summaries, glossaries, tables, list of conclusions, etc.
> 5. To use laboratories to verify facts and principles of physics.
> 6. To emphasize practical (English) units of measurement.[2]

The six objectives listed above were favored significantly by the traditional teachers over PSSC teachers.

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

[2]Ibid., p. 120.

The following objectives were favored significantly by PSSC teachers over teachers of traditional courses:

> 1. To emphasize the intellectual, cultural, and liberal education aspects of physics.
> 2. To develop an understanding of the purposes, uses, development, and limitations of scientific "Theories" in general.
> 3. To teach some of the important historical and philosophical developments of physics.
> 4. To emphasize that physicists are typical people of academic life with typical human aspirations.
> 5. To emphasize the major concepts and principles of physics mainly from the standpoint of their contributions to physics as a pure science rather than an applied science.
> 6. To emphasize the study of a few major topics at considerable depth.
> 7. To emphasize the method of laboratory investigation for learning.
> 8. To emphasize the understanding and use of physical approximations and models in helping to explain theoretical concepts.[1]

A research study, conducted approximately like the Trowbridge study, has been done on the generalizations of the PSSC course. Pate D. Rathe proposed an investigation:

> 1. To identify and state subject matter physics generalizations which are preliminary to and basic for those found in PSSC physics and
> 2. To seek, through the opinions of PSSC high school instructors, the relative desirability of students attaining these generalizations prior to taking the PSSC high school physics course.[2]

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:121, March, 1965.

[2]Pate D. Rathe, "Certain Physics Generalizations Desirable for Student to Attain Before Taking the PSSC High School Physics Course," Science Education, 49:128, March, 1965.

Two hundred twenty-three generalizations were listed and twenty-three selected teachers were used to find out if they believe these generalizations were stressed by the PSSC course. The following conclusions were developed:

> 1. One hundred thirty-four of these generalizations showed relatively high desirability for students to attain before taking PSSC physics.
> 2. Generalizations showing relatively high desirability for students to attain before taking PSSC physics relate mainly to topics of matter, magnetism, and some aspects of light and energy.
> 3. Generalizations showing relatively low desirability for students to attain before taking PSSC physics relate mainly to topics of waves, dynamics, and some aspects of light and energy.
> 4. This investigation indicated disagreement among college and high school physics teachers as to a) the ability of certain science terms to convey a fairly accurate scientific meaning and b) how accurately quantitative relationships should be expressed for pre-PSSC science courses.[1]

A research study was completed on the local level in Grossmont, California.[2] The purpose of the study was to answer the following questions before adopting the PSSC

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[1]Pate D. Rathe, "Certain Physics Generalizations Desirable for Student to Attain Before Taking the PSSC High School Physics Course," Science Education, 49:128, March, 1965.

[2]Leon M. Lessinger, "An Evaluation of PSSC Physics," California Journal of Secondary Education, 37:97-99, February, 1962.

program:

1. What contributions would the new program make in the educational life of the pupils not now being made by the traditional program?
2. Would all pupils commonly electing physics be able to handle the subject matter?
3. What would the reaction be from pupils, parents, teachers, and administrators?
4. Would the course cause lower marks earned by the pupils?
5. What weaknesses were there in the program which might require remediative treatment?[1]

The research plan, selected to answer the above questions, was to have five of the six schools teach the PSSC program while the sixth school taught the traditional course. The Otis test of general intelligence, PSSC tests, and a test produced by the teachers of the district were administered to all pupils. Questionaires and rating sheets were developed to obtain pupil, parent, teacher, and administrator reaction to the program.

The results may be summarized as follows:

1. Pupils stated that they experienced marked growth in their understanding of physics. They were particularly favorable towards their increased ability to see relationships, judge the usefulness of facts, and the opportunity to experiment and use ideas.

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[1]Leon M. Lessinger, "An Evaluation of PSSC Physics," _California Journal of Secondary Education_, 37:97, February, 1962.

2. The parents general reaction was favorable; they stressed, in particular, the contribution of the program in their youngsters ability to think independently.

3. Teachers and administrators felt that the program not only taught physics but also helped the pupils learn to think. A by-product of the program was a more insightful understanding of physics by the teachers themselves.

4. The marks earned, as well as the actual performance of the pupils of comparable ability, on the PSSC and traditional physics tests do not support the thesis that the PSSC program is either harder to grasp or more difficult to succeed in than the traditional program.

5. PSSC pupils were not penalized in their understanding of classical physics when compared to the pupils of comparable ability taking the traditional program in the district.

6. The California sample of PSSC pupils did better, statistically, on one of the PSSC tests and significantly better on two of the five PSSC tests than the New York State sample.

7. Weaknesses in the program center mainly around the text material, time allotted for laboratory and previous preparation of the pupils in the mathematics.[1]

Some of the studies reviewed have tried to compare the PSSC course and the traditional course. The major problem in this type of evaluation will be realistic only if the nature and objectives of the course are taken into account. This is one reason it is practically impossible to compare and evaluate the Committee's physics course and the traditional physics course. The complexity of this problem led the College Board to authorize a special study to determine

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[1]Leon M. Lessinger, "An Evaluation of PSSC Physics," <u>California Journal of Secondary Education</u>, 37:97-99, February, 1962.

the extent of the handicaps of the PSSC physics students on the College Entrance Examination Board Physics Test. The results show the validity of the traditional evaluative instrument was questionable for both types of courses. Consequently, they have reverted to a single examination consisting of questions involving both courses of study.

Another major problem in evaluating a new course such as the PSSC is the difficulty to determine whether the differences are due to variables which are being evaluated or whether the differences exist due to some other variable which has not been taken into consideration.

From the research studies reviewed, the author will attempt to indicate which objectives have or have not been reached. For some of these objectives it will be possible to compare the PSSC and traditional students. In such cases if the scores on a test indicate that the PSSC group did significantly better than the traditional group, then the author will assume that the objective has been reached.

Objective number one, "to emphasize the continuity and unity of physics",[1] and objective number two, "to encourage students to prepare for careers in the physical sciences,"[2] are the only two objectives that are given

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

[2]Ibid.

where the research studies failed to indicate whether or not these objectives have been reached.

Hipsher's research study on the comparison of the PSSC course and the traditional course seems to indicate that objective number three, "to prepare students for advanced work in college and universities,"[1] has not been reached. Hipsher has shown this by comparing test scores of students of both the PSSC course and the traditional course who took the Cooperative Physics Test. These test scores showed the traditional students significantly higher than the PSSC students. This Cooperative Physics Test is designed to measure the level of achievement and the ability of students to succeed in an introductory college physics course. However, as Hipsher has commented, the Cooperative Physics Test is designed for the traditionally oriented student because most of the introductory college courses are taught like the traditional physics course. Because of this the student in the traditional course may have had an advantage over the students in the PSSC course.

Trowbridge's study, conducted by sending questionaires

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

to teachers, indicates that objective number four, "to emphasize the study of a few major topics at considerable depth,"[1] has been reached. This was shown by the fact that this was one of the objectives favored significantly by PSSC teachers over teachers of traditional courses. The author is assuming that because this objective obtained a higher rating from PSSC teachers that this objective has been reached.

Objective number five, to determine the ability of students to reason to logical conclusions when working with unfamiliar data, has been reached and verified by Heath's study and by Day's study. This is shown in Heath's study by the PSSC group getting higher scores on the Concealed Figures Test than the traditional group. The Concealed Figures Test is designed to measure the ability of students to change the function of structural elements of an object and use them in a new way. In Day's study this is shown by the PSSC group scoring higher scores on the items, logical reasoning and deduction on the Watson-Glazer Critical Thinking Appraisal.

On the basis of Heath's study and Lessinger's study objective number six, "to develop the spirit of scientific

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

inquiry,"[1] has been reached. In Lessinger's study, conducted in Grossmont, California, he shows that the objective has been reached by stating that the study showed the pupils who were taking the PSSC course showed more growth in their understanding of relationships and the opportunity to experiment and use ideas as compared to a traditional physics group. Heath's study also shows this objective has been reached by showing the PSSC group scored higher than the traditional group on the Cognitive Preference Test items, "questioning of information given" and "fundamental principles of physics underlying the data".

Objective number seven, "to teach physics to the typical kind of high school group which has traditionally taken high school physics in the past,"[2] has been reached. This is shown by the Ferris study and the Lessinger study. One of the main purposes of the achievement test given to the PSSC group in Ferris's study was to determine if this objective had been reached. This was shown by the results of the aptitude test in that most of the students taking PSSC course scored in the upper 25 percentile of the national norms group of the United States' twelfth grade students

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

[2]Ibid.

on SCAT. The Committee believed that the atudents who traditionally took physics were in the upper 25 percentile on the national norms group.[1] Therefore, in Ferris's judgment, this study indicated that the students who enrolled in the PSSC course are representative of the aptitude range for which the course was designed. He also believes that the scores on the achievement tests indicate that the PSSC students achieved the level of cometency in physics that the Committee had originally expected of them. This objective is also verified in Lessinger's study by the fact that the marks earned, as well as the classroom performance of the pupils in the study, support the objective that the PSSC course is designed to be taught to the students who generally take physics.

Heath's study and Day's study verify that the last objective, "to help students learn techniques of experimentation in order to find the answer to a problem,"[2] has been reached. Heath's study determined if this objective had been reached by comparing the scores of the PSSC group and the traditional group on the Cognitive Preference Test for the

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[1]Frederick L. Ferris, "An Achievement Test Report," Science Teacher, 26:577, December, 1959.

[2]Leslie W. T„owbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

choices "questioning of information given" and "fundamental principles of physics underlying the data". The scores showed the PSSC group ranked significantly higher than the traditional group. Day's study verified that the last objective had been reached by observing the higher scores earned by the PSSC group over the traditional group on the test items deduction and interpretation on the Watson-Glazer Critical Thinking Appraisal.

SUMMARY AND CONCLUSIONS

This report was conducted in order to give a complete summary and compilation of all evaluations that have been made about the Physical Science Study Committee high school physics course. The PSSC course was designed to answer a long-standing feeling of dissatisfaction with the present teaching of physics in the high school. The PSSC designed a completely new high school physics course including a new textbook, laboratory guide, set of inexpensive apparatus, number of films, standardized tests, series of paperback books, and a teacher's guidebook. The aim of this material was to develop in the students a deeper understanding of the meaning of science by teaching the student to develop his critical thinking ability. The Committee's approach was that selected topics are discussed in great detail, with each topic leading to greater generalizations and constant reference to experimental observation.

There has been wide and varied opinion about the PSSC program. The most frequently listed shortcomings of the course are the following:

1. The text is difficult to read and lacks generally the easier drill type problems that bridge the gap between first contact with an idea and some mastery of it.

2. Practical applications are lacking in the course.

3. The quantity of subject matter is substantially more than can be thoroughly covered by a normal class in one year.

4. A large quantity of the subject matter in the course as well as the suggested method of presentation, is unfamiliar to most high school physics teachers.

The advantages of the course usually listed include the following:

1. The laboratory phase of the program is generally outstanding.

2. The students are guided to understand the way a physicist learns by using logical deductions and creative thinking.

3. Physics is both a body of knowledge and an activity. The program unfolds this dual nature of science to the students.

4. The students come away from the course, understanding the general principles better than they would have in a traditional course.

5. The Committee's program foresees every need of the teacher in providing all the necessary items for a complete high school physics course.

Evaluation has been attempted and has produced some insight into the problems confronted. A number of group comparative evaluations have been completed in the high school pertaining to the Committee's physics and traditional physics courses.

The studies reviewed indicate that most of the main objectives first set up by the Committee have been reached. The objectives reached are:

> 4. To emphasize the study of a few major topics at considerable depth.
> 5. To employ tests as a means of determining the ability of students to reason to logical conclusions when working with unfamiliar data.
> 6. To develop the spirit of scientific inquiry.
> 7. To teach physics to the typical kind of high school group which has traditionally taken high school physics in the past.
> 8. To help students learn techniques of experimentation in order to find the answer to a problem.[1]

The research studies also indicate that the objective "to prepare students for advanced work in college and universities," especially for the traditionally oriented colleges course, may not have been reached.

The research studies reviewed did not indicate whether

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

the objective "to emphasize the continuity and unity of physics,"[1] and "to encourage students to prepare for careers in the physical sciences,"[2] had or had not been reached.

Observed from the point of view of educational research the PSSC program offers many problems for further study, but there is no denying that the way has been opened to make physics a far more valuable part of the high school curriculum.[3]

> The achievements of this new course should serve to remind educators what they are often prone to forget, that in physics, and also in every other academic discipline, there lies resources for the solutions of educational problems which are usually neglected.[4]

The author believes if the PSSC course is to be a total success, the primary concern must be to obtain the cooperation of the high school science teacher. He and his students are the customers for this product. The teacher must try out the program, and measure carefully its triumphs and its failures. The teacher must keep a constant feedback flowing to the physicists, the educators, the editors, the film producers, the designers of apparatus, and all those who are seeking to put the course together. If the course

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[1]Leslie W. Trowbridge, "A Comparison of the Objectives and Instructional Material in Two Types of High School Physics Courses," Science Education, 49:117-122, March, 1965.

[2]Ibid.

[3]J. A. Easley, Jr., "The Physical Science Study Committee and Educational Theory," Harvard Educational Review, 29:11, Winter, 1959.

[4]Ibid.

is to succeed in the classroom and in the classroom alone, its final form must in the end be determined by the classroom.

Because of the need for a greater understanding of science, the PSSC course was developed. This does not mean that the PSSC course is the only possible approach to the teaching of physics. Under way at the present time is another project that is being developed for the teaching of high school physics. This project is being done at Harvard University, called the Harvard Project. If man is to continue to live successfully in a scientific world, there is a constant need for physics teaching and the teachings of all sciences to be contemporary with the times.

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A REVIEW OF THE
PHYSICAL SCIENCE STUDY COMMITTEE
HIGH SCHOOL PHYSICS COURSE

by

STEPHEN W. DAESCHNER

B.S., Baker University, 1964

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

The threefold purpose of this study was to answer the following questions:

1. Why and how was the Physical Science Study Committee high school physics course developed?

2. What are the opinions of teachers and educators concerning the course?

3. Are the objectives formulated by the Committee for the course being achieved?

The procedure employed in this study was to review the pertinent literature concerning the PSSC course located at Kansas State University, Kansas University library, and obtained through interlibrary loans, and various sources obtained through correspondence. This investigation produced a considerable amount of information pertaining to the PSSC course which was organized into the following categories:

1. Background and development of the PSSC course.

2. Opinions of teachers and educators on the effectiveness of the PSSC course.

3. Research studies to determine the effectiveness of the PSSC course.

4. Summary and conclusion.

It was found that the PSSC course was a multimillion dollar program designed for the revision of high school physics. The PSSC developed for this course: a textbook, laboratory guide and a set of new and inexpensive apparatus, a large number of films, standardized tests, a growing series of paperback books, and a teacher's guidebook.

The PSSC course was designed to tell a unified story--one in which the successive topics are chosen and developed to lead toward an atomic picture of matter. The student is expected to be an active participant in the course, and use deduction and logical reasoning to develop the fundamental principles.

The main criticisms against the Committee's course are 1) practical applications are lacking, 2) the course is too long to cover in one year, and 3) it is difficult to read and lacks the easier drill type problems. The advantages of the course are usually listed as 1) the laboratory experiments are outstanding, 2) the students are guided to use deductive and creative thinking when solving problems, and 3) the students understand the general principles better than they would in a traditional course.

The research studies reviewed seem to indicate that most of the objectives first proposed by the Committee have been reached.