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*SCIENCE INSTRUCTION, *TEACHING METHODS, SCIENCE COURSES, SCIENCE EDUCATION, *CHEMISTRY, *SCIENCE CURRICULUM, *PHYSICS INSTRUCTION, TEACHER EVALUATION, PHYSICS CURRICULUM, IOWA TEST OF EDUCATIONAL DEVELOPMENT-SCIENCE TEST, EMPORIA, KANSAS, IOWA, NEBRASKA, MISSOURI, OTIS QUICK SCORING MENTAL ABILITIES TEST, THE TEST ON UNDERSTANDING SCIENCE (TOURS)

IT WAS THE PURPOSE OF THIS RESEARCH TO ASSESS THE CONTRIBUTION OF CERTAIN SCIENCE COURSES AND OTHER FACTORS THAT MAY INFLUENCE STUDENTS' UNDERSTANDING OF SCIENTISTS, THE AIMS AND METHODS OF SCIENCE AND THE SCIENTIFIC ENTERPRISE. THE SAMPLE CONSISTED OF 1,275 PHYSICS STUDENTS AND 1,009 CHEMISTRY STUDENTS FROM HIGH SCHOOLS IN IOWA, KANSAS, NEBRASKA, AND MISSOURI. TESTS USED FOR DATA WERE THE TEST ON UNDERSTANDING SCIENCE (TOURS), IOWA TEST OF EDUCATIONAL DEVELOPMENT-SCIENCE TEST, AND OTIS QUICK SCORING MENTAL ABILITIES TEST. CLASSES WERE VISITED AND OBSERVATIONS WERE MADE OF TEACHERS METHODS, MATERIALS USED, AND OTHER FACTORS WHICH SEEMED TO BE FACTORS OF DIFFERENCE BETWEEN THE CLASSES. THE ANALYSIS OF DATA BY USE OF A COMPUTER SHOWED THAT GAIN IN UNDERSTANDING SCIENCE DEPENDS UPON THE TEACHER REGARDLESS OF MATERIALS USED. ALSO, THE LOW MEAN GAIN CLASSROOM ACTIVITIES USED (A) TEACHER DEMONSTRATION-DISCUSSION, (B) TEACHER PROBLEM SOLUTION, (C) STUDENT READING ASSIGNMENT AND PROBLEM TRIAL, (D) STUDENT RECITATION, (E) THE SAME CYCLE WITH NEW MATERIAL, AND (F) LABORATORY EXPERIMENTATION OVER MATERIALS STUDIED IN (A)-(E). THE MEAN GAIN CLASSROOM ACTIVITIES USED (A) INTRODUCTION TO LABORATORY, (B) LABORATORY, (C) POSTLABORATORY DISCUSSION, (D) PROBLEM SOLUTION BY CLASS, (E) STUDENT READING AND PROBLEM SOLUTION ASSIGNMENT, (F) TEACHER-CLASS PROBLEM SOLUTION, AND (G) LABORATORY INTRODUCTION ON NEW MATERIAL. (GC)

INFLUENCES ON STUDENTS' UNDERSTANDING OF SCIENCE

by

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PART ONE

INTRODUCTION TO THE PROBLEM

I. Problem

Although there may be lack of agreement on the specific facts and principles to be taught in modern science courses, there is general agreement on the aims and objectives of science education. The National Society for the Study of Education, in the 59th yearbook, listed the aims of better science teaching as threefold.[1]

> First, to teach some facts and principles of science; second, to inculcate higher virtues such as accuracy, critical thinking, scientific honesty and more generally scientific method; and third to develop an understanding and appreciation of science and scientists, which may last usefully through life.

Researchers have been concerned for years with the role of critical thinking and problem solving in the teaching of secondary-school science, but there has been only limited effort expended to determine to what degree students at this level develop understanding and appreciation of science and scientists.

It is the purpose of this research to assess the contribution of certain science courses and other factors that may influence students' understanding of scientists, the aims and methods of science, and the scientific enterprise.

Definition of Terms

CBA. The Chemical Bond Approach Project course in chemistry. Students who are enrolled in high school chemistry classes in which the materials developed by this project are used as the primary text materials. For the purposes of this study the CBA designation will be used to identify all students enrolled in these classes using the Chemical Bond Approach materials in the participating schools.

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[1] Eric Rogers, Rethinking Science Education. 59th Yearbook National Society for Study of Education, (Chicago: University of Chicago Press, 1960) p. 19.

CHEM. The Chemical Education Materials Study course in chemistry. Students who are enrolled in high school chemistry classes in which the materials developed in this project are used as the primary text materials. The CHEM designation in this study will be used to identify students enrolled in these classes using the Chemical Education Materials Study materials in the participating schools.

STAN. The course of study for high school chemistry that essentially follows the sequence of descriptive chemistry as outlined by the majority of textbooks in print prior to 1960. The STAN group includes all students enrolled in classes in the participating schools using a high school chemistry text in print prior to 1960.

PSSC. Physical Science Study Committee (PSSC) Physics refers to that course in physics designed for the secondary school and developed by the Physical Science Study Committee. This course has its subject matter chiefly embodied in the textbook and accompanying laboratory guide, entitled, Physics, published by D. C. Heath and Company.

TRAD. Refers to those (non-PSSC) courses in high school physics which have as their structure the study of Mechanics, Heat, Light, Electricity and Magnetism, Modern (Atomic and Nuclear) Physics and Sound in segmented units of study or which use textbooks with this format as the principal text for the course.

Background in Science. The knowledge about science in general as measured by a widely used achievement test.

General Intelligence. The general intellectual ability (IQ) of the student as measured by a widely used intelligence test.

Understanding Science. The understanding students have of the aims and methods of science, the scientist and the scientific enterprise.

II. The objectives of this research were:

A. To determine if there was a significant gain in understanding of science among those students studying high school chemistry.

B. To analyze the contributions of high school chemistry and physics to the student's understanding of scientists, the aims and methods of science, and the scientific enterprise.

C. To analyze the contribution to the student's understanding of scientists, the aims and methods of science, and the Scientific enterprise of each of the following: (a) the Physical Science Study Curriculum physics course, (b) the traditional physics course, (c) the Chemical Bond Approach chemistry course, the Chemical Education Materials Study chemistry course, and (e) the Standard chemistry course.

D. To attempt to isolate factors not directly related to the subject content (of the curriculum materials used in the various courses) which may influence student understanding of science.

III. Related Research

Objective evaluation of understanding science is a relatively recent innovation in the field of educational testing, yet considerable progress has been made.

Wilson,[2] as early as 1954, had developed a 26-item questionnaire which was evaluated by scientists and presented to two hundred eighty-five (285) persons in grades eight through the senior year of colle The items were taken largely from the work by Conant on "The tactics

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[2] Leland L. Wilson, "A Study of Opinions Related to the Nature of Science and its Purposed in Society", Science Education. 38:159-166, March 1954.

and strategy of science,"[3] and Mees', The Path of Science.[4] The conclusion reached as the result of the survey was that a considerable lack of understanding of science and its place in society existed among those who responded.

Porter and Anderson,[5] in a 1959 study of high school chemistry students, found that the student's ability to understand and apply scientific method as measured by an attitude scale was related to intelligence per se.

Allen[6] measured the attitude of high school seniors toward science with the use of an attitude scale. He found that the students did not have a clear-cut understanding of the nature of science and scientific work.

Cooley and Bassett[7] used an experimental instrument to assess student perceptions of science and scientists during a ten week summer program at Thayer Academy, Braintree, Massachusetts. The instrument was one under development by Educational Testing Services and dealt with such themes as: the image of science and scientists, distinctions between science and technology, and the nature of the scientific-process.

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[3] James B. Conant, Science and Common Sense, (New Haven: Yale University Press, 1951) p. 4.

[4] Charles K. Mees, The Path of Science, (New York: J. Wiley and Sons, Inc. 1946).

[5] J. W. Porter and R. Anderson, Science Education, 43:12-19, February 1959.

[6] Hugh Allen, Attitudes of High School Students Toward Science, Science Manpower Monograph (Columbia: Bureau of Publications, Teachers College, 1959).

[7] William W. Cooley and Robert D. Bassett, "Evaluation and Follow-up Study of a Summer Science and Mathematics Program for Talented Secondary Students", Science Education, 45:209, April 1961.

One conclusion drawn from this study was that it was possible to design questions which could effectively measure gain in students' perspectives of science and scientists.

Klopfer and Cooley,[8] with a grant from the United States Office of Education, conducted a study of major proportions in terms of both geographic distribution of sample and size. The study was designed to test the effectiveness of the History of Science Cases in teaching conventional topics of high school chemistry, physics, and biology. Achievement on previously established tests of appropriate subject matter content and the Test on Understanding Science (TOUS-Form X) were the criteria for evaluation in the study. One of the conclusions reached by Klopfer and Cooley was that the use of the History of Science Cases Instruction in biology, chemistry, and physics was an effective way of increasing student understanding of science and scientists. The TOUS test was used in the evaluation which led to this conclusion. Two important aspects of this study were:

1. The use of learning outcomes centering about the understanding of science and scientists as objectives of science instruction.

2. The technical rigor of the study, execution, and analysis.[9]

Carrier,[10] in 1962, reported a study using selected items from the

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[8] Leo E. Klopfer and William W. Cooley, Use of Case Histories in the Development of Student Understanding of Science and Scientists, (Cambridge: Harvard University Graduate School of Education, 1961), (Mimeographed).

[9] Maurice Belanger, "Methodology of Educational Research in Science and Mathematics," Review of Educational Research 34:384, June 1964.

[10] Elba O. Carrier, "Using a History of Science Case in the Junior High School," Science Education, 46:416-25, December 1962.

1961 edition of the Test on Understanding Science (TOUS-Form X), by Klopfer and Cooley, to evaluate the Case History of Science Approach in teaching chemistry to junior high school students. He reported that although there was an apparent gain in understandings about the scientific enterprises, about scientists, and about the aims of science as measured by the experimental instrument, the need for some revision was indicated to adjust the test to the vocabulary level of this age group.

Smith[11] reported the use of the TOUS and the Watson-Glaser Critical Thinking Appraisal in an attempt to determine the effectiveness of an 8-week National Science Foundation summer program for eleventh and twelfth grade students in North Carolina. Although this report cannot be placed in the category of a controlled experiment it does indicate that there is some acceptance of the test.

Douglas and Crumb[12] made use of the TOUS in evaluating a pilot study in curriculum research involving study materials in science and social science at the junior high school level. The test was used as a part of a pre-test and post-test battery in an effort to assess student gain in understanding of science over an eight-week period. It was demonstrated that the program did bring about some gain in understanding of science as measured by TOUS and that the change in behavior occurred in a short period of time. The conclusions of the study were limited due to the small size of the sample and the lack of

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11. Paul M. Smith, Jr. "Critical Thinking and the Science Intangibles", Science Education, 47:405-408, October 1963.

12. Thomas Douglas and Glenn H. Crumb, Fusion to Avoid Confusion, (Unpublished Research Report, University of Nebraska Teachers College, 1963).

statistical treatment beyond calculation and comparison of the mean scores.

Crumb,[13] in a recently completed doctoral study, has shown that a significant gain in understanding of science is made by students studying physics over a period of one year, and that these gains seem to be related to the type of course in which the student is enrolled and the methods used by the teacher.

Kleinman,[14] in a doctoral study, analyzed the teaching patterns of junior high school science teachers and identified teachers using critical thinking questions as a part of their respective teaching patterns. She found that the high ability students in the classes taught by the critical thinking pattern scored significantly higher on the TOUS test form Jy.

Hubbard[15] reports the use of a Facts About Science Test as a means of evaluating the effectiveness of a teaching unit on the "ways of the scientists," presented to a class of eighth grade students. He found no significant difference between experimental and control groups.

Trent[16] analyzed the attainment of the concept of understanding

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[13] Glenn H. Crumb, A Study of Understanding Science Developed in High School Physics, Journal of Research in Science Teaching, 3:246-250, 1965.

[14] Gladys Kleenman, Teachers Questions and Student Understanding of Science, Journal of Research in Science Teaching, 3:307-317, 1965.

[15] Howard N. Hubbard, "Junior High School Students Perceptions of Science and Scientists", Dessertation Abstracts, 24:5344.

[16] John H. Trent, "The Attainment of the Concept Understanding Science Using Contrasting Physics Courses", Journal of Research in Science Teaching, 3:224-229, 1965.

science by physics students in fifty-two California high schools. After dividing the students into those studying a traditional physics course and those studying PSSC physics, he found that both courses were equally effective in developing the concept of understanding science.

Schefler[17] conducted a comparative study of the differences in a lecture-illustrative college biology laboratory and an inductive laboratory approach. Analysis of the differences in pre-post scores on TOUS over a 10 week period indicated no significant differences between the experimental and control groups. However, a significant difference between teachers was indicated.

In a study involving introductory microbiology classes at the University of Georgia, the TOUS test was used as an evaluative instrument. Although the experimental group scored significantly higher on the achievement tests administered in the study, there was no significant difference in the gain in TOUS scores over the one semester experimental period. The investigators questioned the advisability of using this instrument at the college level.[18]

Lepper[19] reports that the TOUS test scores of high ability high school juniors participating in a summer science program were considerably above the published scores for this age group.

In a study of the adoption and implementation of the Chemical

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17. William C. Scheller, "A Comparison Between Inductive and Illustrative Laboratories in College Biology", 3:218-223, 1965.

18. Dr. Brown, G. E. Michaels, and J. C. Bledsoe, "An Experiment in the Use of Film Slides in an Introductory Course in Microbiology", Journal of Research in Science Teaching, 3:333-334, 1965.

19. Robert E. Lepper, "Using the OAIS to Select Participants for High School Institutes", Journal of Research in Science Teaching, 3:346-347, 1965.

Education Materials Study course in chemistry in the Detroit Public Schools, McFarland[20] found a high positive correlation between student achievement and the Test On Understanding Science.

Bruce,[21] in a study of prospective science teachers, compared college freshman science majors with no plans to teach with college freshman science majors planning to be teachers. He found both groups to have high mean scores on TOUS but no significant difference between the groups.

Another study of prospective science teachers conducted by Craven[22] compared college science teacher candidates with non-science teacher candidates, college freshman, and in-science teachers of science. Although he found some differences between the various groups on the Test On Understanding Science, the results are questionable because of the ceiling effect of the very high mean scores.

Sorensen[23] compared a laboratory-centered high school biology program with a lecture-centered program in the Salt Lake City School

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[20] Donald F. McFarland, " Implementation of the Chemical Education Material Study in a Large Urban School System." Paper presented at the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

[21] M. H. Bruce, "A Preliminary Study of Early Career Selection Factors in Prospective Science Teachers", Paper presented at the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

[22] Gene F. Craven, "Critical Thinking Ability and Understanding of Science by Science Teacher-Candidates at Oregon State University." Paper presented by the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

[23] LaVar L. Sorenson, "Change in Critical Thinking Between Students in Laboratory-Centered and Lecture-Demonstration-Centered Patterns of Instruction in High School Biology." Paper presented by the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

District. He found significant gains between the pre and post test scores on the TOUS and that these gains differed significantly for the two treatment groups. He also found that the TOUS scores were not significantly related to mental ability.

Snider[24] used the TOUS in a study of seventeen high schools physics teachers using the Flanders interaction analysis of teaching patterns. He found the class mean gains on the TOUS test between pre and post test administration to be essentially zero.

Hukins,[25] in a study of the achievement of science objectives, used the TOUS test to measure scientific attitude. The TOUS test was one of a battery of tests he administered to students enrolled in Science 10 in the Edmonton Alberta Canada School. The TOUS scores correlated very highly with verbal ability but quite low on reasoning and attitudes.

From the survey of the literature, it is apparent that the Test On Understanding Science has been used in a variety of research projects in the last few years. Most studies, however, utilized the TOUS instrument to determine differences in science understanding between small groups involved in an experimental program over a relatively short period.

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[24] Ray M. Snider, "A Project to Study the Nature of Physics Teaching Using the Flander Method of Interaction Analysis", Paper presented by the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

[25] Austin A. Hukins, "A Factorial Investigation of Measures of Achievement of Objectives in Science Teaching", Paper presented at the National Association for Research in Science Teaching Annual Meeting, Chicago, Illinois, February 19-21, 1966.

The data utilized in this study was previously collected in conjunction with two other separate research projects supported by the investigators and Kansas State Teachers College. Hence, the population is not identical between the physics data and the chemistry data. In fact, student test scores represented in either one of the two subject classifications are mutually exclusive.

The physics data was collected during the 1963-64 school year by Crumb and the chemistry test data was essentially all collected by Abegg during the 1964-65 school year. School classroom and community visits, and teacher interviews were completed as part of this project. Participating schools were selected from lists of schools known to be offering the new curriculum courses in either chemistry or physics and from those schools offering standard chemistry and physics courses on a regular basis taught by experienced teachers. To be among the schools selected the chief school officer, the building supervisor or principal, and the teacher had to agree to allow the investigators freedom to complete the testing sequence and to conduct a series of interviews with staff and students in the school. In addition, since no first year teachers were included, many schools were thus excluded due to the criteria of school selection. In subsequent sections the characteristics of the physics sample and the chemistry sample are more completely discussed.

IV Procedures

Selection of the Testing Instruments. The research design of the other studies indicated that intelligence and science background might be possible factors influencing understanding of science. Several instruments used to measure these factors were carefully scrutinized before final selection.

Background in Science. After reviewing several tests, the Iowa Test of Educational Development, Test 2, Background in Natural Science,[26] was selected on the basis of its ability to measure student experiences and achievement in natural science. The class length version of this test, Form Y3s, requires forty minutes of student working time. This test, according to Lindquist,[27] was:

> Designed to measure students' general knowledge and understanding of scientific terms and principals, of common natural phenomena in industrial application and the place of science in modern civilization.

The test is widely used and norms are available for grades nine through twelve (9-12).[28]

General Intelligence. The Otis Quick Scoring Mental Abilities Test[29] was selected as the instrument to measure general intelligence from those reviewed because it could be administered within a class period and is a widely used and accepted research instrument.[30] The Gamma form Em, designed for high school and college, requires only thirty minutes

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26. Published in 1959 by Science Research Associates, Inc., 259 East Erie Street, Chicago 11, Illinois.

27. E. F. Lindquist, General Manual for the Separate Booklet Form of the Iowa Tests of Educational Development, (Chicago: Science Research Associates, Inc., 1959).

28. Science Research Associates, op. cit.

29. The Otis Test was copyrighted in 1954 and is published by Harcourt Brace and World, Inc., Saddle Brook Industrial Park, Saddle Brook, New Jersey.

30. Oscar K. Boros (Editor), The Fifth Mental Measurements Handbook, (Highland Park, New Jersey: The Gryphon Press, 1959) pp. 496-500.

of student working time.

Understanding Science. There is only one known reliable instrument available to assess the areas of science understanding as outlined earlier. This instrument known as the Test On Understanding Science,[31] contains sixty (60) items designed to measure three aspects of science understanding:

Scale 1 - Understanding about the scientific enterprise (18 items)
Scale 2 - Understanding about scientists (18 items)
Scale 3 - Understanding about the methods and aims of science (24 items)

To further illustrate the scope of the test, the editors list the following items as being included in the test.[32]

1. The human element in Science
2. Distinction between science and technology
3. Communication among scientists
4. International character of science
5. Interactions of science and society
6. Generalizations about scientists as people
7. Unfounded stereotypes about scientists
8. Institutional pressures on scientists
9. Scientific attitude
10. Scientific method
11. Tactics and strategy of sciencing
12. Nature of scientific theories and models
13. Aims of science
14. Function of scientific societies
15. Importance of instruments in science
16. Unity and interaction of the sciences

Methods of Data Collection

As indicated earlier, the data used in this research was collected in conjunction with two other studies. The method of collection of the test data used differed only slightly from the physics sample to the

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[31] Published by Educational Testing Services, Princeton, New Jersey, Form W was copyrighted 1961 by W. W. Cooley and Leo E. Klopfer.

[32] Refer to descriptive material on this instrument published by Educational Testing Services, Princeton, New Jersey.

chemistry sample. All criterion tests (TOUS) used were identical and were administered under the direction of the project directors. All of the physics and chemistry sample were administered the criterion pre-test during the first six-weeks of school. At the end of one semester of study, the physics group was administered a mid-year criterion post-test. Within the last six-weeks of school, both the physics and chemistry groups were adminstered criterion post-tests. The Otis Mental Ability test and the Iowa Test of Educational Development were given at the convenience of the teacher and school program between the administrations of the criterion tests. The testing took place during the 1963-64 school year for the physics group and during the 1964-65 school year for the chemistry group. Only the pre-test and mid-year criterion post-test scores for the physics group are used in this research.

The test scores and other data collected for each student was entered on a master-log form and punched on IBM cards.

Methods Used In Data Analysis

The data punched on IBM cards was verified by a second keypunch operator and then double-checked for any inconsistencies. A program specifically revised for an IBM 1621 computer with a 20K memory core was used to determine the mean, standard deviation, and correlation coefficient for each of the variables.

IBM library programs (revised form) were used to determine the homogeneity of variance, t-test for the difference in means of the subgroups, and analysis of covariance by subgroups.

As a result of the manner in which the data was collected, it was also possible to compile the TOUS scores by classes and with the use of an analysis of variance (nested design with cross-classification) control for the individual difference of each teacher. This analysis was accomplished on the IBM 1620 computer with the use of two programs specifically written by the authors.

PART TWO

ANALYSIS OF THE DATA AND FINDINGS

I. Description of Physics Sample

Stratification of teachers and classes. The teacher population consisted of thirty-three individual physics teachers who were teaching one or more physics classes. In two cases teachers were selected who taught one or more PSSC physics classes and one or more traditional physics classes. These two teachers thus carry a double identity when the population is stratified by the course being taught. The seventy-five classes of the thirty-three teachers in the study composed the initial physics class population. This population was stratified by type of course, either PSSC physics or traditional physics, and whether or not the teacher of the course had participated in a special study program in teaching PSSC physics.

Table 1 presents the initial sample of classes and teachers stratified as indicated.

In order to avoid a lengthy description of the subgroups of the sample hereafter, the codification below will be used.

Subgroup Code	Subgroup Description
P-P	Identifies those students enrolled in PSSC Physics taught by teachers who have completed a special study program in the teaching of PSSC physics.
P-T	Identifies those students enrolled in PSSC Physics taught by teachers who have completed no special study program in the teaching of PSSC physics.
T-P	Identifies those students enrolled in traditional physics taught by teachers who have completed a special study program in the teaching of PSSC physics.
T-T	Identifies those students enrolled in traditional physics taught by teachers who have completed no special study program in the teaching of PSSC physics.

TABLE 1

STRATIFICATION OF PHYSICS SAMPLE

Subgroup Code	Course	PSSC Training	Number Teachers	Number Classes	Number Schools
P-P	PSSC	yes	10	22	10
P-T	PSSC	no	3	6	3
T-P	Trad.	yes	8	22	8
T-T	Trad.	no	14	25	13
		Totals	35*	75	34**

* The number of teachers in the study is 33 but two teach both PSSC physics and traditional physics.

** The number of schools in the study is 29 but more than one type of course is identified in one school.

TABLE 2

IDENTIFICATION OF PHYSICS SAMPLE BY COMMUNITY POPULATION

Community Population*	Number of Schools	Number of Teachers	Classes in Subgroup				
			P-P	P-T	T-P	T-T	Total
Over 100,000	19	23	18	6	20	19	63
9,000 to 100,000	1	1	0	0	0	3	3
4,000 to 8,999	3	3	1	0	0	2	3
1,500 to 3,999	4	4	1	0	1	2	4
Below 1,500	2	2	1	0	0	1	2
Totals	29	33	21	6	21	27	75

* Arbitrary population ranges are used in this table to fit the communities from which the sample was drawn.

The fact that the major portion of the physics class sample was drawn from the more populous communities is illustrated by the data in Table 2. Eighty-three percent of the seventy-five classes were from schools in communities with populations greater than 100,000. The physics class sizes represented in the population as shown in Table 3 range from seven to thirty-seven with the mode falling in the twenty to twenty-four size group.[1]

In Table 4 is presented the distribution of the physics pupil population by class size. No attempt was made to obtain classes such that a normal distribution of pupils would be found over the range of class sizes, although large numbers of extremely small classes was avoided in the interest of economy of time and effort in obtaining data. The data in Table 4 compare favorably with that of Table 3 due to the physics class size mode of the student population distribution (twenty-two to twenty-four).

Since the PSSC program only recently appeared in the high school curriculum, it was not possible to obtain teachers with extensive experience teaching the subject. Table 5 verifies this as it indicates that a disproportionate share of the teachers experienced in teaching the subject included in this study belong to the traditional physics subgroup. Because of the requirements of teaching experience used in the selection process, many of the PSSC physics teachers selected could present numerous years of classroom experience prior to teaching PSSC physics. When the teacher population was examined in terms of total years of teaching experience

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[1] The mean class size was 22.6 students.

TABLE 3

IDENTIFICATION OF PHYSICS SAMPLE BY CLASS SIZE

Class Size	Number of Classes By Subgroup*				Class Totals	Per Cent
	P-P	P-T	T-P	T-T		
7-9	1	0	1	1	3	4.00
10-12	0	1	0	2	3	4.00
13-15	1	2	0	0	3	4.00
16-18	3	1	4	6	14	18.68
19-21	3	1	0	3	7	9.30
22-24	9	0	4	5	18	24.00
25-27	1	0	6	3	10	13.41
28-30	1	0	2	5	8	10.60
31-33	2	1	0	2	5	6.67
34-up	0	0	2	2	4	5.34
Totals	21	6	19	29	75	100.00

* For meaning of symbols, see page 17.

TABLE 4

STUDENT POPULATION OF PHYSICS SAMPLE BY CLASS SIZE

Class Size**	Number of Students By Subgroup*				Class Totals	Per Cent
	P-P	P-T	T-P	T-T		
7-9	7	0	6	5	18	1.4
10-12	0	12	0	18	30	2.3
13-15	11	17	0	0	28	2.2
16-18	43	11	47	85	186	14.6
19-21	44	14	0	47	105	8.4
22-24	158	0	70	91	319	25.0
25-27	22	0	124	55	201	15.7
28-30	27	0	31	102	160	12.5
31-33	48	24	0	45	117	9.2
34-up	0	0	58	53	111	8.7
Totals	360	78	336	501	1275	100.0

* For meaning of symbols, see page 17.

** The class size refers to all students enrolled in the class but the number of students in each subgroup presented in the table refers only to those completing all phases of the study testing program.

and then stratified, the information, presented in Table 6, was determined. This table indicates that more than half (61.5 percent) of the PSSC teachers had more than five years of experience in the classroom. This group of teachers of PSSC physics then compares favorably with the 68.5 percent of traditional physics teachers who had more than five years experience. Since several physics teachers had two or more classes it was possible that the classes still would not be distributed in a suitable manner among the experienced and inexperienced teachers. For example it was found, as shown in Table 7, that only seven of the twenty-seven PSSC classes were taught by teachers with four or more years experience in teaching the subject, while thirty-five classes (73 percent) of the forty-eight traditional physics classes were taught by teachers with four or more years experience teaching the subject. As shown in Table 8, sixteen PSSC classes (58.3 percent) of traditional physics were taught by teachers having more than five years of classroom experience. Yet, thirty-seven classes (77 percent) of traditional physics were taught by teachers with more than five years experience.

Stratifications of the physics pupil population. The sample student population selection was influenced by many factors, some of them beyond the control of the investigator.

In Table 9 stratification and sex of the physics student population is presented. It can be seen that only a relatively small percent of the students included in the study were female. In the physics sample there were six hundred thirty-two in grade eleven and six hundred forty-two in grade twelve, a very uniform distribution between these two grades. The stratification of the student

TABLE 5

PHYSICS TEACHERS CLASSIFIED BY YEARS TEACHING SUBJECT INCLUDED IN STUDY

Years Teaching	Teachers Classed By Subgroups*				Totals
	P-P	P-T	T-P	T-T	
2-3	9	2	3	6	20
4-5	1	1	1	3	6
6-7	0	0	1	0	1
8-9	0	0	2	0	2
10-up	0	0	1	5	6
Totals	10	3	8	14	35

* For meaning of symbols, see page 17.

TABLE 6

PHYSICS TEACHERS CLASSIFIED BY TOTAL TEACHING EXPERIENCE

Years Teaching	Teachers Classed By Subgroups*				Totals
	P-P	P-T	T-P	T-T	
2-3	1	1	0	6	8
4-5	2	1	0	1	4
6-7	1	1	3	2	7
8-9	0	0	2	0	2
10-up	6	0	3	5	14
Totals	10	3	8	14	35

* For meaning of symbols, see page 17.

TABLE 7

PHYSICS CLASS DISTRIBUTION PRESENTED BY EXPERIENCE OF TEACHERS IN SUBJECT INCLUDED IN STUDY

Years Experience	Number of Classes By Subgroups*				Totals By Experience
	P-P	P-T	T-P	T-T	
2-3	16	4	3	10	33
4-5	5	2	1	5	13
6-7	0	0	2	0	2
8-9	0	0	8	0	8
10-up	0	0	5	14	19
Totals	21	6	19	29	75

* For meaning of symbols, see page 17.

TABLE 8

PHYSICS CLASS DISTRIBUTION PRESENTED BY TOTAL EXPERIENCE OF TEACHERS

Years Experience	Number of Classes By Subgroups*				Totals By Experience
	P-P	P-T	T-P	T-T	
2-3	1	2	0	10	13
4-5	6	2	0	1	9
6-7	3	2	1	3	9
8-9	0	0	4	0	4
10-up	11	0	14	15	40
Totals	21	6	19	29	75

* For meaning of symbols, see page 17.

population presented by the total years of experience of the teachers who taught them is presented in Table 10. Nearly 60 per cent of those in the

TABLE 9

STUDENT POPULATION PRESENTED BY SEX

Subgroup Code*	Male No.	Male Per Cent	Female No.	Female Per Cent	Total No.
P-P	312	86.5	48	13.5	360
P-T	66	84.5	12	15.5	78
T-P	298	88.6	38	11.4	336
T-T	443	88.5	58	11.5	501
Totals	1119	87.7	156	12.3	1275

* For meaning of symbols, see page 17.

study population were taught by teachers with ten or more years of experience, and less than 16 percent had teachers with fewer than four years of classroom work. A comparison between the P-P and T-T subgroups reveals little difference between the percentage of students of the respective groups being taught by teachers with ten or more years of experience. (Compare 56.5 percent with 55.6 percent). Likewise, for the same two groups, little difference exists between the percentage (32.7 percent compared with 35.6 percent) of students of the respective groups that were taught by teachers with five or less years of experience. The P-T and T-P subgroups differ radically from one another and from the other two groups in the distribution of students among teachers with different ranges of years of teaching experience. The information in Table 10 is quite important as it shows that the information in Table 8 (distribution of sample class population by teacher experience) does not clearly indicate how the pupils were distributed among the teachers having various ranges of years of teaching experience.

TABLE 10

PHYSICS STUDENT SAMPLE PRESENTED BY TOTAL EXPERIENCE OF TEACHERS

Years of Experience	P-P Subgroup*		P-T Subgroup*		T-P Subgroup*		T-T Subgroup*		Study Sample	
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent
2-3	7	1.9	44	56.5	0	0.0	168	33.6	219	17.2
4-5	111	30.8	20	25.6	0	0.0	10	2.0	141	11.0
6-7	39	10.8	14	17.9	6	1.8	44	8.8	103	8.1
8-9	0	0.0	0	0.0	81	24.1	0	0.0	81	6.3
10-up	203	56.5	0	0.0	249	74.1	279	55.6	731	57.4
Totals	360	100.0	78	100.0	336	100.0	501	100.0	1275	100.0

* For meaning of symbols, see page 17. NOTE: This table should be read as follows: eighty-one of the students in the T-P subgroup were taught by teachers having years of experience in the range of eight to nine years. These eighty-one physics students represent 24.1 per cent of the T-P subgroup and 6.3 per cent of the physics sample.

II. Analysis of Test Results of Physics Sample

A preliminary study of the results of total scores by the physics sample indicated that physics students showed a significant gain in understanding science over the period of one semester as well as over the total school year.[1] However, in the analysis of these test results no attempt was made to control for teacher or class variance.

In order to assess the contribution of the class and teacher characteristics as they may influence science understanding, an analysis of variance-nested design was utilized for treatment of the criterion test results for the physics sample collected at the beginning and at the end of the first semester.

Physics-Nested Analysis

The instruction in physics identified in each of four groups, depended upon the course materials used and special training of the teacher. It seemed appropriate, therefore, to analyze the effects of the treatments of each of the four groups by class rather than individuals. By using this analysis of variance, the difference between the classes of a teacher and the difference between teachers within treatments can be identified. This same analysis provides evidence on the gain in understanding science between the pre-test and post-test if a cross-classification is applied to the nested group. The means for the TOUS scores of each physics class and the design for the nested analysis are presented in the Appendix.

The results of the nested analysis of variance for the physics group is presented in Table 11.

The F values from Table 11 provide the following information.

---

[1] Crumb, Glenn H., "Understanding of Science in High School Physics," Journal of Research in Science Teaching, 3:246-250, September, 1965.

TABLE 11

ANALYSIS OF VARIANCE -- NESTED DESIGN COMPARING PRE AND POST TOUS MEANS FOR THE PHYSICS GROUPS*

Source	df	Sum of Squares	Mean Square	F	p*
Treatment	3	527.33	175.77	8.31	.001
Teacher by Treatment	17	359.78	21.163	0.25	no
Classes by Treatment	39	329.185	84.406	163.26	.001
Pre-Post (TOUS)	1	51.726	51.726	44.90	.01
Treatment x Pre-Post	3	3.075	1.025	0.89	no
Teacher x Pre-Post	17	19.586	1.152	2.23	.05
Class x Pre-Post	39	20.170	0.517		

* See page 428 Scheffe

PERTINENT TABLE VALUES OF F

df	P=.05	P=.01
17,3	3.20	5.18
17,40	2.11	2.92
40,40	1.69	2.11
1,17	4.45	8.40
3,17	8.69	26.83
40,16	1.90	2.49

1. Physics students, on the average, did show a significant gain in understanding science regardless of teacher or treatment. ($F_{1,17} = 44.9$)

2. There are very significant differences in the gain in understanding science between classes of physics students even when the same teacher directs the class. ($F_{39,39} = 163.26$)

3. The amount of gain in understanding science by the physics students depends upon the teacher regardless of the treatment. ($F_{17,39} = 2.228$)

4. When the physics classes were grouped by teacher conducting the class within treatment, no significant difference was found in the understanding of science developed during the experimental period. This statement ($F_{17,39} = 0.251$) holds within each of the four physics subgroups.

5. Without regarding variance contributed by teacher of classes, a very significant difference in understanding science was found over the period due to the treatment alone. ($F_{3,17} = 8.31$)

6. Significant differences were not found in gain between pre-test and post-test due to the treatment when factors of teacher and class differences are considered. ($F_{3,17} = 0.889$)

Analysis of TOUS Subscores

The test on Understanding Science provides three identifiable subscores previously discussed. The reader is cautioned that the analysis of students' subscores must be placed in the proper perspective as the reliability of the subscores cannot be expected to be equal to that of the entire test of which they are a part.

For this analysis the physics subgroups were pooled into two categories-- one for PSSC physics and one for the traditional course in physics.

Analysis of the gains by the physics pupils over the period of one semester on each of the three scales of the TOUS instrument was conducted to see if each of the scales contributed to the total scores on TOUS.

The hypotheses tested were:

> There is no significant gain in understanding about the scientific enterprise (Scale I) as measured by the criterion instrument among students studying high school physics for one semester.
>
> There is no significant gain in understanding about scientists (Scale II) as measured by the criterion instrument among students studying high school physics for one semester.
>
> There is no significant gain in understanding about the methods and aims of science (Scale III) as measured by the criterion instrument among students studying high school physics for one semester.

The means on each of the three scales of the TOUS are presented in Table 12 along with the calculated value of t for the difference between the pre and post-test means for the pooled physics sample. Each value of t is highly significant, thus the null hypotheses are rejected with considerable confidence where the entire physics sample is concerned.

A within physics sample analysis was made to determine whether the students studying PSSC physics and those studying traditional physics each made significant gains on the three scales of TOUS. Essentially the same null hypotheses were tested for each of the two subsamples of the physics group.

The means of the PSSC and traditional physics students on Scale I of TOUS are presented in Table 13 along with the calculated value of t for the difference between pre-test and post-test means. This table shows a highly significant value of t, thus the null hypotheses concerning gain in understanding about the scientific enterprise (Scale I) is rejected

TABLE 12

ANALYSIS OF POOLED PHYSICS SUBGROUP TOUS SUBSCORES (SCALE I, II, III)

Scale	df	Pre-Test Mean	Post-Test Mean	t	p
I	1274	10.95	11.72	7.29	<.001
II	1274	11.76	12.11	3.60	<.001
III	1274	12.11	13.11	7.95	<.001

TABLE 13

ANALYSIS OF TOUS SCALE I SUBSCORES WITHIN THE PHYSICS SUBGROUP

Subgroup	df	Pre-Test Mean	Post-Test Mean	t	p
PSSC	437	11.56	12.39	4.71	<.001
Traditional	836	10.63	11.37	5.74	<.001

TABLE 14

ANALYSIS OF TOUS SCALE II SUBSCORES WITHIN THE PHYSICS SUBGROUP

Subgroup	df	Pre-Test Mean	Post-Test Mean	t	p
PSSC	437	12.20	12.47	1.70	no
Traditional	836	11.52	11.93	3.29	<.01

for each of the two subgroups with considerable confidence.

Scale II means for the PSSC and traditional physics students on the pre-test and post-test are presented in Table 14 along with the calculated value of t for difference between means. The calculated value for t using the means of the traditional physics group is sufficiently large as to be significant at the .01 level of confidence, thus the null hypotheses concerning gain in understanding about scientists is rejected with confidence for this group. This same null hypotheses is not rejected for the PSSC physics students as the calculated value of t fell below that needed for rejection at the .05 level.

TABLE 15

ANALYSIS OF TOUS SCALE III (SUBSCORES) WITHIN THE PHYSICS SUBGROUP

Subgroup	df	Pre-Test Mean	Post-Test Mean	t	p
PSSC	874	13.08	14.19	5.33	.001
Traditional	836	11.60	12.54	6.23	.001

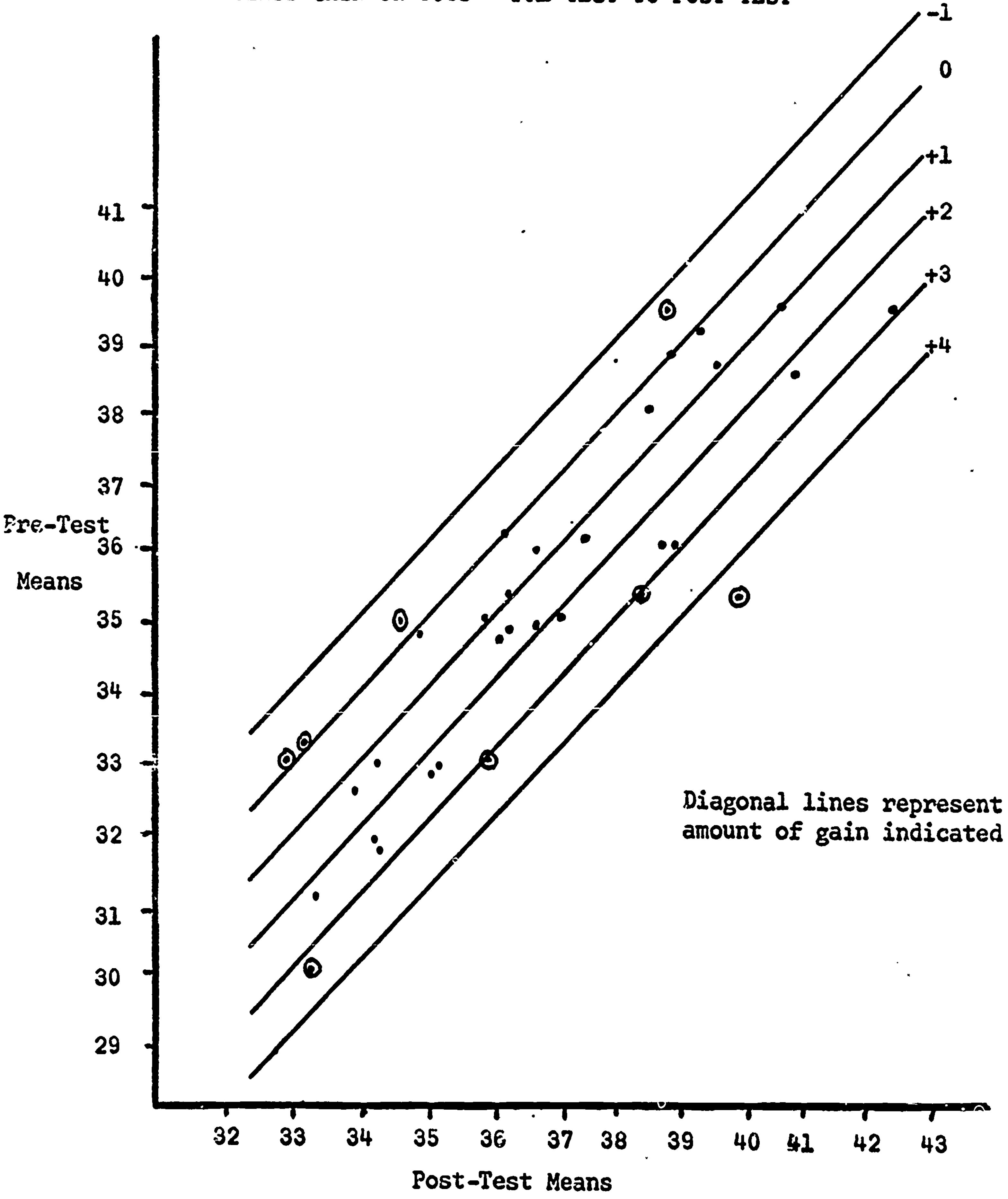
The means and calculated values of t for difference between means for the PSSC physics and traditional physics subgroups are presented in Table 15. Each calculated value of t indicates that a very significant difference exists between the means thus, the null hypotheses dealing with understanding about the methods and aims of science is rejected with considerable confidence for each of the two physics subgroups.

III. Results of Interviews with Physics Teachers and Physics Classroom Observations

After the tests results for the midyear test had been compiled it was possible to determine which teachers' classes showed the greatest gain on the criterion test, TOUS, and which ones showed the least. Figure 1 presents presents the TOUS means plotted with the pre-test means on the ordinate and the post-test means on the abscissa. This graphic method of looking at the data was used in determining which teachers' classes would be visited. By drawing appropriate lines with a slope of positive one it was possible to obtain ranges of gain on the TOUS between the pre-test and mid-year test. Four teachers near the top in gain and four near the bottom in gain were selected for visitation. These eight teachers' class means are indicated in Figure 1 by a circle about the data point. Three of the four teachers whose classes showed the highest gain in mean score on TOUS taught PSSC physics, the other one had completed the special training program. Of the four teachers whose classes showed lowest mean gain, one taught PSSC physics, the remainder taught the traditional physics. One of the latter three teachers had completed the special program in teaching PSSC physics.

FIGURE 1

MEAN CLASS GAIN ON TOUS - PRE-TEST TO POST-TEST



The purpose of the visits and interviews, was to obtain information about the methods used in teaching the courses. The results of the interviews with the eight teachers, including the questions asked and the responses obtained, are presented in Table 16. The order of the questions presented is that used in the interview.

<u>Analysis of results of interviews.</u> In examining the tabulated results of the interviews an attempt was made to note differences of a marked nature in order that differences in patterns might be isolated. The following items seem worthy of attention.

1. The four teachers whose classes showed highest mean gain on TOUS between pre-test and post-test made use of graphic procedures in presenting and analyzing experimental data. The teachers of the four classes with the lowest mean gain on TOUS between pre-test and mid-test frequently substituted a lecture-demonstration for a laboratory exercise; while the teachers of the high mean gaining classes did not.

2. The four teachers with classes that showed the lowest gain on TOUS between pre-test and mid-test reported that they spent a larger proportion of the time on class recitation of reading assignment than was reported by the teachers with classes which had highest mean gain on TOUS between pre-test and mid-test.

3. Although all eight teachers reported the use of out-of-class problem assignment, the teachers whose classes showed the lowest gain on TOUS between pre-test and mid-test reported a higher incidence of this practice than did the teachers whose classes showed highest gain between the two tests.

4. The use of technological applications in class discussion was reported to occur with a higher incidence in the classes showing the lowest mean gain on TOUS between pre-test and mid-test than in the classes having the higher mean gain on TOUS in the same testing sessions.

TABLE 16

TEACHER INTERVIEW QUESTIONS AND RESPONSES

Questions	Responses By Class Gain	
	High	Low
1. How do you introduce a new topic? By laboratory	3	1
By reading and problem assignment	1	2
By class discussion or other techniques	0	varies
2. How closely do you follow a text? Very closely	4	3
Change sequence of topics	0	1
3. Do you use a workbook, with exercises, that accompanies the textbook? Yes	0	3
No	4	1
4. Do you use the laboratory manual or guide that accompanies the textbook? Yes	3	2
No	1	2
5. Do you use a pre-laboratory discussion? Yes	4	2
No	0	2
6. Is there a post-laboratory discussion, that is, do you discuss the laboratory experiment or exercise to any extent after it has been completed? Yes	2	1
No	2	3
7. Are students allowed to do calculations pertaining to their laboratory experiments during the period allotted for laboratory experimentation? Yes	2	1
No	2	3
8. Do you require a formal write-up? Yes	2	2
No	2	2
9. Are graphs used in presenting data and in its analysis? Yes	4	1
No	0	3
10. Are standardized tests given? Yes	3	3
No	1	1
11. Are standardized tests used in determing the grades of your students? Yes.	0	2
No	4	2
12. Do you frequently substitute lecture-demonstrations for laboratory exercises? Yes	0	4
No	4	0

TABLE 16 (continued)

Questions	Responses By Class Gain	
	High	Low
13. Does problem solution precede or follow laboratory work?		
Precede	1	2
Follow	2	1
Varies	1	1
14. Is the regularity of the behavior of nature stressed in your course?		
Yes	2	0
No	2	4

The responses to question 15 were recorded and later summarized by assigning values of: High = 3; Medium = 2; Low = 1. The sum of the responses was then found and a mean value calculated. The mean value is presented in the table by class gain.

15. In terms of your class, what proportion of time is spent with the following? (rate incidences on the basis of 5 classes per week, with 4-5 incidences per week being high, 3 being medium and 1-2 incidences being low).		
a. Lecture demonstration	1.75	2.50
b. Recitation of reading assignment	1.50	2.50
c. Problem solution in class	1.75	2.00
d. Problem solution at home	2.00	3.00
e. Laboratory time, including both pre and post discussion periods	2.50	1.75
f. Technological applications	1.25	2.25
g. Films	1.50	2.00

Responses to question 16 were written out in the presence of the teachers being interviewed and are thus presented in quotation form. Each entry is to be identified with a different teacher.

16. What do you do in your class that you think may be unique or different from other classes in the same Subject?

TABLE 16 (continued)

A. Responses from teachers of high mean gain classes:

a. "I use student study guide sheets to help the students in their learning process."

b. "I follow the same routine semester by semester, but I make an effort to keep my own enthusiasm up."

c. "I encourage students to investigate laboratory type projects on their own. Students are not rebuked when they challenge the subject authority I represent, as long as they can present sound arguments of their own."

d. "I use the laboratory very extensively. I rely upon it and the problems to carry the course."

B. Responses from teachers of low mean gain classes:

a. "This course is a practical course for everyday life as well as being a college prep course. I use a lot of 'math'; 'trig' is needed. Because of the poor text that we use, the continuity of the subject is lacking."

b. "I stay on the topic until the students understand the material, instead of trying to cover the book."

c. "I place the students pretty much on their own, both in the laboratory and in working out the study exercises."

d. "I do quite a few lectrue-demonstrations in place of 'lab'. I prepare overlays of the data that would be obtained in an experiment, then discuss it with the class."

17. How typical was today's class session:

	Responses By Class Gain	
	High	Low
Typical . . .	3	4
Students slow to respond . . .	1	0

A second phase of the visit to the classrooms of the eight teachers selected dealt with evaluation of the teachers performance during the time the class was in session. The form used was one with which the investigator was familiar as it was used by him in evaluating student teacher performance throughout the year during which the study was conducted. Although the investigator knew at the time of the visit to the classroom whether the teacher's classes ranked as high or low in gain on TOUS, over one semester the bias was recognized and an effort was made to be objective in the evaluation. Each teacher was rated on the basis of a scale of "very poor," "poor," "fair," "good," or "very good," then the scale assigned numerical values 1 through 5 respectively. The scores on each item were summed and a mean was determined for each of the two groups of four teachers in the high and low category. The results of this procedure are presented in Table 17. A column headed, "COMMENT" which appeared on the form used in the evaluation is not presented as the comments recorded during the actual evaluation contained entries of a confidential nature that could be identified with a particular teacher and course.

Analysis of results of observations. No attempt was made to analyze statistically the results of the classroom observations. Rather the investigator found the following patterns which were considered worthy of reporting. The findings based upon these observations and the interviews must be considered in the light of the limited amount of time spent in observations, the possible bias of the observer and the limitations of the technique used. That differences existed was apparent to the investigator, although

TABLE 17

OBSERVED PERFORMANCE OF TEACHERS OF CLASSES WITH MAXIMUM OR MINIMUM GAIN ON TOUS

Item Evaluated	Mean Performance Of Teachers By Class Gain on TOUS High	Low
PERSONAL QUALITIES		
Appearance	4.25	4.75
Poise	4.00	4.50
Posture	4.75	4.25
Resourcefulness	4.25	3.00
Voice	4.75	4.75
English Usage	4.50	4.50
Enthusiasm	4.75	3.00
Sense of Humor	4.50	3.25
TEACHING METHODS		
Methods used effectively	4.50	2.50
Careful Planning and preparation evident	4.75	2.75
Information organized effectively	4.25	3.00
Use of illustrative and visual materials (graphic anlaysis, chalkboard, etc.)	5.00	3.00
New Methods and Approaches used	4.75	3.25
TEACHING KNOWLEDGE		
General knowledge	4.50	3.75
Mastery of subject matter taught	3.75	3.25
Up-to-date	3.75	2.00
CLASSROOM MANAGEMENT		
Students respond favorably	4.25	2.75
Student control maintained	3.75	3.75
Students share in presentation	4.50	2.00
Good eye contact	4.50	3.00
Wise use of class time	3.50	3.25
TEACHING RESULTS		
Effective in achieving objectives	4.25	2.00
Individual differences provided for	4.00	1.75
Interest at a high level	4.75	2.75
Skills and attitudes developed	4.00	1.75
Subject matter related to previous presentation	5.00	4.50

the significance of these differences was not established.

Three of the four teachers whose classes showed highest mean gain on TOUS over the period of the first semester taught PSSC physics. The other teacher used the PSSC laboratory guide where equipment limitation permitted, and supplemented the manual where it did not. Of the four teachers whose classes showed the lowest mean gain on TOUS over the first experimental period, only one taught PSSC physics. The teacher of PSSC physics and one other teacher had completed the special program in teaching PSSC physics while the other two had not. The four teachers whose classes showed the lowest mean gain on the criterion test (TOUS) over the one semester period scored consistently lower in performance than did the four teachers whose classes showed the highest mean gain on TOUS on all items but one under the headings of "Teaching Methods"; "Teaching Knowledge"; "Classroom Management"; and "Teaching Results." The greatest differences in teacher performance during the evaluation by the investigator were found to be in: "Students share in presentation" (2.50); and "Effective in achieving objectives" (2.50). Slightly lesser differences (2.25 points) in performance were shown in: "Individual differences provided for" and "Skills and attitudes developed." There were two points of difference in performance as viewed by the investigator on the factors of: "Methods used effectively"; "careful planning and preparation evident"; and "Use of illustrative and visual materials (graphic analysis, etc.)"

IV. Description of Chemistry Sample

The chemistry sample was composed of all the students in the classes of eighteen different high school chemistry teachers. Since two of the teachers were teaching classes that fit into two different categories when the classes were separated by type of program, they were assigned to both categories. Table 18 presents the number of teachers, classes and schools involved in the chemistry sample.

The data in table 19 shows the number of students involved in each of the groups identified in the study. The number of students completing the first test session (Pre-TOUS) represents essentially all the students enrolled in the chemistry classes at the beginning of the school year. By comparing these enrollment numbers with the enrollment numbers for the students completing the course, it can be seen that only seventy-eight (78) students dropped out of the chemistry classes during the school year. Teachers indicated that most of these students moved from the district during the school year.

The number of students completing all phases of the test program was reduced by an additional ninety-seven (97) students. This number was not considered to be too large when it was taken into account that each student must have completed four tests in order to be included in the final sample. Absences from school on the date of testing was the principal cause for the students missing one or more of the tests. The total of one thousand and nine (1009) students was used in all subsequent analysis and was assumed to be representative of the initial group of one thousand one hundred and eighty four (1184) enrolled in the fifty-four chemistry classes.

The number of students in each group separated by sex is presented in Table 20. Since one of the schools in the CBA group was a girl's academy,

TABLE 18

NUMBER OF TEACHERS, CLASSES, AND SCHOOLS IN EACH GROUP OF THE CHEMISTRY SAMPLE

Group	Number Teachers*	Number Classes	Number Schools**
STAN	11	29	10
CBA	4	8	3
CHEM	5	17	5
TOTAL	20	54	18

*Although there were only eighteen different teachers, two of the teachers had classes that fit into two of the group classifications.

**Although there were only sixteen schools involved in the study, two schools fit two of the group classifications.

TABLE 19

CHEMISTRY SAMPLE COMPARED TO POTENTIAL SAMPLE FROM CHEMISTRY CLASSES OF PARTICIPATING SCHOOLS

Group	Number Completed Pre Test	Number Completed Course	Number Completed All Tests
STAN	610	568	511
CBA	187	176	164
CHEM	387	362	334
TOTAL	1184	1106	1009

the number of girls in the CBA group was proportionately larger than in either of the other two groups. The proportion of girls to boys in the other two groups was approximately two to three and was perhaps more nearly what one would expect in the chemistry classes of most coeducational schools.

TABLE 20

NUMBER OF MALE AND FEMALE STUDENTS IN EACH GROUP OF THE CHEMISTRY SAMPLE

Group	Male	Female	Total
STAN	311	200	511
CBA	65	99	164
CHEM	199	135	334
TOTAL	575	434	1009

Grouped by grade level in school, the chemistry sample distribution is shown in Table 21. The largest number of students were in grade eleven as might be expected. Only one school in the study placed chemistry at the twelfth grade in its recommended sequence of courses. Since most schools required a previous or concurrent enrollment in second year algebra for enrollment in chemistry, students normally were not eligible until grade eleven or twelve. Several schools encouraged acceleration in mathematics and science, hence there was a surprising number of tenth grade students enrolled in chemistry.

TABLE 21

NUMBER AND PER CENT OF CHEMISTRY SAMPLE PRESENTED BY GRADE IN SCHOOL

	Grade			
Group	10	11	12	Total
STAN	37	286	188	511
CBA	16	53	95	164
CHEM	45	142	147	334
TOTAL	98	481	430	1009
PER CENT	9.7	47.6	42.6	100

Students completed a questionnaire on the science courses they had completed prior to enrollment in chemistry. The data in Table 22 summarizes the responses to this questionnaire. More than ninety per cent of the students had completed a course in biology whereas only about thirteen per cent had completed a course in physics.

During visits with each of the teachers, data was collected on the years experience, background and preparation. Every teacher in the chemistry sample had participated in some type of institute program during the previous five years. All of the CHEM and CBA teachers had some training in the use of the specific materials they were using. Several of the teachers in the STAN group had some training in the use of CHEM or CBA materials even though they were not using these materials.

The median years of teaching experience was six years with a range from 2 - 19 years experience and each teacher had been teaching in their present position for at least one year before the study was conducted.

TABLE 22

NUMBER AND PER CENT OF CHEMISTRY STUDENTS HAVING COMPLETED BIOLOGY AND PHYSICS PRIOR TO ENROLLMENT IN CHEMISTRY

Group	Total	Biology		Physics	
		Number	Per Cent Group Total	Number	Per Cent Group Total
STAN	497	456	91.7	53	10.6
CHEM	323	308	95.3	63	19.5
CBA	164	160	97.5	14	8.5
TOTAL	984*	924*	93.9	130*	13.2

*These totals do not include the 25 students who did not reply to the questionnaire.

V. Analysis of Test Results for Chemistry Sample

The data in Table 23 presents the mean and standard deviation on all tests for the 1009 chemistry students completing the entire testing program. The mean scores on the OTIS and Background in Science tests are well above the published norms for this age groups, which indicates the students in the sample are drawn from a better than average group of students. One objective of this study was to determine whether significant gain in understanding science occurs over a year's study of chemistry.

TABLE 23

MEANS AND STANDARD DEVIATION ON ALL TESTS
FOR CHEMISTRY SAMPLE

	Mean	Standard Deviation
OTIS I.Q.	117.71	13.99
Background in Science	21.33	4.33
Chemistry Grade	2.67	1.05
TOUS (Pre)	33.91	6.37
TOUS (Post)	36.15	6.44

The null hypothesis to be tested for the chemistry sample is:

> There is no significant gain in understanding science as measured by the criterion instrument among students studying high school chemistry for one school year.

The means of the TOUS pre-test and the TOUS post-test (Table 23) indicate that there was some gain shown by the sample for the period of one school year. The values of 6.37 and 6.44 respectively for the standard deviations indicates that the distribution of scores was approximately the same for both test administrations.

The results of the t-test for the difference in means are presented in Table 24. Since the value of t is significant (.001), the null hypothesis is rejected with considerable confidence.

Analysis By Groups

The students of the chemistry sample were divided into groups identified on the basis of the chemistry materials in use in the schools. Analysis of the data from each of the groups was conducted similar to the total group analysis. The principal hypotheses to be tested, involving an analysis of differences within each group, can be stated in null form:

> There is no significant difference between the group's pre-test and post-test means on the Test on Understanding Science.

The mean and standard deviation on each test for all students in the STAN, CBA and CHEM groups are presented in Tables 25, 26, and 27 respectively. The analysis of the pre-post gain on TOUS within each chemistry group resulted in the t values presented in Table 28. Since the t values for each group were highly significant, the null hypothesis for the analysis of gain within each group is rejected with considerable confidence.

TABLE 24

ANALYSIS OF DIFFERENCE IN TOUS MEANS FOR CHEMISTRY SAMPLE

Means Tested	$r_{1,2}$	df	t*	p
Pre-Post	0.6791	2016	7.84	.001

*Table values for t with 2016 degrees of freedon

p	.05	.01	.001
t	1.96	2.57	3.300

Comparison of Chemistry Groups

The null hypotheses to be tested for the analysis of the gains on TOUS between the chemistry groups are:

> There is no significant difference in the gain in understanding science as measured by the criterion instrument between the STAN and CHEM groups.
>
> There is no significant difference in the gain in understanding science as measured by the criterion instrument between the STAN and CBA groups.

> There is no significant difference in the gain in understanding science as measured by the criterion instrument between the CBA and CHEM groups.

The analysis to determine the difference in gain in mean scores on TOUS between the three chemistry subgroups is dependent upon the homogeneity of the subgroups on the pre-test as well as other influencing factors. The OTIS Mental Abilities Test and the ITED Background in Science Test were administered to the students to measure some of these factors. The means on these tests presented in Tables 25, 26, and 27 were tested for differences between groups and are presented in Table 29.

TABLE 25

MEANS AND STANDARD DEVIATION ON ALL TESTS FOR THE STAN GROUP

	Mean	Standard Deviation
OTIS I.Q.	117.41	14.68
Background in Science	21.77	3.98
TOUS (Pre)	33.98	6.10
TOUS (Post)	35.99	6.28

Since the Background in Science Test showed a significant difference to exist the chemistry groups it was used as a control in an

TABLE 26

MEANS AND STANDARD DEVIATION ON ALL TESTS FOR THE CBA GROUP

Test	Mean	Standard Deviation
OTIS I.Q.	117.19	12.49
Background in Science	20.73	4.47
TOUS (Pre)	33.57	6.00
TOUS (Post)	35.94	6.35

TABLE 27

MEANS AND STANDARD DEVIATION ON ALL TESTS FOR THE CHEM GROUP

Test	Mean	Standard Deviation
OTIS I.Q.	118.40	13.61
Background in Science	21.11	4.67
TOUS (Pre)	33.95	6.94
TOUS (Post)	36.50	6.75

TABLE 28

ANALYSIS OF THE DIFFERENCE IN PRE AND POST TOUS MEANS WITHIN EACH GROUP

Group Tested	df	t	p
STAN	1020	5.18	.001
CBA	326	3.46	.001
CHEM	666	4.78	.001

Table values for t

df	t	p
300	3.32	.001
600	3.30	.001
1000	3.30	.001

analysis of covariance design. The design presented in Table 30 utilizes the Background in Science score and the pre-test TOUS score as independent variables with the post-test TOUS score being the dependent variable.

The analysis of covariance for all possible combinations of the three chemistry groups is presented in Tables 31, 32, and 33. The null hypotheses for the difference between the STAN and CHEM groups is rejected at the .05 level of confidence. There is no basis, however, for the rejection of the null hypotheses for the comparison of the CHEM and CBA groups and for the comparison of the STAN and CBA groups.

TABLE 29

RESULTS OF t-TEST FOR DIFFERENCE IN MEANS ON ALL TESTS FOR THE CHEMISTRY SUBGROUPS

Groups Compared	df	Test	t	p
STAN vs. CBA	673	Otis	-0.17	**
STAN vs. CHEM	843	Otis	0.99	**
CBA vs. CHEM	496	Otis	0.97	**
STAN vs. CBA	673	Background in Science	-3.80	.01
STAN vs. CHEM	843	Background in Science	-2.18	.05
CBA vs. CHEM	496	Background in Science	1.69	**

** Not significant at the .05 level

Table values for t

df	.05	.01
500	1.965	2.586
1000	1.962	2.581

TABLE 30

COVARIANCE DESIGN FOR CHEMISTRY SUBGROUP ANALYSIS

X_1	X_2	Y
Background in Science	TOUS (Pre)	TOUS (Post)

TABLE 31

ANALYSIS OF COVARIANCE COMPARING PRE AND POST TEST MEANS FOR THE STAN AND CBA SUBGROUPS

Source	df	Mean Square	Adj. f	p
Groups	1	62.04	2.99	*
Within	671	20.73		

Groups	Unadj. Mean	Adj. Mean
CBA	35.94	36.52
STAN	35.99	35.80

*Not significant at the .05 level.

TABLE 32

ANALYSIS OF COVARIANCE COMPARING PRE AND POST TEST MEANS FOR THE STAN AND CHEM SUBGROUPS

Source	df	Mean Square	Adj. f	p
Groups	1	113.39	5.49	.05
Within	841	20.63		

Groups	Unadj. Mean	Adj. Mean
STAN	35.99	35.89
CHEM	36.49	36.64

Table values for F for 1 and 841 degrees of freedom

.05	.01
3.85	6.66

TABLE 33

ANALYSIS OF COVARIANCE COMPARING PRE AND POST TEST MEANS FOR THE CBA AND CHEM SUBGROUPS

Source	df	Mean Square	Adj. f	p
Group	1	1.977	.09	*
Within	494	21.15		

Group	Unadj. Mean	Adj. Mean
CBA	35.94	36.22
CHEM	36.49	36.36

* Not significant at the .05 level

Nested Analysis of Variance - Chemistry Sample

Since the three different types of chemistry programs identified in this study were utilized in the various schools on a class basis, it seemed appropriate to analyze the effects of the treatments on each class rather than on individuals.

By using a nested analysis of variance, the differences between classes within teachers and the differences between teachers within treatments can be identified. This analysis also provides evidence on the gain in understanding science between the pre and post test if a cross-classification is applied to the nested groups.

The means for the TOUS test for each class are presented in the Appendix. The teacher and class identification number which were assigned on an arbitrary basis were utilized in the data processing and recording.

The results of this nested analysis in Table 34 provide evidence for the following statements:

1. Chemistry students, on the average, when grouped by teachers, display a positive gain in understanding science. ($F_{1,14} = 53.80$)
2. There are differences in the gain in understanding science between chemistry classes even when the same teacher is involved. ($F_{33,33} = 9.87$)
3. The amount of gain in understanding science by the chemistry students depends on the teacher regardless of the treatment. ($F_{14,33} = 2.34$)
4. When the chemistry classes were grouped by teacher within each treatment group, a significant difference in understanding science was found. ($F_{14,33} = 2.18$)

5. When controls are made for teacher and class differences, no significant differences were found in understanding science among the treatment groups in the chemistry sample. ($F_{2,14} = 1.00$)

TABLE 34

ANALYSIS OF VARIANCE-NESTED DESIGN COMPARING PRE AND POST TOUS MEANS FOR THE CHEMISTRY GROUPS

Source	df	Sum of Squares	Mean Square	F	p
Treatment	2	1.28	0.64	*	*
Teacher by treatment	14	220.0	15.71	2.18	0.05
Classes by teacher	33	237.95	7.21	9.87	0.001
Pre-Post (TOUS)	1	92.0	92.0	53.80	0.001
Treatment x PrePost	2	0.93	0.47	*	*
Teacher x PrePost	14	24.0	1.71	2.34	0.025
Classroom x PrePost	33	23.96	.73		

*Negative values for F, not significant

Subscores on TOUS

Analysis of the gains pre to post on each of the three scales of the TOUS instrument was conducted to see if each of the scales contributed significantly to the total scores for the chemistry sample on TOUS.

The hypotheses tested were:

> There is no significant gain in understanding about the scientific enterprise (scale I) as measured by the criterion instrument among students studying high school chemistry for one school year.
>
> There is no significant gain in understanding about scientists (scale II) as measured by the criterion instrument among students studying high school chemistry for one school year.
>
> There is no significant gain in understanding about the methods and aims of science (scale III) as measured by the criterion instrument among students studying high school chemistry for one school year.

The pre-post gains on each scale of the TOUS test were analyzed and the results of the t-test for the difference in means are presented in Table 35. Each of the three scales show a highly significant t value, thus the null hypotheses are rejected with considerable confidence.

Analysis of TOUS subscores by chemistry groups

The analysis of the subscores on the TOUS for the total chemistry group computed earlier indicated that a significant difference existed between the pre and post-test means.

The null hypotheses to be tested by the analysis of the subscores for each chemistry group stated in null form are:

> There is no significant gain in understanding about the scientific enterprise (scale I) as measured by the criterion instrument among the students of the STAN, CHEM, and CBA groups.
>
> There is no significant gain in understanding about scientists (scale II) as measured by the criterion instrument among the students of the STAN, CHEM, and CBA groups.

> There is no significant gain in understanding about the methods and aims of science (scale III) as measured by the criterion instrument among the students of the STAN, CHEM, and CBA groups.

The results of a t-test for the difference in means for the STAN chemistry subgroup is presented in Table 36. The null hypotheses for the STAN group are therefore rejected at the .001 level on scales I and III and at the .01 level on scale II.

The means on each of the subscores on TOUS for the CBA group and the t-test for the difference in means are presented in Table 37. The null hypotheses for the difference in means on scales I and II are rejected whereas the calculated value for t is not sufficiently large to reject the null hypotheses for scale II.

The subscore means on TOUS for the CHEM group and the t-test results are presented in Table 38. It indicates significant differences existing between the pre-post scores on scales I and III, but that no difference exists for scale II. The null hypotheses for scales I and III are therefore rejected. The null hypotheses for scale II cannot be rejected, however.

TABLE 35

ANALYSIS OF POOLED CHEMISTRY GROUPS TOUS SUBSCORES (SCALE I, II, III)

Scale	df	Pre-Test Mean	Post-Test Mean	t	p
I	2016	10.75	11.50	6.47	.001
II	2016	11.49	11.86	3.54	.001
III	2016	11.72	12.76	7.46	.001

TABLE 36

ANALYSIS OF TOUS SUBSCORES FOR THE STAN CHEMISTRY GROUP

Scale	df	Pre-Test Mean	Post-Test Mean	t	p
I	1020	10.84	11.49	4.10	.001
II	1020	11.48	11.91	2.94	.01
III	1020	11.69	12.50	4.35	.001

TABLE 37

ANALYSIS OF TOUS SUPSCORES FOR THE CBA CHEMISTRY GROUP

Scale	df	Pre-Test Mean	Post-Test Mean	t	p
I	326	10.71	11.45	2.87	.01
II	326	11.36	11.76	1.49	no
III	326	11.59	12.85	3.64	.001

TABLE 38

ANALYSIS OF TOUS SUBSCORES FOR THE CHEM CHEMISTRY GROUP

Scale	df	Pre-Test Mean	Post-Test Mean	t	p
I	666	10.65	11.54	4.15	.001
II	666	11.55	11.83	1.47	no
III	666	11.81	13.02	4.96	.001

VI. Summary of Findings

The sample used in this study consisted of 1275 physics students and 1009 chemistry students from high schools in the states of Iowa, Kansas, Nebraska, and Missouri. Neglecting the contribution made by including an academy for girls, the male-female ratio of students in the chemistry sample was three to two. However, only 12.3 percent of the 1275 physics students in the sample were female. Ninety-four percent of the chemistry sample had previously taken a course in Biology and thirteen percent had previously taken a course in physics.

Even though most schools participating in the study recommended that chemistry be taken in grade eleven, only 47.6 percent of the students in the study were in that grade while 42.6 percent were in grade twelve. Those in grade ten who were included in the chemistry sample represented only 9.7 percent of that group.

Although the chemistry and physics samples were not studied parallel and were mutually exclusive from one another, it was found that: (1) students studying physics for the period of one semester do show a significant gain in understanding science as measured by the TOUS and (2) students studying chemistry for the period of approximately one school year also show a significant gain in understanding science as measured by the TOUS. When gains of the chemistry groups were examined in terms of the course classifications (treatment), no significant difference in gain in understanding science as measured by TOUS was found among students studying CHEM, CBA, or STAN chemistry materials.

The TOUS has three subscores (scales) available. The chemistry group, when studied together, showed a significant gain in mean score on each of the three scales. The same thing was found when the entire physics group was studied together. All of the various chemistry and physics subgroups, when studied independently, showed significant gains in mean scores on scales I and III of the TOUS over the respective periods that they were studied. However, only in the case of STAN chemistry subgroup and the TRAD physics subgroup was there a significant difference in pre-test and post-test means on scale II of the TOUS.

By using nested analysis of variance design, the physics and chemistry populations pre-post TOUS means were studied grouped by classes, teacher and treatment with cross-classifications. The results of this data treatment yielded the finding that gain in understanding science by physics students depends upon the teacher regardless of the kind of materials being used. Similarly, for the chemistry sample, the variance due to the teacher was found to outweigh other factors studied.

Based upon interviews of a (limited) sample of eight teachers, four who had classes with the highest mean gain and four who had classes with the lowest mean gain, treatment of the classes in terms of teacher method differ most with respect to:

(a) Use of a printed supplementary exercise or workbook in the course.
(b) Student use of illustrative materials such as graphs in presenting and analyzing data.
(c) Substituting lecture-demonstrations for laboratory exercises.
(d) Problem solution outside of class.
(e) Use of recitation of a reading assignment as a class activity.

In addition to these specific differences in methods used by teachers with classes having high mean gains on TOUS and those used by teachers with classes having low mean gains on TOUS, one other difference was detected in both the chemistry and physics classes. The sequential pattern of classroom activity used by teachers with classes having low mean gain was of the following cyclic nature:

(a) Teacher demonstration-discussion;
(b) Teacher problem solution;
(c) Student reading assignment and problem trial;
(d) Student Recitation;
(e) Repeat cycle (a) through (d) on new material;
(f) Laboratory experimentation over materials studied (a) through (e).

This cycle was not followed rigidly but the pattern was easily identified. Similarly a different pattern was observed in use by those teachers having classes of high mean gain in understanding science. It is:

(a) Introduce laboratory;
(b) Laboratory;
(c) Post laboratory discussion;
(d) Problem solution by class;
(e) Student reading and problem solution assignment;
(f) Teacher-class problem solution;
(g) Laboratory introduction on new material.

Although extensive documentation is not provided in this study, serious consideration must be given to the following as in-class and/or extra-class influences on students' understanding of science:

(a) Community attitude toward education in general, its importance and emphasis upon the academic subjects versus extra-curricular activities such as the interscholastic athletic program.

(b) School administration support of and belief in importance of, science subjects in the curriculum of a majority of the school pupils.

(c) Although lack of teaching facilities does hamper teachers in developing a science program, the absence of excellent facilities and an abundance of equipment for student use in the laboratory and/or teacher demonstration does not seem to correlate negatively with gain in understanding of science as measured by TOUS in either chemistry or physics. This does not mean to say that poor facilities enhance gain in understanding science. Rather, it should be interpreted to mean that gain in understanding science can occur in spite of the poor facilities and limited equipment.

PART THREE

CONCLUSIONS AND IMPLICATIONS

I. CONCLUSIONS AND IMPLICATIONS

Based upon the limitations of the sample and the instrument utilized, the results of this study verify the importance of the teacher in the classroom as no other single variable studied was found to contribute as much to gain in understanding science as did the teacher.

Significant gains in understanding science as measured by TOUS were made by students in chemistry and in physics over the period of study. Differences in the gains in understanding science was found in the physics sample between those studying PSSC physics and those studying traditional physics but no differences in gains were found among those studying CBA, CHEM, or standard chemistry materials. When analysis of the TOUS test scores was made taking into account teacher and class differences, it was found that the differences in gains found within the physics subgroups on TOUS were not significant. The most dominant factor contributing to the gain seemed to be the teacher, not the materials.

The three scales of TOUS are based upon a limited number of items on the test thus lessening the strength of any conclusion based upon the performance of students on any one scale. However, the fact that the students in traditional physics classes and standard chemistry classes made significant gains on all three scales while those students in classes using CBA chemistry, CHEM study chemistry, or PSSC physics materials made significant gains on only scales one and three may be of importance. If one recognizes (1) that in each the CBA, CHEM study and the PSSC materials the laboratory plays an important role and that (2) part of the rationale for this is that students do science, not read about it or attempt to verify what has already been proven, hence learn what scientists do in a laboratory; then he is lead to the hypothesis as a result of findings here that perhaps this activity or approach may not contribute at all to helping a student understand about what scientists are like. The results of this study has not tested this hypothesis because of the limitations of the instrument used. It does seem reasonable to conclude that of the three scales, the ones with items that seem to discriminate best are scale I with eighteen items and scale III with twenty-four items. Further, one might offer the conjecture that either scale II is very weak or that the modern curriculum developments in physics and chemistry do not contribute greatly to students' understanding about scientists.

Since the teacher has been isolated as a key influence upon students understanding of science, careful scrutinizing of the methods utilized by teachers having success in bringing about high gain in understanding science may be of importance. The results of this study suggests that differences both in the use of a specific method of instruction as well as the cyclic order of methods or classroom activities may be contributing factors influencing students gain in understanding of science although no cause and effect relationship has been established.

A sympathetic school administration is coincident with high gain in understanding science among the chemistry population. The converse was also found to exist. Whether this is a cause and effect relationship is not clearly established but rather is implied through the observations of the investigators as a result of the community and school visitations coupled with student performance on the criterion instrument.

Examination of the classification of the physics subgroups reveals that identification is by teacher training in special PSSC institutes as well as by materials being used in class. The results of the nested analysis reveals two findings which may be considered important.

First, within a physics subgroup (or treatment group) all teachers were using the same type of materials, either PSSC or traditional, and had either attended a PSSC training session or not. The finding based upon this observation was that within such a teacher-treatment subgroup, significant differences were not observed in gain in understanding science. This would seem to imply that teachers using the same materials and having the experience of participating in a PSSC institute could, on the average, be about equally successful in developing gain in understanding science.

The second finding is dual in nature. A very significant difference in gain in understanding science was found due to treatment (favoring PSSC) when controls for teacher and class interaction are not considered. When these controls were brought into the analysis, there was no significant difference found, due to the treatment. The implication here seems to be that teachers were the most influential factor isolated in this study, but their influence may be related to both the PSSC materials they are using and the training they have had in the use of these special materials.

II. Recommendations

The results of this study point up the possible importance of teacher's role in developing understanding of science in high school chemistry and physics. A very careful analysis of the impact that retraining teachers in terms of the philosophy of the more recent science curriculum innovations may yield some very significant findings. The duration of impact as well as what real changes occur in the methods of teaching used by teachers who attend special training sessions to learn about these new curricula needs careful consideration.

Although not a direct objective of this study, the data collected and observations made, provide some indication that no real inroads are being made into the area of providing an education in physics and chemistry for the vast majority of American youth. Of particular concern to the authors are those youth who plan to attend college for study in non-science areas.

A study should be conducted among college youth to determine to what extent science understandings differ between (a) those who study chemistry and physics in high school and (b) those who do not; and to determine whether later college study in physical science tends to eleviate any difference that might exist.

The data from this study indicates that other science courses at the secondary school level may contribute to students' understanding of science. A longitudinal study of a sizable sample of youth should be made to determine whether the growth in this specific area of understanding is uniform or whether it occurs in a stepwise fashion according to age, science, and mathematics taken and/or other factors that may be analyzed.

APPENDIX A

TABLE A

PRE AND POST TOUS MEAN SCORES FOR EACH CLASS IN THE PP TREATMENT GROUP

Class	Pre-test	Post-test
1001	37.154	39.692
1002	38.684	40.053
1003	33.909	38.136
1021	37.933	38.467
1022	37.231	38.538
1023	42.727	41.364
1031	41.636	41.545
1032	39.077	41.000
1234	38.864	40.682
1235	40.143	43.762
1421	40.857	40.786
1422	30.923	42.385
1423	40.778	42.111
1424	39.450	40.300
1425	38.278	38.778
1431	36.714	36.679
1432	32.650	33.700

TABLE B

PRE AND POST TOUS MEAN SCORES FOR EACH CLASS IN THE PT TREATMENT GROUP

Class	Pre-test	Post-test
2091	36.000	38.125
2092	42.556	44.000
2601	38.833	39.500
2602	37.636	37.545
2611	36.792	38.458
2612	40.071	40.857

TABLE C

PRE AND POST TOUS MEAN SCORES FOR EACH CLASS IN THE TP TREATMENT GROUP

Class	Pre-test	Post-test
3221	35.250	36.969
3222	35.115	37.038
3231	30.438	29.625
3232	36.615	36.231
3233	32.750	33.750
3251	35.120	37.600
3252	35.867	36.667
3253	35.895	37.368
3254	34.810	35.976
3451	35.750	38.583
3452	27.364	29.000
3621	33.130	34.739
3623	32.500	32.813
3624	32.526	32.947
3625	32.095	34.333

TABLE D

PRE AND POST TOUS MEAN SCORES FOR EACH CLASS IN THE TT TREATMENT GROUP

Class	Pre-test	Post-test
4041	37.864	39.955
4042	35.783	36.696
4043	34.095	35.000
4061	41.385	41.846
4062	36.857	36.571
4063	37.500	39.188
4064	38.300	38.500
4081	30.692	33.769
4082	32.053	35.000
4111	33.467	33.467
4112	32.308	33.615
4113	34.188	38.938
4211	30.857	32.571
4212	34.360	36.880
4213	32.348	34.696
4214	34.063	36.188
4241	31.632	34.737
4242	30.737	32.211
4441	32.450	35.200
4442	32.900	36.100
4443	34.462	37.385
4444	31.889	34.889

TABLE E

Pre and Post TOUS Mean Scores For Each Class In the STAN Treatment Group

Class Number	Pre	Post
101	34.000	33.733
102	33.947	34.263
106	35.136	35.318
110	32.750	35.380
111	33.880	35.880
121	32.421	36.263
122	32.762	35.667
123	34.300	35.100
124	36.278	36.944
131	32.632	35.421
133	32.368	35.789
134	34.250	35.200
135	36.786	38.143
136	35.048	39.143
141	34.429	33.929
143	32.250	33.438
155	31.864	35.045
158	34.400	36.520
163	33.200	34.100
164	32.409	35.000
168	35.667	36.417
171	32.824	37.000
172	32.067	34.067
175	31.900	37.900
183	35.857	38.429
184	37.000	38.500
185	38.308	41.231
193	37.538	39.692
194	32.786	33.786

TABLE F

Pre and Post TOUS Mean Scores For Each Class In the CBA Treatment Group

Class Number	Pre	Post
212	34.467	36.667
213	33.632	36.211
233	33.227	34.000
234	33.050	37.400
235	31.300	32.850
252	34.250	36.375
253	33.792	36.333

TABLE G

Pre and Post TOUS Mean Scores For Each Class in the CHEM Treatment Group

Class Number	Pre	Post
301	28.308	31.846
303	32.346	35.077
304	31.862	33.655
314	32.067	34.800
315	31.900	34.000
316	30.737	32.053
317	35.500	37.200
331	34.273	36.091
332	38.941	39.294
333	38.667	39.944
334	42.240	44.880
335	34.609	37.130
341	33.077	34.385
343	32.188	38.500
344	32.643	36.643
346	33.250	37.375

APPENDIX B

NESTED ANALYSIS OF VARIANCE

The problem of computing the F values for the nested analysis of variance can be divided into several stages. The first stage was the building of contingency tables using the means of the various classes of each teacher. (See example-Table 25). From these tables the main effect sum of squares and the sum of squares for the interaction were computed, using the formulas:

$$\left.\begin{array}{l}\text{Main Effect}\\ \text{Sum of Squares}\\ \text{(SScp)}\end{array}\right\} = \frac{\Sigma(\bar{X}_j^2 + \bar{Y}_j^2) - [(\Sigma \bar{X}_j)^2 + (\Sigma \bar{Y}_j)^2]}{2} - \frac{[(\Sigma X_1Y_1)^2 + (\Sigma X_2Y_2)^2 \;\ldots\ldots\; (\Sigma X_jY_j)^2]}{M} + \frac{(\Sigma\Sigma \bar{X}_1\bar{Y}_1 \ldots\ldots \bar{X}_j\bar{Y}_j)^2}{n}$$

TABLE H
TEACHER A

Class Number	Pre-TOUS	Post-TOUS	
C_1	$\bar{X}_1$	$\bar{Y}_1$	$\Sigma \bar{X}_1\bar{Y}_1$
C_2	$\bar{X}_2$	$\bar{Y}_2$	$\Sigma \bar{X}_2\bar{Y}_2$
C_3	$\bar{X}_3$	$\bar{Y}_3$	$\Sigma \bar{X}_3\bar{Y}_3$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
C_j	$\bar{X}_j$	$\bar{Y}_j$	$\Sigma \bar{X}_j\bar{Y}_j$
	$\Sigma \bar{X}_{1\ldots j}$	$\Sigma \bar{Y}_{1\ldots j}$	$\Sigma\Sigma \bar{X}_1\bar{Y}_1 \ldots \bar{X}_j\bar{Y}_j$

$$\left.\begin{array}{l}\text{Interaction}\\ \text{Sum of Squares}\\ \text{(SSct)}\end{array}\right\} = \frac{(\Sigma \bar{X})^2 + (\Sigma \bar{Y})^2}{2} - \frac{(\Sigma\Sigma \bar{X}\,\bar{Y})^2}{m}$$

Where m = number of cell/2
n = number of cell

The degree of freedom (m-1 for each teacher), the sum of squares (main effect and interaction) and the pre and post TOUS means were computed for each teacher.

Using the means on the pre and post TOUS for each teacher, contingency tables were built for each teacher within treatment and the same calculation was done. The result at this stage of computation was the pre and post TOUS means for each treatment, the sum of square values and the degrees of freedom based on the number of teachers with each treatment.

The third and final set of contingency tables were then built using the pre and post TOUS means for each treatment as the table entries. The sum of squares, degrees of freedom and total means (pre and post) were obtained. An additional computation was performed during this stage. This computation yielded a sum of squares due to the cross-classification of the pre and post test and can be summarized with the formula:

$$\text{Sum of Squares} = \frac{(\Sigma \bar{X}_1\bar{Y}_1)^2 + (\Sigma X_2Y_2)^2 \;\ldots.\; + (\Sigma \bar{X}_j\bar{Y}_j)^2}{m} - \frac{(\Sigma\Sigma X_1Y_1 \;\ldots.\; X_jY_j)^2}{n}$$

Where m = number of cells/2
n = number of cells

Since the number of classes for each teacher and the number of teachers in each treatment were not the same, the harmonic mean for the classes and teachers was computed. Using the following formula:

$$\text{Harmonic Mean} = \frac{k}{\left(\frac{1}{p_1} + \frac{1}{p_2} + \frac{1}{p_3} \;\ldots.\; + \frac{1}{p_j}\right)}$$

Where p = number of classes per teacher or the number of teachers per treatment.
k = number of teachers or treatment

The sum of square values resulting from the three step computation was then compiled with the harmonic mean values according to the format presented in Table I. The results of this computation become the sum of square values in Table 11 and Table 34. The Mean Square and F values were then computed for the appropriate pairs of scores.

TABLE I

MAIN EFFECT SUM OF SQUARES

Source

Treatment = (Harmonic Mean-Classes) (Harmonic Mean-Teachers) (Sum of Sq. Treatment)

Teachers within Treatment = (Harmonic Mean-Classes) (Sum of Sq. Teacher)

Classes within Teachers = (Sum of Squares-Classes)

INTERACTION SUM OF SQUARES

Treatment = (Harmonic Mean-Classes) (Harmonic Mean-Teacher) (Sum of Sq.-Treatment Inter.)

Teachers within Treatment = (Harmonic Mean-Classes) (Sum of Squares Teacher)

Classes within Teachers = (Sum of Squares-Classes)

Pre-Post Cross Classification = (Sum of Squares-Pre-Post)