AN INVESTIGATION OF THE EFFECT OF

INTRODUCTORY PHYSICAL SCIENCE ON

THE ACHIEVEMENT OF GRADE XI STUDENTS

IN CHEMISTRY AND PHYSICS

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ABSTRACT

AN INVESTIGATION OF THE EFFECT OF INTRODUCTORY PHYSICAL SCIENCE ON THE ACHIEVEMENT OF GRADE XI STUDENTS IN CHEMISTRY AND PHYSICS

by RICHARD ALLEN ZABOLOTNY

The purpose of this study was to examine student achievement in two Grade XI science programs in a Manitoba school.

The two samples of students whose results were examined included 178 Chemical Educational Material Study, CHEMS, students and 72 Physical Science Study Committee, PSSC, students from Kelvin High School. In the CHEMS sample, 89 of the students had previously taken a course known as Introductory Physical Science, IPS, at the Grade X level. Only 59 of the PSSC students had studied the same course. The remainder of the students in both groups had followed a program based on the textbook An Introduction to Physical Science by R.L. Hedley.

Prior-knowledge scores were obtained in mathematics and science from common achievement tests administered to all students in the province at the Grade IX level. In addition, the Intelligence Quotients, as calculated from the Dominion Intermediate Test of Learning Capacity, Form A, and the percentile ranks of students based on their performance on the SCAT test, Level 3, were included as prior-knowledge scores. Each of the groups were given two criterion tests. One, a Test on Understanding Science by Cooley and Klopfer, yielded scores on pupil understanding of scientific enterprise, the aims and methods

of science and the role of scientists. The other criterion test was a content-test for either CHEMS or PSSC intended to measure pupil achievement in the respective courses. Another criterion measure of achievement that was used in this study was the composite mark of the students based on their year's work in each course. With the addition of Age, Sex and Grade XI science teacher, a total of seventeen variables were available for consideration.

Correlation matrices of these seventeen variables were examined for significant correlations. The mean scores and standard deviations were calculated for each of the groups in the study along with the t-tests of difference between group means. This analysis disclosed a significant difference in prior-knowledge between the two groups of each sample. To overcome this discrepancy sub-groups were chosen from the original PSSC groups and then the same calculations were made. For the CHEMS sample an analysis of covariance was conducted for three criteria variables and the six prior-knowledge variables.

The students who had studied the IPS program in Grade X scored consistently higher than the other students on the criteria variables. However, the result of the t-test for differences between means was not always significant. This was especially true when corrections were made for the prior-knowledge scores of the PSSC sample. The study indicated that the Age, Sex and Teacher were relatively unimportant factors in student achievement.

The study also showed that it is possible to evaluate the effect of different preparatory science courses on an objective basis, and indicated the relative effectiveness of the two preparatory programs.

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Dr. R. Hedley and Professor H. Grunau, as members of the advisory committee, were of great assistance in planning the study.

The writer would also like to acknowledge the assistance of Mr. F. Hastings in designing the CHEMS content-test used in the study.

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INTRODUCTION

Statement of the Problem

The purpose of this study was to compare the suitability of two Grade X matriculation science programs as preparatory courses for the Grade XI chemistry and physics courses known as the Chemical Educational Material Study, CHEMS, and the Physical Science Study Committee's physics program, PSSC, respectively.

The major course of study that was investigated was the Introductory Physical Science course, IPS. This program was specifically designed to form a basis for such newer high school science programs as CHEMS, PSSC and the Biological Sciences Curriculum Study program, BSCS. After these newer senior high school science programs had been instituted in Manitoba, the teachers of these courses were led to the belief that students had not been adequately prepared by their Grade X science program for the laboratory assignments associated with these new courses since the students were unable to complete these assignments as quickly or as well as demanded by the objectives of these courses. As a result, there was a need for Manitoba educators to find a satisfactory program to prepare students for senior high school science. The IPS course is currently being utilized in an attempt to provide such preparation.

In this study a comparison of student achievement in the Grade XI CHEMS and PSSC programs was made between a group of students which had studied the IPS program and a group which had studied another course authorized for use in the Grade X science program in Manitoba schools. This second course utilized the textbook An Introduction to Physical Science by R.L. Hedley, and attempted to provide students with a body of scientific knowledge as a basis for future training in technical fields. It also attempted to develop in students a favorable attitude towards science and an appreciation of the nature and role of science in effective citizenship. Although no longer authorized for use in the matriculation program in Manitoba, the Hedley textbook is currently being utilized as the basis of the General Course Science 101 program for which it was originally developed.

With the acceptance of CHEMS, PSSC and BSCS in the senior grades of the University Entrance program in Manitoba, the traditional preparatory science course, based on the textbook Everyday Problems in Science by Beauchamp, Mayfield and West, seemed to be of little benefit to the students. Consequently, the two textbooks, Introductory Physical Science and An Introduction to Physical Science were authorized for use, on an experimental basis, in the Grade X matriculation program in Manitoba during the school year 1966-1967. By 1968 it was decided to use the IPS program as the only form of preparatory science in the Grade X matriculation course.

Typically, such decisions have been made on a subjective basis. The teachers involved in experimental programs have submitted written anecdotal reports which evaluated the programs subjectively. These pilot-class teachers have also answered questions of concern to curriculum revision committees. These committees then made recommendations for curricular changes on the bases of the judgments available from these sources.

With the attitude that revisions may be necessary in the high school curriculum, it is possible that a new course of study could be accepted merely because it is new. It is usual to determine whether or not these new courses actually satisfy the aims and objectives which they are purported to fulfill. Thus some objective evidence indicating the suitability of the recent changes in the Grade X matriculation science program is desirable. It is the intent of this study to provide some such evidence, and thereby indicate that progress is being made towards improving the readiness of students for senior high school science and also to partially validate the recent General Science 100 course change to the IPS program.

A Synopsis of Recent Developments

Every student enrolled at the Grade X level of the University Entrance Course program in Manitoba is required to study the course known as General Science 100 as part of his program. In practice, this course has been based on elementary chemistry and physics, with approximately equal emphasis placed on each of these sciences.

In the mid 1950's there had been increasing resentment about and rejection of the then current General Science 100 program. At that time this program was based on the textbook Everyday Problems in Science by Beauchamp, Mayfield and West; published in Canada by W. Gage and Company in 1948. One apparent fault with this textbook was that the "modern" technology presented to the students was so antiquated that students, teachers and laymen all ridiculed the treatment of certain topics. From an educational standpoint, the technological orientation of the textbook and the lack of emphasis upon an experimental foundation for the course gave rise to even more dissatisfaction with the program.

In order to facilitate the quest for a new science program, the Manitoba Department of Education sponsored a University Entrance Course Seminar in the summer of 1963. This seminar group, which was composed of local educators, recommended:

> "1. that the Grade ten required science be an introduction to basic physical science containing approximately 50% basic Physics and 50% basic Chemistry.
>
> 2. that the Grade ten required science serve both as a terminal course for students leaving the science sequence in Chemistry and Physics, and as a prerequisite for Grade eleven Chemistry and Physics courses.
>
> 3. That a modified form of the course prepared by the Physical Science Study Committee be used in Grades eleven and twelve Physics.
>
> 4. That the course in Chemistry stress the modern approach to the concept of chemical bonding.
>
> 5. That in all Science subjects:
> (a) The emphasis be on the discovery of the principles rather than on more verification;
> (b) There be instruction to make use of the inductive and experimental approach;
> (c) There be taught an appreciation of the significance of magnitude;
> (d) There be emphasis on the quantitative aspects especially in the examination principles."
> (Initial Report: University Entrance Course Seminar, 1963)

As a result of these recommendations, curriculum committees were established for the areas of chemistry and physics in October of 1963. These committees suggested the first alternative to the Beauchamp, Mayfield and West textbook. They believed that a possible resolution of the situation that existed in General Science 100 might be achieved by utilizing the initial chapters of the PSSC physics and

CHEMS chemistry textbooks.

The Department of Education implemented this recommendation for the school year 1964-1965 on a pilot basis, in schools where appropriately trained teachers were available. By the spring of 1965 local educators were led to the belief that the course based on the introductory chapters of CHEMS and PSSC was not a satisfactory alternative to the Grade X General Science 100 program, and the Department of Education decided to abandon this approach by the end of the 1965-1966 school year. Further recommendations from the Curriculum Committee were requested by the Department of Education for September 1966.

Between the fall of 1963 and the spring of 1965, increased pressure from educators and the general public, as expressed by local communications media, for the removal of the Beauchamp, Mayfield and West textbook from the list of authorized textbooks compounded the problems faced by the Department of Education. The Curriculum Committee was seeking another experimental-science course, while the Department of Education needed a course to serve as a temporary measure until a new textbook and accompanying course could be found.

The Joint Physics and Chemistry Curriculum Revision Committee now focused its attention upon a program entitled Introductory Physical Science. It was believed that, since the PSSC physics and CHEMS chemistry courses had been accepted as satisfactory programs for Manitoba high schools by 1965, perhaps the latest program by the same authors would be able to provide the necessary solution for the dilemma then present in Manitoba. The basic philosophy of this IPS course seemed to be similar to that expressed by the Curriculum Committee.

Thus it was believed to be likely that school systems in the United States utilizing the newer science programs, CHEMS, PSSC and BSCS, had been faced with problems similar to those experienced in Manitoba. Therefore, Educational Services Incorporated of Boston, Massachusetts, with support from the National Science Foundation, had, in fact, developed the IPS program under similar circumstances in 1963. Haber-Schaim, director of the IPS group, states:

> "In planning the present course for junior high school we had before us the work of PSSC in physics, of BSCS in biology, and of CBA [Chemical Bond Approach] and CHEMS in chemistry, so the matter of aims was not an entirely independent question anymore.
>
> The greatest handicap faced by science teachers in the new curricula is that most students in senior high school have no experience in observations, no basic laboratory skills, no knowledge of how to apply elementary mathematics to experimental results; they also lack the ability to correlate an abstract idea with a concrete situation. Often they have no idea of orders of magnitude, no feeling for approximation, no ability to judge what is important and what is not." (IPS Progress Report, 1969)

The following quotation, from an IPS progress report, indicates the similarity of the complaints voiced by teachers of chemistry as well as physics in both the United States and Manitoba:

> "Students need time to digest knowledge. From the very first, PSSC physics teachers kept saying that if only we could get into the earlier grades some of the basic ideas and skills which are needed so badly in PSSC, it would make the course much easier to teach and give the students much more time to digest the materials. And so ... came the call to start something to serve as a common foundation for the later courses in the senior high schools. This means not only a foundation of subject matter, but also an attitude of inquiry coupled with experimental and mathematical skills." (IPS Progress Report, 1969)

Another reason for the acceptance of the IPS program was provided when Haber-Schaim indicated that this course should serve as a prerequisite for further high school science courses but should also serve as a valuable terminal science course:

> "Thus we must have a program to serve two purposes: on the

> one hand to be a sound foundation for future physics, chemistry, and perhaps biology courses; and on the other hand to furnish sufficient nourishment in the essence, the spirit, and the substance of physical science to be a good terminal course for those who will not study physical science later on."
> (IPS Progress Report, 1969)

Thus the Joint Physics and Chemistry Curriculum Revision Committee recommended the implementation of IPS on a controlled, pilot-course basis. The first thirty classes in the IPS program began in September of 1966 following an in-service training of teachers.

Concurrent with the recommendations of the Curriculum Revision Committee the Department of Education decided that the Grade X General Course Science 101 could be substituted, on a permissive basis, for General Science 100. The General Course Science program made use of the textbook An Introduction to Physical Science by R.L. Hedley and published by Holt, Rinehart and Winston of Canada Limited in 1964, written specifically for this course. Despite the traditional approach followed in the textbook, it was felt that the laboratory orientation of the General Course Science 101 would improve the General Science 100 program based on the Everyday Problems in Science textbook. Furthermore, the aims and objectives of this program, as stated in the course outline, were relatively similar to those of later senior high school science programs. In part the course outline reads:

> "The prime objective of the general science course is the development of scientific literacy to the fullest extent within the capabilities of each student. Scientific literacy is considered to be dependent upon, among other things, the following:
>
> 1. The development of a background of ordered knowledge of science.
>
> 2. The acquisition of a vocabulary of technical and scientific terms commonly used to explain natural phenomena.
>
> 3. The utilization of these terms for effective communication.

4. The development of a method of inquiry through the use of reliable data to suggest possible conclusions.

5. An appreciation of the methods and procedures of science.

6. A disposition to use the knowledge and methods of science approximately.

7. The development of skills and abilities normally associated wiht science." (Program of Studies, 1968-1969)

Thus for the 1966-1967 school year there were three authorized courses available for use in science at the Grade X matriculation level. Encouraging results from the IPS pilot classes during 1966-1967 influenced the decision to expand the experimental program with this course for 1967-1968. Also, effective September 1967, the textbook Everyday Problems in Science was deleted from the list of authorized textbooks, and hence only the IPS textbook and An Introduction to Physical Science by Hedley were available for the school year of 1967-1968. By September of 1968 it was decided that IPS would be the only course and textbook authorized for use in General Science 100.

Review of Evaluative Investigations

Appraisal of the Introductory Physical Science program in the United States has, until recently, consisted of a narrow view of the process of feedback. This method of evaluation utilizes written comments from the teachers of the program as a basis for modifications. Their annotations, on all aspects of the course, have been submitted on a regular basis during the introductory phase of the program. As a result of this process, Haber-Schaim claims:

"In summary, we believe that this course will greatly facilitate the teaching of physics and chemistry: several chapters of chemistry can be eliminated and much of the first part of PSSC will not be needed. But, most important, we believe that pupils will enter physics and chemistry with an improved orientation and attitude toward science, and well-equipped with essential skills." (IPS Progress Report, 1969)

It was expected that some form of quantitative study had been undertaken in the United States in order to evaluate the major objectives of the program. However, Harry U. Felton, Professional Assistant of the Evaluation and Advisory Service, Educational Testing Service, Princeton New Jersey, informed this author that no objective test had been designed for this purpose. (Personal communication, November 29, 1968) His suggestions for some suitable devices, which might be useful in such a study, included the standardized tests for the PSSC and CHEMS programs. Therefore, it must be concluded that some statements are based exclusively on the feedback process whenever post-Introductory Physical Science performance in science is concerned. One example is:

"The first few trial years of the IPS program showed that it was serving the two groups for which it was designed: students who plan to take further courses in biology, chemistry and/or physics in senior high school, and those for whom the IPS is followed only by biology." (IPS Progress Report, 1969)

During the 1966-1967 school year, Kenneth H. Charlesworth undertook a comparative study of the three authorized science programs in Manitoba. As a result of this purely objective evaluation of student reaction to and appreciation of these programs, Charlesworth concluded that those students in the program based on the Introductory Physical Science textbook had the most favorable attitude towards their science program, and had the greatest understanding of the aims, methods and objectives of science. On the other hand, students enrolled in the program using Everyday Problems in Science most often had the poorest results of the three groups on each of the measurements. The only sub-test in which the latter students scored higher than all others was on a test of student interest in science. The result in this one exception to the general pattern was not statistically significant.

Therefore, it may be concluded, on the basis of the minimal evidence available regarding the appreciation and understanding of science, that the Department of Education has made appropriate decisions regarding the temporary alternative for the Beauchamp, Mayfield and West textbook and also for the current program of Introductory Physical Science.

Chapter 2

METHOD

Design of the Study

During the school year 1967-1968 all Grade X matriculation students in Manitoba schools were required to study either the IPS program or that based on the Hedley text. A unique situation existed at Kelvin High School in Winnipeg during that year as both of these authorized programs were taught. When time-tabling arrangements were being made, four of the future Grade X matriculation classes were scheduled to be taught by one of each of four teachers prepared to teach the IPS course to these classes. These same four teachers also taught the program based on the Hedley textbook to the remaining Grade X classes in the school. This situation at Kelvin High School provided the basis for this study which was conducted during the following school year.

In October of the 1968-1969 school year lists of all students enrolled in the CHEMS and PSSC courses in Kelvin High School were compiled from the results of a content pre-test given for each of the sciences. It was found that, as a result of varied option choices, there was a general intermixing of the previous year's Grade X students in the Grade XI teaching sections with respect to both the Grade X science course and teacher. These first lists showed that 208 former Kelvin students were studying CHEMS while 95 were studying PSSC. It was the year's progress of these students that was of concern to this study.

Those students enrolled in one of the three PSSC classes were taught by three of the four Grade X IPS teachers of the previous year. The CHEMS students were taught by three different teachers. With the intermingling of students from the two Grade X programs and from the various teachers, no Grade XI class had a majority of students that had been taught by a particular Grade X science teacher. All six Grade XI teachers co-operated in the testing program required for the completion of this study.

In order to obtain some background information about the Grade XI students the school's student record cards were consulted. These cards supplied the writer with the results obtained by most of the students on each of two intelligence tests, the Dominion Intermediate Test of Learning Capacity, Form A, developed by the Ontario Institute of Studies in Education, and the SCAT test, Level 3, developed by the Educational Testing Service. In addition, the final, adjusted results of student achievement on a set of common, externally set and marked Departmental Examinations for final Grade IX standings were available. Since these results had had a correction factor applied to the raw scores obtained by the students on the examinations, the assistance of the Department of Education was sought in order to revert the recorded results to the original raw scores. The Department of Education supplied two tables of raw scores with the correspondingly adjusted marks. These tables enabled the conversion of the recorded mathematics and science marks, back to the original raw scores, to take place.

As this additional information was included with the pre-test scores on the lists of students' names, some of the names were deleted if a part of the new data was missing. Thus the initial groups of students were reduced in size by approximately ten percent. To be of continued concern to this study the students had to be enrolled in the Winnipeg School Division for their junior high school years. During these years they had to write both sets of intelligence tests and also had to write at least the final Departmental Examinations in mathematics and science in June of 1967. Those students who met these requirements and then enrolled at Kelvin High School in September 1967 and again in September 1968 formed the two samples of students for this study, if they enrolled in CHEMS and/or PSSC at that time. No student who had repeated Grade X, or who was to repeat Grade XI in 1968, was included in the samples since he could not have written the Grade IX Departmental Examinations in 1967. Although all students in CHEMS or PSSC wrote the two remaining tests required for the study, results were recorded only for those students listed in the initial samples described above.

In May of 1969 all students studying CHEMS or PSSC wrote an objective, multiple-choice test based on the content of the respective courses. These fifty-item tests were assembled by selecting questions from the standardized tests provided for each of the courses. One of the three CHEMS teachers assisted the writer by selecting the items that dealt with the CHEMS course content to be taught from October 1968 to the end of the year. The writer followed the same procedure for the PSSC content-test. Both sets of fifty-items reflected the emphasis placed on the course content by the respective programs.

In May 1969 the students took the Test on Understanding Science, TOUS, developed by Cooley and Klopfer for Educational Testing Service.

Since Charlesworth, (University of Manitoba Thesis, 1969), had determined that Grade X IPS students have a greater understanding of science than the students from other Grade X science programs, the TOUS instrument was administered in the hope of determining whether the Grade X IPS students maintained their advantage over other students after a year in another laboratory-oriented science course. The opinion of the authors of this instrument is that:

> "For many years, science educators have acknowledged the importance of teaching and learning certain so-called 'intangible' aspects of science. These intangibles include an understanding of the nature of scientific inquiry, of science as an institution, and of scientists as people. Such understandings are particularly important today, as our nation and the world are increasingly affected by the results of scientific activity, and as we seek to attract young people into scientific careers.
>
> While numerous tests have been prepared to measure student achievement in the facts and principles of science, no adequate instrument has previously been available to assess the extent to which the important instructional outcome of understanding science and scientists has been achieved. Numerous studies of science curriculum methods assert that a particular technique or procedure has contributed to these understandings in the students, but, in the absence of a valid instrument, such judgments cannot be made objectively to any extent. Thus there exists a definite need for an instrument that adequately measures these understandings. It is the purpose of TOUS to meet this need." (TOUS Manual, 1961)

However, as indicated by the author of TOUS, there need not be any relationship between scores on TOUS and school grades.

> "It must be emphasized here that TOUS is not for use in student selection or determining the ability of individual students or teachers. Because most textbooks or lecturers do not now provide direct, specific answers to most of the questions in the test, there will not be any necessarily high correlation between course grades and TOUS scores. Nor need there be any significant changes between TOUS scores at the beginning of a course and those at the end of the course, although curriculum planners and teachers will be seeking ways in which to make courses strengthen and broaden students' understanding of science as a discipline, of scientists as an occupational group within our society, and, finally, of the methods and aims of science. Because students are subject to strong influences outside the school, their growth in sophistication in attitudes and understandings may be slower than good teaching and sound content may lead us to believe."
> (TOUS Manual, 1961)

Since course work is normally completed by the end of May of a school year, mid-May was believed to be an appropriate time for the administration of these tests. Any further delay might have had a deleterious effect upon either those students preparing for final exams or upon the study since those students exempted from final exams might not be working as diligently as they normally would just before the end of the school year.

In addition to these last two tests, the composite marks for each student in the samples were recorded for either CHEMS or PSSC. These composite marks were calculated from the results of term tests, laboratory work and a mid-year exam. Each of the three school terms, from September to mid-November, November to the end of January and February to mid-May, contributed 25% of each student's composite mark and the mid-year exam provided the remaining 25% of this mark. This mark was then used to determine exemption standing in each subject. Thus a partially subjective score was also available for each student.

Upon the completion of the tables of results for the students it was discovered that some students had not written one or more of the tests. With the deletion of their names from the initial samples, the author obtained the final samples for analysis. These final samples consisted of 178 CHEMS students and 72 PSSC students. The CHEMS sample contained 89 graduates of the IPS program while the PSSC sample contained 59. The remainder of the students in both samples had studied the Grade X science program based on the Hedley text. In the analysis of the data which follows, those students that had studied the IPS program will be referred to as group A in both samples; the other students will be referred to as group B.

The following data were then available on the tabulation sheets for each student in the samples.

1. The age of the student.

2. The sex of the student.

3. The raw score for Grade IX science, June 1967.

4. The raw score for Grade IX mathematics, June 1967.

5. The mental ability of the student as an Intelligence Quotient derived from the Dominion Form A.

6.-8. The mental abilities of the student as percentile ranks on the three levels of the SCAT test, Verbal, Quantitative and Total.

9. The science course completed in Grade X, 1968.

10. The score obtained on the content pre-test, October 1968.

11. The score obtained on the content re-test, May 1969.

12.-15. The score each of three subtests of the TOUS instrument and the total score, May 1969.

16. The composite mark of each student, May 1969.

17. The Grade XI course teacher of each student, recorded as a number.

The above information was transferred to punch cards for an analysis of the data by computer. The statistics obtained from the computer included the mean and standard deviation for each variable in the study, a correlation matrix and an analysis of variance for all data of each sample. The initial analysis led to tests of covariance between six of the prior-knowledge variables and the content re-test, the composite mark and the total score on the TOUS instrument.

Assumptions and Limitations of the Study

It was assumed that all students participating in the testing program had similar experience in handling multiple-choice tests. It was also assumed that the tests were properly supervised and that security was maintained for the three sets of tests which were written by all students at approximately the same time.

The study was restricted to those students who met the previously outlined requirements. The evaluation did not include any students who failed or repeated course work in either Grade X or Grade XI.

The manner of selecting the students limits this study to a narrow urban region. Although students represented a broad spectrum of socio-economic classifications, the sample consisted predominantly of students from upper-middle class families. Furthermore, the intermingling of students for the Grade XI programs should de-emphasize the influence of any one teacher on the study.

Another limitation of the study may have resulted from utilizing only Grade IX mathematics and science scores. Some other achievement scores may be as important as those which were considered.

The teachers connected with the study may have influenced the final results obtained from the analysis of the data. However, the seven teachers involved over the two years of the study have similar qualifications. Although the minimum teaching experience for any of the teachers was three years for the Grade X science, four years for the PSSC teachers and ten years for the teachers of CHEMS, it was believed that effects on the study due to experience or enthusiasm may have been partially nullified by the intermixing of the students from Grade X to Grade XI.

Hypotheses Tested

The following null hypotheses were tested in this study:

1. There is no significant difference in student achievement in CHEMS or PSSC as a result of different Grade X science programs.

2. There is no significant difference in student understanding of science after the completion of CHEMS and/or PSSC as a result of different Grade X science programs.

3. There is no significant difference in student achievement in CHEMS or PSSC as a result of partially subjective grading as opposed to totally objective grading.

Chapter 3

ANALYSIS OF DATA

The results derived from the data of the study are examined in this chapter. These results include: (1) the means and standard deviations of all variables used for both samples in this study; (2) the t-tests of differences between the means of the two groups in each sample; (3) the correlation matrices for the total samples and for each group of both samples; (4) the analysis of covariance for the CHEMS sample; and (5) the t-tests of differences between the means for the modified groups of the PSSC sample. Owing to the small number of students involved in Group B of the PSSC sample, the analysis of the PSSC data did not parallel that of the CHEMS data, and the results from the PSSC sample were analyzed in relation to the CHEMS results.

Analysis of the CHEMS Sample

Table 1 shows the mean scores and the standard deviations of the sixteen variables for each group of the CHEMS sample. The variables listed under the SCAT scores and the Intelligence Quotient are indicative of the mental abilities of the students involved in this study. These scores, together with those for Grade IX mathematics and science, constitute the six indicators of the prior-knowledge of the students participating in the study. The scores on the content pre-test, given in October 1968, provided the expected confirmation of the students' lack of knowledge about the work that they were to study

Table 1

Means, Standard Deviations and t-tests for Differences

Between the Means for the CHEMS Sample

	Variables		Group A, N_A=89		Group B, N_B=89		
	List	Code	Mean	s.d.	Mean	s.d.	t-test
S	Verbal	V	78.56	17.39	68.45	22.31	3.36*
C	Quantitative	Q	74.76	20.56	55.92	27.57	5.27*
A	Total	T	80.66	16.46	64.98	24.16	5.04*
T							
	Intelligence Quotient	I.Q.	125.80	12.49	117.78	12.16	4.36*
	IX Mathematics	M	78.94	11.15	66.81	14.91	6.12*
	IX Science	S	66.42	11.13	57.44	13.25	5.34*
	Pre-test	P	2.93	2.49	2.63	2.32	.83
	Content-test	C	17.99	4.77	15.40	4.57	3.70*
	Composite Mark	CM	62.81	12.56	53.55	11.69	5.07*
	TOUS 1	T_1	11.83	2.51	10.08	2.69	4.48*
	TOUS 2	T_2	11.56	2.25	11.34	2.25	.65
	TOUS 3	T_3	12.82	3.33	11.00	2.88	3.90*
	TOUS Total	T_T	36.21	6.06	32.42	5.64	4.32*
	Age	Age	16.43	.66	16.70	.70	-
	Sex	Sex	.64	.48	.43	.50	-
	Teacher	Tea.	2.02	.94	2.34	.74	-

* Difference significant at .05

($t \geq 1.96$)

during the remainder of the school year. The content-test results, the scores on the four levels of the TOUS instrument and the composite marks that the students obtained in May 1969 are the criteria variables of principal concern to this study.

The means in Table 1 indicate that Group A was superior to Group B in each of the prior-knowledge and criteria variables. This result was expected since the original selection of students for the four classes of Grade X IPS was made on the basis of high mental abilities and/or high scholastic averages in Grade IX. The t-tests for differences between the means indicate that this superiority is generally statistically significant. Only the results from the content pre-test and the second level of the TOUS instrument do not indicate significant superiority. The fact that there were more boys in Group A and more girls in Group B may indicate that boys have a greater bent for science than girls, perhaps as a result of social mores.

TOUS 1, TOUS 2 and TOUS 3 refer respectively to Understanding About the Scientific Enterprise, Understanding About Scientists and Understanding About the Methods and Aims of Science. The heading TOUS Total represents the total score achieved on the instrument. Just as Charlesworth established, (University of Manitoba Thesis, 1969), Group A has an understanding of science superior to that of Group B as shown by the results of TOUS 1, TOUS 3 and TOUS Total. Charlesworth also found that the difference between the two groups on TOUS 2 was statistically insignificant.

Table 2 includes the correlation coefficients between the seventeen variables for the entire CHEMS sample. Since any correlation matrix is symmetrical, only the lower triangle is shown. To find the correlation between any two variables, locate the intersection of the row and column containing the desired variables. The value at that intersection is that of the correlation coefficient being sought. In Table 2, those coefficients equaling or exceeding the value 0.20 are considered to show a relationship between the variables in question, that is significantly different from zero at the five percent level.

Correlation matrices for both Groups A and B are presented in Tables 3 and 4 respectively. Since the two groups are distinguished on the basis of the science course studied in Grade X, each of the two groups is homogeneous with respect to the variable Course. This homogeneity causes all the correlations with this variable to equal zero. An examination of Tables 3 and 4 reveals that the variables Sex, Teacher, and Age show relatively few significant correlations with other variables. In spite of the significant influence of the different teachers on the performance of Group B students, it was decided to delete these three variables and obtain a new pair of matrices for each group. Because the zero correlations exhibited by the variable Course may have affected the other correlations, this variable was also deleted when the revised tables were obtained.

Table 5 represents the revised correlation matrix for Group A of the CHEMS sample. A comparison with Table 3 reveals that only one coefficient, that of TOUS 3 correlated with Grade IX science, has changed its value. Comparison of Table 6, the revised matrix for Group B, and Table 4 shows that none of the values have changed. Thus at least one of the four factors which were deleted did have an effect on the matrices, but for all practical purposes that effect was negligible. Therefore, if the effects of age, sex and teacher are not

Table 2

Correlation Matrix for the Total CHEMS Sample

N=178

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3	T_T	Age
Sex	1.00																
V	.10	1.00															
Q	.26*	.42*	1.00														
T	.19	.84*	.79*	1.00													
IQ	.10	.60*	.57*	.68*	1.00												
M	.05	.32*	.61*	.53*	.49*	1.00											
S	-.01	.42*	.33*	.42*	.42*	.38*	1.00										
Tea	-.03	-.06	.09	-.09	-.10	-.07	-.15	1.00									
Course	.21*	.25*	.36*	.37*	.31*	.42*	.35*	-.18	1.00								
P	.15	.08	.23*	.16	.10	.08	.10	-.02	.06	1.00							
C	.17	.35*	.44*	.44*	.48*	.31*	.41*	-.20*	.23*	.26*	1.00						
CM	.08	.37*	.50*	.48*	.45*	.55*	.45*	-.20	.36*	.15	.52*	1.00					
T_1	.11	.44*	.21*	.36*	.36*	.30*	.41*	-.25*	.32*	.06	.25*	.34*	1.00				
T_2	.10	.35*	.16	.29*	.30*	.28*	.22*	-.08	.05	.03	.13	.15	.32*	1.00			
T_3	.19	.51*	.37*	.50*	.47*	.32*	.48*	-.13	.28*	.10	.41*	.43*	.34*	.32*	1.00		
T_T	.19	.59*	.34*	.53*	.52*	.40*	.51*	-.21*	.31*	.09	.38*	.43*	.75*	.68*	.80*	1.00	
Age	-.06	-.18	-.22*	-.24*	.41*	-.21*	-.09	.03	-.20	.03	-.16	-.16	-.08	-.12	-.12	-.15	1.00

* Correlation significant at .05 ($r \geq .20$)

Table 3

Correlation Matrix for CHEMS Group A

N=89

* Correlation significant at .05 (r ≥ .22)

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3		Age
Sex	1.00																
V	-.07	1.00															
Q	.05	.34*	1.00														
T	-.04	.85*	.74*	1.00													
IQ	-.08	.63*	.46*	.66*	1.00												
M	-.16	.25*	.58*	.46*	.45*	1.00											
S	-.17	.32*	.15	.24*	.34*	.29*	1.00										
Tea	-.06	.00	-.13	-.06	.01	.01	-.08	1.00									
Course	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
P	.24*	.01	.27*	.12	.07	-.02	.09	-.08	0.00	1.00							
C	.15	.29*	.50*	.46*	.50*	.33*	.36*	-.16	0.00	.15	1.00						
CM	.12	.34*	.47*	.44*	.42*	.42*	.37*	-.08	0.00	.17	.61*	1.00					
T_1	.10	.39*	.11	.27*	.28*	.30*	.32*	-.11	0.00	.02	.15	.29*	1.00				
T_2	.01	.35*	.10	.25*	.17	.19	.14	-.09	0.00	.03	.13	.09	.31*	1.00			
T_3	.09	.41*	.19	.38*	.47*	.22*	.37*	-.02	0.00	.04	.31*	.39*	.36*	.32*	1.00		
T_T	.10	.52*	.19	.41*	.43*	.31*	.39*	-.09	0.00	.04	.28*	.37*	.73*	.67*	.82*	1.00	
Age	.06	-.12	-.11	-.15	-.40	-.07	-.12	-.13	0.00	.02	-.16	.02	-.02	-.06	-.15	-.10	1.00

Table 4

Correlation Matrix for CHEMS Group B

N=89

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3	T_T	Age
Sex	1.00																
V	.13	1.00															
Q	.30*	.39*	1.00														
T	.24*	.82*	.77*	1.00													
IQ	.15	.53*	.57*	.66*	1.00												
M	.04	.24*	.52*	.45*	.41*	1.00											
S	-.03	.40*	.29*	.39*	.36*	.26*	1.00										
Tea	.10	-.02	.07	.00	-.12	.01	-.12	1.00									
Course	.00	.00	.00	.00	.00	.00	.00	.00	0.00								
P	.04	.12	.19	.17	.10	.13	.08	.08	.00	1.00							
C	-.10	.33*	.29*	.34*	.37*	.15	.35*	-.16	.00	.36*	1.00						
CM	-.12	.30*	.41*	.40*	.33*	.52*	.38*	-.24*	.00	.11	.33*	1.00					
T_1	.00	.41*	.10	.29*	.31*	.12	.35*	-.32*	.00	.06	.21	.21	1.00				
T_2	.19	.35*	.19	.32*	.43*	.36*	.28*	-.05	.00	.02	.12	.21	.34*	1.00			
T_3	.19	.54*	.40*	.52*	.37*	.25*	.47*	-.18	.00	.15	.42*	.33*	.19	.32*	1.00		
T_T	.17	.61*	.33*	.53*	.51*	.33*	.52*	-.26*	.00	.11	.36*	.35*	.71*	.72*	.73*	1.00	
Age	-.08	-.16	-.20	-.20	-.36*	-.20	.06	.13	.00	.08	-.08	-.23*	-.05	-.17	.01	-.09	1.00

*Correlation significant at .05 ($r \geq .22$)

desired in a particular study, these variables may be ignored without affecting other results.

Since the revised matrices are more compact than Tables 3 and 4 they may be more suitable for direct comparisons between the two groups of students. For example, the fact that Group B generally had correlations for the TOUS instrument which were more highly significant and also had more correlations which were significant at the five percent level is readily apparent from the revised matrices. Furthermore, of the 78 coefficients in both Tables 5 and 6 not equal to 1.00, 44 of the coefficients in Table 6, for Group B, are larger than the corresponding coefficients for Group A in Table 5 whereas 3 of the values are equal. Thus the similarity of the matrices for the two groups is more striking in the revised tables as are the important characteristics in and differences between Tables 5 and 6.

Because an obvious pattern was established by the t-tests for differences between means, it was decided to attempt an analysis of covariance for certain variables. The computer program selected for this purpose provided the adjusted means for each of the two groups for a criterion variable. This adjustment was based on different values of the means for the two groups of a fixed prior-knowledge variable. The adjusted criteria means were then tested for a significant difference by the t-test. The three criteria variables that were examined were the results of the content-test, the composite marks, and the total scores on the TOUS instrument. These three variables were compared with each of the six prior-knowledge variables to obtain the eighteen pairs of adjusted means listed in Table 7.

Table 5

Correlation Matrix for Thirteen Selected Variables

for Group A of the CHEMS Sample

N=89

	V	Q	T	IQ	M	S	P	C	CM	T_1	T_2	T_3	T_T
V	1.00												
Q	.34*	1.00											
T	.85*	.74*	1.00										
IQ	.63*	.46*	.66*	1.00									
M	.25*	.58*	.46*	.45*	1.00								
S	.32*	.15	.24*	.34*	.29*	1.00							
P	.01	.27*	.12	.07	-.02	.09	1.00						
C	.29*	.50*	.46*	.50*	.33*	.36*	.15	1.00					
CM	.34*	.47*	.44*	.42*	.42*	.37*	.17	.61*	1.00				
T_1	.39*	.11	.27*	.28*	.30*	.32*	.02	.15	.29*	1.00			
T_2	.35*	.10	.25*	.17	.19	.14	.03	.13	.09	.31*	1.00		
T_3	.41*	.19	.38*	.47*	.22*	.38*	.04	.31*	.39*	.36*	.32*	1.00	
T_T	.52*	.19	.41*	.43*	.31*	.39*	.04	.28*	.37*	.73*	.67*	.82*	1.00

* Correlation significant at .05 ($r \geq .22$)

Table 6

Correlation Matrix for Thirteen Selected Variables

for Group B of the CHEMS Sample

N=89

	V	Q	T	IQ	M	S	P	C	CM	T_1	T_2	T_3	T_T
V	1.00												
Q	.39*	1.00											
T	.82*	.77*	1.00										
IQ	.53*	.57*	.66*	1.00									
M	.24*	.52*	.45*	.41*	1.00								
S	.40*	.29*	.39*	.36*	.26*	1.00							
P	.12	.19	.17	.10	.13	.08	1.00						
C	.33*	.29*	.34*	.37*	.15	.35*	.36*	1.00					
CM	.30*	.41*	.40*	.33*	.52*	.38*	.11	.33*	1.00				
T_1	.41*	.10	.29*	.31*	.12	.35*	.06	.21	.21	1.00			
T_2	.35*	.19	.32*	.43*	.36*	.28*	.02	.12	.21	.34*	1.00		
T_3	.54*	.40*	.52*	.37*	.25*	.47*	.15	.42*	.33*	.19	.32*	1.00	
T_T	.61*	.33*	.53*	.51*	.33*	.52*	.11	.36*	.35*	.71*	.72*	.73*	1.00

* Correlation significant at .05 (r ≥ .22)

The t-tests for differences between means indicate that when the Verbal percentile ranks from the SCAT test or the Grade IX mathematics scores are used as the independent variable, the superiority of Group A on the content-test is significant at the five percent level. All other differences between means for the content-test are only significant at the ten percent level. The differences between the means for the composite marks and for the total scores on the TOUS test are at least significant at the five percent level. The differences between the means of Groups A and B on the composite marks, when based on the Verbal percentile ranks, on the Intelligence Quotients, or on the Grade IX science scores, are significantly different at a level of one-tenth of one percent. Another five of the last twelve results show a difference significant at the one percent level.

On the bases of the results of the t-tests for composite marks and the total scores on the TOUS test, it may be said, with at least ninety-five percent certainty, that students from Group A achieved better results in CHEMS and had a better understanding of science than their counterparts in Group B. Since the only difference between the two groups was the particular Grade X science program that was experienced by each group, it may be concluded that the IPS program in Grade X provides a better background for Grade XI CHEMS achievement than the program based on the Hedley textbook. The parallelism of the differences between the means for the TOUS instrument subtests presented in Table 1 of this study and in Tables 2 and 4 of the Charlesworth study leads to the further conclusion that any increased understanding of science, gained by the IPS students, was maintained even after both groups of students experienced a full year in a different

Table 7

Analysis of Covariance for Selected CHEMS Variables

$N_{A'}=89$, $N_{B'}=89$

Controlled Variable	Variable	Adjusted Mean A	Adjusted Mean B	t-test
V	C	17.63	15.77	2.69*
Q	C	17.31	16.09	1.75
T	C	17.31	16.08	1.77
IQ	C	17.32	16.07	1.89
M	C	17.50	15.89	2.14*
S	C	17.38	16.01	1.95
V	CM	61.84	54.52	4.10*
Q	CM	60.81	55.55	2.97*
T	CM	60.93	55.43	3.09*
IQ	CM	61.31	55.05	3.53*
M	CM	60.20	56.16	2.27*
S	CM	61.15	55.21	3.30*
V	T_T	35.39	33.24	2.84*
Q	T_T	35.62	33.01	2.86*
T	T_T	35.17	33.46	2.06*
IQ	T_T	35.32	33.31	2.46*
M	T_T	35.36	33.27	2.27*
S	T_T	35.24	33.39	2.21*

* Difference significant at .05

($t \geq 1.96$)

laboratory-oriented science course.

Analysis of the PSSC Sample

Table 8 gives the means, standard deviations, and t-tests for differences between the means for Groups A and B of the PSSC sample. A comparison of Tables 1 and 8 immediately indicates that the PSSC students, from both groups, were superior to the respective groups of students in the CHEMS sample. Both groups of PSSC students had higher results on all of the prior-knowledge variables than did the comparable groups of the CHEMS students. This might indicate that PSSC is acceptable for only a select, highly capable group of students. Further examination of the table reveals that the PSSC students also scored much higher than the CHEMS students on all six criteria variables. The average PSSC student may therefore be more intelligent, achieve better grades, and have a better appreciation of science than the average CHEMS student. One factor influencing the results concerning student understanding of science may be that all the PSSC students studied a second Grade XI science course and approximately a third of these students studied all three science courses offered in the Grade XI matriculation program. If only two sciences were studied, the second course was generally the CHEMS program. One other factor is indicated in Table 8. The proportion of males in both groups is much higher than the proportion of males studying CHEMS.

Analysis of Table 8 alone again indicates that although Group A was generally superior to Group B on both the prior-knowledge and criteria variables, there are some exceptions to this tendency. The means for Grade IX science, TOUS 2 and TOUS 3 are higher for the

Table 8

Means, Standard Deviations and t-tests for Differences

Between the Means for the PSSC Sample

Variables		Group A, N_A=59		Group B, N_B= 13		
List	Code	Mean	s.d.	Mean	s.d.	t-test
Verbal	V	83.58	13.65	69.15	26.25	1.93
Quantitative	Q	80.29	18.89	76.38	17.90	.71
Total	T	86.17	12.58	74.85	23.99	1.66
Intelligence Quotient	IQ	129.10	12.58	125.31	15.47	.83
IX Mathematics	M	81.59	10.19	76.92	16.06	1.00
IX Science	S	68.59	11.46	69.31	12.48	-.19
Pre-test	P	2.73	2.41	1.85	1.91	1.43
Content-test	C	22.88	6.44	22.31	7.38	.26
Composite Mark	CM	66.64	10.38	58.92	11.76	2.18*
TOUS 1	T_1	12.36	2.58	11.00	2.65	1.68
TOUS 2	T_2	12.24	1.72	12.38	1.85	-.25
TOUS 3	T_3	13.63	3.22	13.77	3.42	-.14
TOUS Total	T_T	38.22	5.45	37.15	6.09	.59
Age	Age	16.41	.59	16.38	.77	-
Sex	Sex	.80	.41	.77	.44	-
Teacher	Tea.	2.08	.82	1.92	.76	-

* Difference significant at .05

($t \geq 2.00$)

Group B students. The differences between the means are significant only at low values for this sample in contrast to the results of the t-tests for the CHEMS sample. In fact, the means for only one variable, the composite marks, had a t-test result significant at the five percent level; and only three more variables, the Verbal, and the Total percentile ranks of the SCAT test, and TOUS 1, had results significant at a level as high as ten percent.

In spite of these initial results, further analysis of the PSSC sample was carried out. Since some difference did exist in the prior-knowledge variables it was believed that a pairing of the students from the two groups might affect the differences between the means. The pairing was carried out on the bases of the Intelligence Quotients and the Total score of the SCAT test. It was possible to obtain only eleven pairs of students because two of the Group B students had such low Intelligence Quotients that none of the Group A students came within fifteen points of these two Group B values. The results of the analysis of the eleven pairs of students are given in Table 9. Although it was not possible to obtain a perfect matching of all prior-knowledge variable, the differences between the means of these variables for the two subgroups are statistically insignificant. The criteria variables also exhibit insignificant differences between their means. Thus Table 9 indicates that those students who completed Grade XI PSSC were only slightly affected by Grade X IPS. Perhaps these students had sufficient innate intelligence to learn regardless of the type of program presented to them the previous year.

Further contrasts with the CHEMS sample are apparent upon examination of the correlation matrix presented in Table 10. The most

Table 9

Means, Standard Deviations and t-tests of Differences

Between Means for Groups A' and B' of the PSSC Sample

	Group A', $N_{A'}$=11		Group B', $N_{B'}$=11		
Variable	Mean	s.d.	Mean	s.d.	t-test
V	80.00	14.70	77.64	17.70	.34
Q	80.74	16.69	81.56	12.21	-.13
T	82.64	14.23	83.00	14.54	-.06
IQ	127.00	12.19	128.45	14.48	-.25
M	80.74	7.67	82.27	10.24	-.40
S	67.36	10.08	71.00	12.82	-.54
P	2.26	2.210	2.00	2.05	.03
C	26.73	6.01	23.45	7.43	1.14
CM	66.00	9.30	61.09	11.61	1.09
T_1	11.91	2.54	11.18	2.86	.63
T_2	11.82	.94	12.36	1.68	-.93
T_3	13.91	4.23	14.09	3.62	-.01
T_T	37.64	5.65	37.64	6.36	0.00

* Difference significant at .05

($t \geq 2.09$)

Table 10

Correlation Matrix for the Total Sample

N=72

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3	T_T	Age
Sex	1.00																
V	-.29*	1.00															
Q	-.09	.37*	1.00														
T	-.25*	.84*	.72*	1.00													
IQ	-.19	.60*	.44*	.63*	1.00												
M	-.22	.44*	.57*	.59*	.47*	1.00											
S	-.27*	.33*	.13	.25*	.29*	.28*	1.00										
Tea	.12	-.11	-.08	-.11	-.13	-.24*	-.22	1.00									
Course	.03	.32*	.08	.28*	.11	.16	-.02	.08	1.00								
P	.26*	.10	.29*	.21	.12	.05	.05	-.11	.15	1.00							
C	-.37*	.24*	.33*	.37*	.45*	.30*	.37*	.06	.03	.03	1.00						
CM	-.07	.40*	.46*	.48*	.36*	.37*	.37*	.07	.27*	.03	.37*	1.00					
T_1	-.10	.29*	.08	.25*	.33*	.27*	.33*	.04	.20	.11	.06	.28*	1.00				
T_2	-.04	.23*	.01	.12	.07	.00	-.01	-.07	-.03	-.02	-.15	-.01	.22	1.00			
T_3	-.10	.39*	.11	.34*	.42*	.11	.47*	-.21	-.02	.01	.28*	.35*	.34*	.23*	1.00		
T_T	-.09	.44*	.11	.35*	.42*	.19	.43*	-.13	.07	.05	.14	.33*	.74*	.55*	.82*	1.00	
Age	-.05	-.10	-.08	-.10	-.26*	-.09	.07	-.07	.01	.12	.01	-.11	-.04	-.06	-.04	-.06	1.00

* Correlation significant at .05 (r ⩾ .23)

obvious difference between Tables 2 and 10 is that Table 10 contains fewer correlations which are significant at the five percent level. The correlations between prior-knowledge variables and the TOUS instrument are not significant to the same degree. Also, there is a complete lack of significant correlations between the course teacher and the criteria variables.

The total PSSC sample was divided in the same manner as the CHEMS sample and correlation matrices were obtained for each group. Table 11 gives the correlation coefficients for Group A, and Table 12 gives those for Group B of the PSSC sample. As with the CHEMS sample, the number of significant correlations decreased when the sample was subdivided. Though Group A did not show too great a change from the matrix for the entire sample, Group B revealed a drastic reduction in the number of significant correlations from the total sample. In the CHEMS sample the opposite was true. The Group B correlation matrix showed the greater stability. For the PSSC sample neither group had the significant correlations between the course teacher and the criteria variables that were evident for Group B of the CHEMS sample. This would indicate that the performance of PSSC students was not noticably influenced by any particular instructor. One basic and expected similarity with the CHEMS sample is the significant correlation that exists in both groups between the content-test and the composite mark.

From Table 12 it would appear that, for Group B, ability and achievement are not significantly correlated. This is in contrast with the correlation evident in Group A of the PSSC sample and in both groups of the CHEMS sample. A possible explanation for this discrepancy may be the high value of the coefficient 0.55 which is required so that

Table 11

Correlation Matrix for PSSC Group A

N=59

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3	T_T	Age
Sex	1.00																
V	-.23	1.00															
Q	-.07	.25	1.00														
T	-.20	.72*	.71*	1.00													
IQ	-.15	.57*	.41*	.61*	1.00												
M	-.25	.27*	.52*	.46*	.45*	1.00											
S	-.19	.31*	.14	.24	.30*	.33*	1.00										
Tea	.11	-.19	-.11	-.20	-.17	-.39*	-.30*	1.00									
Course	.00	.00	.00	.00	.00	.00	.00	.00	0.00								
P	.31*	-.01	.26	.14	.04	-.03	.13	-.07	.00	1.00							
C	-.33*	.10	.29*	.29*	.44*	.28*	.36*	.05	.00	.06	1.00						
CM	.06	.29*	.49*	.44*	.36*	.31*	.34*	.01	.00	.06	.27*	1.00					
T_1	-.03	.11	.02	.10	.25	.28*	.27*	-.06	.00	.09	-.03	.23	1.00				
T_2	.05	.25	-.07	.05	.00	.01	.00	-.11	.00	-.08	-.17	.06	.17	1.00			
T_3	.02	.42*	.06	.33*	.50*	.15	.45*	-.24	.00	.02	.19	.36*	.32*	.26	1.00		
T_T	.01	.38*	.03	.26	.41*	.23	.39*	-.20	.00	.03	.05	.34*	.72*	.55*	.82*	1.00	
Age	-.08	-.20	-.13	-.18	-.27*	.00	.07	.03	.00	.13	-.02	-.07	-.03	-.10	-.19	-.16	1.00

*Correlation significant at .05 (r ⩾ .27)

Table 12

Correlation Matrix for PSSC Group B

N=13

	Sex	V	Q	T	IQ	M	S	Tea	Co	P	C	CM	T_1	T_2	T_3	T_T	Age
Sex	1.00																
V	-.55*	1.00															
Q	-.19	.74*	1.00														
T	-.46	.96*	.88*	1.00													
IQ	-.36	.71*	.57*	.71*	1.00												
M	-.18	.66*	.77*	.77*	.50	1.00											
S	-.61*	.50	.13	.37	.28	.20	1.00										
Tea	.19	-.05	.00	.00	-.07	.17	.16	1.00									
Course	.00	.00	.00	.00	.00	.00	.00	.00	0.00								
P	-.05	.28	.47	.36	.41	.27	-.34	-.47	.00	1.00							
C	-.64	.58*	.52	.62*	.50	.35	.45	.11	.00	-.14	1.00						
CM	-.65*	.49	.35	.48	.29	.48	.61*	.22	.00	-.40	.76*	1.00					
T_1	-.43	.59*	.29	.50	.57*	.16	.66*	.41	.00	.02	.41	.26	1.00				
T_2	.02	.30	.42	.32	.33	.00	-.07	.14	.00	.37	-.07	-.27	.49	1.00			
T_3	-.59*	.48	.36	.45	.14	.03	.56*	-.07	.00	.02	.61*	.39	.50	.09	1.00		
T_T	-.52	.61*	.45	.57*	.43	.09	.58*	.18	.00	.13	.50	.25	.86*	.57*	.81*	1.00	
Age	.04	.03	.11	.02	-.25	-.30	.08	-.52	.00	.10	.10	-.25	-.08	.06	.48	.25	1.00

* Correlation significant at .05 ($r \geq .55$)

any particular value is significant when the sample size is thirteen.

The deletion of the Sex, Age, Teacher, and Course variables would again leave 78 coefficients as in the revised Tables, 5 and 6, of the CHEMS sample. Of these coefficients, 62 from Table 12 are larger than the corresponding values for Group A in Table 11, and one value is the same in both tables. Hence the scores of the Group B students in both CHEMS and PSSC would appear to be more predictable than the scores of Group A students. Since there was little effect upon the CHEMS matrices when the aforementioned variables were deleted, no revised matrices were obtained for the PSSC sample.

Chapter 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

In this investigation, 178 students who were enrolled in a Grade XI chemistry course, CHEMS, and 72 students in a Grade XI physics course, PSSC, were given the Test On Understanding Science and an appropriate objective content-test. Of the CHEMS students, 89 students had been enrolled the previous school year in the Grade X science program known as Introductory Physical Science. Only 59 of the PSSC students had studied the same program whereas the remainder of the students in both samples had been enrolled in the Grade X science program based on the textbook An Introduction to Physical Science. All students in both samples attended Kelvin High School in Winnipeg, Manitoba, for both Grades X and XI, and had previously written common, externally set and marked examinations in mathematics, science and mental aptitude.

The general purpose of this study was to examine pupil achievement in senior high school science programs after one of two different preparatory science courses in Grade X were studied, and to determine whether or not either preparatory science program made a marked contribution to the student's understanding of science. The content-tests in the two subject areas were given in order to evaluate the primary aim of this paper. Results from these tests were corroborated by using the composite marks obtained by each student near the end of Grade XI. These subject marks reflected each student's performance throughout the academic year and were used to exempt those students, attaining more than 67%, from writing the final examinations. Thus two criteria of performance were used: one entirely objective; the second, at least partially subjective.

The second test given to the students is not course-oriented. The items in Test On Understanding Science are intended to reflect a general appreciation of scientific method.

Since other scholastic factors in the years immediately prior to this study were similar for all students, only the Grade X science course should be responsible for any variation in results between students in both samples. Hence the two groups of students in each sample were selected on the basis of the program followed in Grade X science. Those students who had studied the Introductory Physical Science program were placed in Group A whereas the students who had taken the other course formed Group B in both samples.

The null hypotheses tested in this study were presented in Chapter 2 and are reproduced here together with the results determined by the evaluation.

1. There is no significant difference in student achievement in CHEMS or PSSC as a result of different Grade X science programs.

In the CHEMS sample, the scores of students in Group A were consistently and significantly higher than the scores of Group B on both the content-test and the composite marks. No significant or consistent difference was observed between the students in the PSSC sample. Thus the null hypothesis can be rejected only for the CHEMS sample; for these students, the Introductory Physical Science program was apparently a more adequate preparatory science program.

2. There is no significant difference in student understanding of science, after the completion of CHEMS and/or PSSC, as a result of different Grade X science programs.

The students of Group A again achieved significantly higher scores on the TOUS instrument in the CHEMS sample. The difference in the scores of the two groups of the PSSC sample were again inconsistent and insignificant. Therefore, once more, the hypothesis can be rejected only for the CHEMS sample. Hence CHEMS students had a greater understanding of science if they had studied the Introductory Physical Science program in Grade X.

3. There is no significant difference in student achievement as a result of partially subjective grading as opposed to totally objective grading.

For each group, in both the CHEMS and PSSC samples, there was a significant, positive correlation between student scores on the content-test and the results of the student's composite marks. Because the correlations between the two variables were significant, the variables must have measured the same factors of student ability; therefore, the hypothesis is accepted.

Examination of the correlation matrices also revealed significant correlations between most of the prior-knowledge variables and the two achievement criteria. Because of the small number of students in Group B of the PSSC sample, this relationship was not significant for that group. Further examination of the matrices presented in Chapter 3 showed that most of the prior-knowledge variables were significantly correlated with each other and with the TOUS instrument, and that the TOUS instrument itself had significant inter-correlations. Thus TOUS was a relatively consistent measure of a student's general appreciation of science. There were fewer significant correlations, however, between TOUS and the achievement variables. Also, Group B of both the CHEMS and PSSC samples generally showed higher correlations for TOUS with the other variables than did Group A; therefore, the results of Group B students were more predictable.

Conclusions

It has been shown that CHEMS students achieved significantly better if their Grade X science program had been Introductory Physical Science rather than the program based on the textbook An Introduction to Physical Science. This difference in achievement was apparent regardless of whether the content-test or the composite mark was used as the criterion. However, the degree of significance varied, and was most significant when the composite mark was the criterion. The composite mark, therefore, provided the more reliable criterion in this study.

Group A CHEMS students also had a superior understanding of science. Charlesworth showed that a similar difference existed after students had completed the Grade X science programs. This superiority gained through the study of the Introductory Physical Science program, was evidently maintained after both groups had studied a common, laboratory-oriented program in Grade XI.

No conclusions paralleling the CHEMS results can be made for the PSSC sample. Although the achievement scores for the Group A students were higher than those for Group B, and although the difference between the composite mark means was significant at the five percent level, the differences between the two groups were not significant when adjustments were made to correct for differences in prior-knowledge. When adjusted values were considered, the differences between the means of all variables for the two groups were neither consistent nor significant.

It may therefore be concluded that the Introductory Physical Science program is beneficial to the achievement of the majority of students in Grade XI CHEMS. However, since all PSSC students also studied CHEMS and/or BSCS, either their natural ability or the number of science courses studied reduced the difference in the performance of the two groups on every criterion variable. Therefore, the recent course changes instituted by the Department of Education in the Grade X science program of the matriculation course have been at least partially justified by the improved achievement and comprehension of science demonstrated by the Grade XI CHEMS students.

This study has again shown that it is possible to evaluate on an objective basis the effects or suitability of a particular science course. The statistical techniques used in this study could be used in curriculum research in other subject fields.

Recommendations

The CHEMS correlation matrices indicated that different Group B students, taught by one of the three different chemistry teachers, showed achievement levels significantly affected by the particular teacher they studied under. Such an effect may be due only to the grouping of the students to form instructional units, but the negative correlations between the Teacher variable and the achievement variables more likely stemmed from student attitudes toward science, student-teacher relationships, and the resulting teacher effectiveness. Since there were no significant relationships for the Group A students, all teachers must have been equally effective with their better students. In contrast, the PSSC teachers appeared to be uniformly effective with all students. It is therefore recommended that a more carefully controlled study be undertaken in order to gauge teacher effectiveness upon various types of students. The results from such a study would allow teacher and student placement that are more appropriate, and thereby foster learning situations that are more effective. An alternative approach to achieve the same result would be to ensure that each instructional unit be taught by at least two different teachers during a school year. This is one of the advantages, maintained for team-teaching, which was confirmed by the evidence available in this study.

It is recommended that another analysis of the students in the CHEMS sample of this study be conducted when these students complete the Grade XII chemistry program in June, 1970. Such an analysis would determine whether or not the differences in achievement in and understanding of science are maintained for another year. Natural attrition of the PSSC sample renders difficult a similar analysis for those students.

Revisions of the Introductory Physical Science program are inevitable. The effectiveness of any revision of this program, regardless of the magnitude of the change, should be evaluated immediately. Use of the TOUS test would provide an appraisal of the effect of a new course, by the end of the first year of a pilot program, upon student understanding of science. Unfavorable results at that time would allow schools, by the start of the subsequent school year, to revert to the older program or to adopt an alternative revision. If, on the other hand, the revision appeared successful, evaluations concerning the effective preparation of students for successive courses should be conducted when the school year is nearly completed. Again, if the present facilities are considered, there is no reason for the results and subsequent decisions not being available so that these decisions could be implemented in time for the succeeding school year. Since the Department of Education has used only subjective evaluations of pilot programs up to the present time, it is recommended that objective studies, such as those described in this paper, be conducted prior to the acceptance of any new program.

BIBLIOGRAPHY

BIBLIOGRAPHY

Charlesworth, Kenneth H., "An Investigation of Student Achievement in and Attitude Toward Grade Ten Science Programs in Manitoba Secondary Schools." An unpublished M.Ed. thesis in Education, University of Manitoba, Winnipeg, Manitoba, 1969.

Cooley, William W., and Leo E. Klopfer. Manual for Administering, Scoring and Interpreting Scores on Test on Understanding Science, Form W. Princeton: Educational Testing Service, 1961.

Dominion Tests, The. Manual of Directions. The Ontario Institute for Studies in Education, 1966.

Felton, Harry U. Personal letter to the author dated November 29, 1968.

Haber-Schaim, Uri, "Objectives and Content of the Course," A Progress Report, IPS Group, Education Development Center, 55 Chapel Street, Newton Massachusetts, undated, received September 30, 1969.

Haber-Schaim, Uri, "The What and Why of PS II," A Progress Report, IPS Group, Education Development Center, 55 Chapel Street, Newton Massachusetts, undated, received September 30, 1969.

Initial Report, University Entrance Course Seminar, Manitoba Teachers College, 22 July-2 August, 1963, mimeographed.

Minutes, Joint Physics-Chemistry Curriculum Revision Committee, February 1, 1966, mimeographed.

Program of Studies, General Course, Grades 10, 11 and 12, 1968-1969. Winnipeg: Queen's Printer, 1968.

SCAT. Directions for Administrating and Scoring Cooperative Test Division, Princeton: Educational Testing Service, 1957.

APPENDIX

ANALYSIS OF VARIANCE FOR THE CHEMS AND PSSC SAMPLES

The analysis of variance, rotated factor matrix, for the entire CHEMS sample, Group A and Group B respectively are presented in Tables 13-15. Only six factors contributed more than five percent of the variability of the scores for the variables listed. Together these six factors accounted for approximately seventy percent of the total variability. The first factor in each table showed a strong relationship to the mental ability and performance scores, and accounted for approximately thirty percent of the variability of the scores for each group.

When the variables Age, Sex and Teacher were deleted from the data, the analyses of variance for Groups A and B of the CHEMS sample altered the tables substantially. These revised tables, 16 and 17, indicated that the mental aptitude factor now accounted for more than forty percent of the variance for both groups, and the total variability accounted for exceeded eighty percent. In all five of these tables the second factor appeared to be related to student achievement on TOUS.

Tables 18-20 present the results of the analysis of variance for the PSSC sample. In the first two tables seven factors were required to account for more than seventy percent of the variability. Table 20, however, accounted for more than eighty percent of the variability of Group B students in this sample with only five factors.

In all three tables the first factor was again closely related to mental aptitude and was also the most important factor. Factor two of Tables 18 and 19 again seemed to be related to the TOUS scores. In Table 20 such a relationship did not appear until factor four was analyzed.

Table 13

Analysis of Variance for the Total CHEMS Sample

on Seventeen Variables

Variable \ Factor	1	2	3	4	5	6
V	.42	-.63	.20	-.19	.08	-.20
Q	.75	-.13	.14	-.28	-.19	-.22
T	.68	-.44	.22	-.25	-.06	-.26
IQ	.53	-.42	.03	-.20	.07	-.49
M	.78	-.18	.01	.07	-.01	-.09
S	.52	-.42	-.23	-.13	.25	.13
P	.04	.00	-.01	-.81	-.16	.10
C	.42	-.20	-.28	-.57	.04	-.17
CM	.68	-.20	-.26	-.24	.10	-.03
T_1	.25	-.66	-.34	.08	-.07	.09
T_2	-.06	-.76	.05	.05	-.08	-.15
T_3	.33	-.66	-.09	-.21	-.05	-.01
T_T	.26	-.92	-.18	-.05	-.08	-.02
Age	-.14	.04	.11	-.08	.05	.90
Sex	.07	-.13	.00	-.17	-.90	-.03
Tea	-.02	.10	.82	.10	.00	.09
Course	.65	-.06	-.34	.19	-.35	.01
Cumulative % Variability Accounted for	37.0	46.2	53.5	60.3	66.4	71.7

Table 14

Analysis of Variance for Group A of the CHEMS Sample

on Seventeen Variables

Variable \ Factor	1	2	3	4	5	6
V	.65	.52	-.09	.19	.02	.01
Q	.84	-.06	.20	-.03	-.22	-.11
T	.90	.29	.03	.13	-.06	-.03
IQ	.61	.27	-.03	.46	-.31	.08
M	.60	.12	-.24	-.19	-.40	.12
S	.03	.28	-.21	.17	-.73	-.14
P	.14	-.05	.64	.05	-.08	-.18
C	.43	.05	.27	.17	-.61	-.13
CM	.41	.15	.23	-.15	-.68	.06
T_1	.10	.72	-.01	-.21	-.25	.01
T_2	.15	.72	-.01	.04	.17	-.17
T_3	.11	.68	.12	.22	-.37	.12
T_T	.16	.94	.06	.05	-.25	.00
Age	-.08	-.01	.03	-.89	.06	-.09
Sex	-.10	.13	.84	-.10	.04	.11
Tea	-.02	-.07	-.07	.10	.09	.93
Cumulative % Variability Accounted for	31.2	41.9	50.9	57.7	64.1	69.5

Table 15

Analysis of Variance for Group B of the CHEMS Sample

on Seventeen Variables

Variable \ Factor	1	2	3	4	5	6
V	.79	.27	.01	-.05	-.02	-.08
Q	.71	-.02	-.18	.11	-.36	.30
T	.89	.14	-.07	.03	-.23	.13
IQ	.60	.29	-.10	.06	-.44	-.02
M	.30	.29	-.13	.54	-.37	.40
S	.56	.28	-.06	.36	.28	-.13
P	.02	.05	-.90	.01	.05	.14
C	.42	.02	-.65	.05	-.04	-.32
CM	.38	.10	-.17	.67	-.28	-.11
T_1	.21	.66	-.03	.05	.04	-.40
T_2	.16	.87	.00	.01	-.18	.16
T_3	.71	.27	-.18	.01	.17	-.15
T_T	.52	.80	-.11	.03	.03	-.20
Age	-.06	-.04	-.07	.00	.85	.17
Sex	.27	.12	.13	-.69	-.24	.20
Tea	.00	-.13	.01	-.16	.18	.80
Cumulative % Variability Accounted for	32.8	42.8	50.9	58.7	64.8	70.2

Table 16

Analysis of Variance for Group A of the CHEMS Sample

on Thirteen Variables

Variable \ Factor	1	2	3	4	5	6
V	.90	-.24	.06	-.02	.02	-.22
Q	.43	-.02	.34	.28	.67	.14
T	.86	-.15	.21	.11	.35	-.01
IQ	.70	-.10	.40	-.04	.17	-.18
M	.15	-.10	.22	-.12	.85	-.23
S	.14	.02	.45	.03	-.02	-.69
P	.02	-.01	.10	.98	.00	-.04
C	.22	-.08	.82	.08	.21	.01
CM	.16	-.07	.71	.11	.30	-.23
T_1	.16	-.40	-.10	.03	.24	-.75
T_2	.10	-.89	-.03	.03	.12	.03
T_3	.28	-.57	.47	-.06	-.16	-.30
T_T	.26	-.81	.21	-.01	.05	-.47
Cumulative % Variability Accounted for	40.3	54.4	63.1	70.8	77.6	83.1

Table 17

Analysis of Variance for Group B of the CHEMS Sample

on Thirteen Variables

Variable / Factor	1	2	3	4	5	6
V	.74	.30	-.02	-.08	-.36	.15
Q	.76	-.14	-.13	.42	-.09	.03
T	.91	.10	-.07	.18	-.23	.10
IQ	.70	.19	-.09	.23	-.11	.25
M	.31	-.08	-.07	.78	.04	.34
S	.15	.28	.03	.30	-.69	.06
P	.08	.00	-.94	.04	.01	.05
C	.19	.14	-.57	.13	-.54	-.09
CM	.16	.16	-.06	.79	-.33	-.04
T_1	.15	.92	-.05	.05	-.12	.22
T_2	.16	.17	.01	.15	-.10	.90
T_3	.35	-.11	-.10	.01	-.78	.34
T_T	.32	.45	-.07	.09	-.49	.64
Cumulative % Variability Accounted for	42.0	53.4	62.7	70.3	76.9	82.6

Table 18

Analysis of Variance for the Total PSSC Sample

on Seventeen Variables

Variable / Factor	1	2	3	4	5	6	7
V	-.70	.30	-.19	-.06	-.23	-.30	.00
Q	-.85	-.05	.22	.03	.04	.10	.02
T	-.91	.17	-.03	-.01	-.11	-.17	.02
IQ	-.68	.37	-.05	-.04	.03	.03	-.24
M	-.70	.08	-.11	-.27	.11	-.16	-.08
S	-.18	.67	-.16	-.22	.38	.07	.16
P	.26	.04	.76	-.10	.04	-.04	.31
C	-.50	.26	-.25	.29	.42	.27	.17
CM	-.49	.41	.05	.26	.30	-.20	-.11
T_1	-.09	.69	.03	.05	.13	-.37	-.03
T_2	-.06	.28	-.01	.02	-.85	.08	.00
T_3	-.18	.82	-.01	-.07	-.08	.17	-.03
T_T	-.17	.90	.00	-.01	-.37	-.05	-.03
Age	.14	-.01	.02	-.04	.02	-.04	.92
Sex	.27	-.07	.79	.09	-.07	-.04	-.23
Tea	.11	-.11	-.01	.93	.00	-.10	-.05
Course	-.18	.02	.06	.09	.07	-.88	.05
Cumulative % Variability Accounted for	29.8	41.9	51.1	58.7	65.9	72.1	77.1

Table 19

Analysis of Variance for Group A of the PSSC Sample

on Seventeen Variables

Variable \ Factor	1	2	3	4	5	6	7
V	.34	-.04	-.11	.11	-.12	-.14	.80
Q	.91	.06	.13	.04	-.03	-.07	-.04
T	.76	.02	.01	.11	-.09	-.17	.51
IQ	.47	-.22	-.06	.35	-.09	-.45	.32
M	.68	-.26	-.26	-.05	-.45	-.12	-.11
S	.06	-.34	.06	-.19	-.33	-.64	.18
P	.18	.03	.81	-.23	-.11	-.12	.00
C	.26	.03	-.15	.00	.13	-.79	-.02
CM	.56	-.37	.15	.01	.26	-.24	.13
T_1	.14	-.87	-.03	-.03	-.04	.01	-.12
T_2	-.08	-.41	-.08	-.07	.00	.43	.57
T_3	-.03	-.57	.13	.25	-.12	-.39	.50
T_T	.02	-.87	.04	.11	-.09	-.09	.42
Age	-.08	.04	.03	-.91	.01	-.05	-.09
Sex	-.11	-.09	.76	.23	.13	.31	-.12
Tea	-.07	.07	-.03	-.03	.93	.01	-.13
Cumulative % Variability Accounted for	27.3	40.1	48.8	57.0	63.9	69.7	74.9

Table 20

Analysis of Variance for Group B of the PSSC Sample

on Seventeen Variables

Variable \ Factor	1	2	3	4	5
V	-.73	.16	.01	.31	-.47
Q	-.93	.07	.19	.24	-.03
T	-.87	.12	.05	.27	-.33
IQ	-.57	.31	-.36	.38	-.33
M	-.90	-.06	-.25	-.09	-.06
S	-.07	-.22	.05	.17	-.83
P	-.36	.75	-.01	.31	.29
C	-.52	-.18	.21	-.03	-.64
CM	-.44	-.33	-.12	-.29	-.73
T_1	-.16	-.19	-.09	.77	-.53
T_2	-.17	.08	.04	.86	.21
T_3	-.17	-.01	.61	.26	-.64
T_T	-.22	-.06	.32	.75	-.53
Age	.08	.23	.93	.03	.00
Sex	.13	-.26	.05	-.05	.88
Tea	-.06	-.88	-.31	.29	.04
Cumulative % Variability Accounted for	38.9	54.3	67.2	77.9	83.7