AN INVESTIGATION OF STUDENT ACHIEVEMENT IN AND ATTITUDE TOWARD GRADE TEN SCIENCE PROGRAMS IN MANITOBA SECONDARY SCHOOLS

A THESIS

Presented to
the Faculty of Graduate Studies and Research
The University of Manitoba

In Partial Fulfillment
of the Requirements for the Degree of
Master of Education

by

Kenneth Harold Charlesworth

June 1969

ABSTRACT

AN INVESTIGATION OF STUDENT ACHIEVEMENT IN
AND ATTITUDE TOWARD GRADE TEN
SCIENCE PROGRAMS IN
MANITOBA SECONDARY SCHOOLS

by Kenneth Harold Charlesworth

The purpose of the study was to examine student achievement in and student attitude toward three grade ten science programs in Manitoba schools.

A total group of 1,396 students enrolled in grade ten was obtained from eighteen schools selected so that the sample population would be fairly representative of the student population in the Province. Of these students 455 were enrolled in the program known as I.P.S. - Introductory Physical Science developed by Educational Services Incorporated of Watertown, Massachusetts, U.S.A. Another group of 496 students followed the program based on the textbook An Introduction to Physical Science by R.L. Hedley while the remaining 445 students followed the traditional program using the textbook Everyday Problems in Science by Beauchamp, Mayfield and West. All students were enrolled in grade ten for the first time.

From the scores of common achievement tests administered to all students in the province at the ninth grade level, prior knowledge scores were obtained in mathematics and science. In addition Intelligence Quotients were calculated from The Lorge-Thorndike mental

ability test, level 5 form A verbal which had been administered at the same time as the grade nine achievement tests. Two separate criterion tests were used. One, a Test On Understanding Science, by Cooley and Klapfer yielded scores on pupil understanding of the scientific enterprise, the aims and methods of science and the role of scientists, while the other a Student Attitude Toward Science instrument, by Hedley provided a measure of student acceptance of text material, course content, laboratory work, interest in the course, involvement and satisfaction of perceived needs. With the addition of Age and Sex factors a total of sixteen variables was available for consideration.

A correlation matrix of the sixteen variables was examined for significant correlations. The mean scores and standard deviations of each of the three groups was calculated for the sixteen variables. Using the means and standard deviations of the sixteen variables for each group, t-tests of differences between means of each group were calculated. This analysis disclosed a slight variation in prior knowledge between the three groups and to overcome this discrepancy sub-groups were chosen within each of the original groups. Means and standard deviations were calculated for each of the sub-groups and utilizing the new means and standard deviations, t-tests of differences between means for each of the sixteen variables of each group were again calculated. A multiple regression analysis of each of the eleven dependent variables on the five independent variables, i.e. prior knowledge in mathematics and science scores, I.Q., Age and Sex, was conducted for each group together with an analysis of variance.

The students following the program known as I.P.S., Introductory Physical Science, had very positive and significant correlation coefficients indicating a general acceptance of the program being followed. This was in marked contrast to the results obtained from the other two programs. Also the scores of the students following the I.P.S. program were consistently and significantly higher than the scores obtained by the students in the other two groups. In general the scores of the students following the program based on the textbook An Introduction to Physical Science by R.L. Hedley were significantly higher than the scores obtained by the students enrolled in the program based on the textbook Everyday Problems In Science by Beauchamp, Mayfield and West.

The results of the multiple regression analysis and the analysis of variance indicated that the five predictor variables, when used together, are very significant in predicting the results on the sub-tests of the Test On Understanding Science. The same analysis when applied to the results of the sub-tests of the Student Attitude Toward Science instrument showed that the five predictor variables, although still significant, were not of the same degree of importance.

The study showed that it is possible to evaluate different science courses on other than a subjective basis, to show which are effective and acceptable to students.

ACKNOWLEDGEMENTS

It is with considerable gratitude that the writer wishes to acknowledge the assistance of Dr. R.L. Hedley who, as friend and chairman, exhibited remarkable patience and understanding as well as providing much needed counsel and encouragement.

Professor C.C. Wood and Professor M. McPherson, as members of my advisory committee, have been of great assistance in advising and in planning my study.

The writer would also like to acknowledge the assistance of Dr. D. Hemphill and Dr. F. Chebib with the statistical analysis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Statement of the Problem

It is the purpose of this study to examine student achievement in and student attitude toward three grade ten science programs.

The major course of study to be investigated is known as I.P.S. - Introductory Physical Science, and was developed by Educational Services Incorporated of Watertown, Massachusetts, U.S.A. This course was deliberately designed to form an adequate base upon which the newer high school science programs, CHEMS - the Chemical Education Material Study, P.S.S.C. Physics - the Physical Science Study Committee's program in physics, and B.S.C.S. Biology - the Biological Sciences Curriculum Study, could rest. Experience both in Manitoba and the United States has shown the students' inability to handle the laboratory assignments connected with new science programs of the senior high school within the time limits of a class period. There is a real need to find a satisfactory program to remedy this situation.

Comparisons of student achievement in and acceptance of the program will be made between groups of students taking the I.P.S. program and two other programs also authorized for use in grade ten of the University Entrance program in Manitoba schools. The first of these other programs uses the textbook <u>An Introduction to Physical</u>

Science by R.L. Hedley. This program attempts to provide the student with a body of scientific knowledge as a basis for future training in technical fields. As well, it is trying to develop in the student a favourable attitude towards science, and an appreciation of the nature and role of science in effective citizenship. The final program to be considered is the traditional Matriculation General Science program which since 1948 has made use of the textbook Everyday Problems in Science by Beauchamp, Mayfield and West.

The Importance of the Study

With the acceptance of the newer science courses, CHEMS, P.S.S.C. Physics and B.S.C.S. Biology for use in the senior grades of the University Entrance high school progrmm, the traditional preparatory general science course has proven to be of little benefit to the students. Consequently, two other programs based on the textbooks Introductory Physical Science developed by E.S.I. and An Introduction to Physical Science by R.L. Hedley were authorized on an experimental basis for use in the University Entrance program in Manitoba schools during 1966-67. As a result a decision will have to be made concerning the relative value of these courses as preparatory general science programs.

In most cases, this type of decision has been made on a purely subjective basis. Teachers who have been involved in the experimental programs have been asked for an anecdotal reports which are subjective in nature. Teachers of pilot classes are asked to answer questions selected arbitrarily by the Curriculum Revision Committee.

On the basis of this evidence the committee charged with the decision makes its recommendations. When the pressures to make changes are great and the time in which to make a decision grows short, the chances for errors in judgement greatly increase.

With the attitude that change is necessary in the high school curriculum becoming generally accepted, it is possible that new courses could be accepted merely because they are new and not because they actually satisfy the objectives they propose to satisfy. Thus the need for evidence on which to base judgement other than that of the subjective evaluation is becoming critical. It is the intent of this study to supply some such evidence.

Design of the Study

Students enrolled in the grade ten University Entrance science program in September 1966 were chosen as the subjects of the study and were separated into Groups A, B and C on the basis of the program to be followed.

The population of Group A was made up of students who were to use the textbook Introductory Physical Science. They were, of necessity, chosen from those schools where pilot classes were being conducted in this program. The choice of schools was, therefore, somewhat restricted but samples of urban, suburban, and rural schools were included.

The population of Group B was composed of students using the textbook An Introduction to Physical Science and the population of Group C of students using the textbook Everyday Problems in Science.

In the latter two cases schools were chosen, as much as possible, to match the socio-economic background and the geographic locations of schools in Group A. Chapter III presents a more detailed explanation of the study.

The schools chosen were contacted and asked for their co-operation. In all instances the administration was very willing to cooperate. Principals of the schools chosen supplied the writer with the names of all students in their school registered for the grade ten University Entrance science program. The scores of these students on external achievement examinations in mathematics and science administered at the ninth grade level in June of 1966, were obtained from the files of the Registrar, Department of Education. The mental ability as an Intelligence Quotient for each student was also obtained and recorded. Any student for whom, for any reason, it was not possible to obtain this information was eliminated from the study. This procedure was felt to be necessary to ensure that the measurements of prior knowledge and I.Q. were made by the same instruments at the same time.

Two criteria tests were selected for administration by the science teachers to all students during the last two weeks of May 1967, by which time all classes had completed ninety percent or more of the course work. The first test selected was the <u>Test On Understanding Science</u> (TOUS), Form W, developed by W.W. Cooley and L.K. Klopfer of the Graduate School of Education, Harvard University. This instrument was designed to measure understanding of the scientific enterprise, understanding about the role of scientists and understanding about the aims and methods of science. The second instrument chosen was entitled Student Attitude Toward Science (SATS) and was developed by R.L. Hedley in the course of research at the College of Education, Michigan State University, East Lansing, Michigan. This instrument was designed to obtain a reaction from students that would indicate their feelings about their science program in the areas of text materials, course content, student interest, student needs, laboratory work and student involvement.

The test results were scored, and the data were recorded together with the I.Q. and prior knowledge test scores and prepared for entry on punched cards for analysis on the computer.

Assumptions and Limitations of the Study

Assumptions

It was assumed that all students participating in the study had approximately equal experience in handling multiple-choice response items. It was further assumed that the teachers were experienced in handling test directions and that adequate test conditions as well as test security was maintained. It was also assumed that the tests were administered at or about the same time to all students in the study.

Delimitations

The study was restricted to those students who were in grade nine in 1965-66, who graduated to grade ten for the school year 1966-67 and does not include an evaluation of those grade ten students who failed or repeated course work in grade ten.

Limitations

The study is limited by the manner in which the populations were obtained. Random sampling of the student population of Manitoba was not possible because of the relative scarcity of pilot classes. The results can, therefore, be said to be applicable to the sample populations only and not to the universal population.

The study was also limited by the fact that only science and mathematics achievement scores were used as pre-test information. It might well be that other achievement scores, such as English or reading comprehension, would contribute to successive achievement and in acceptance of a course even more significantly than the science and mathematics scores.

Hypotheses Tested

The following null hypotheses were tested in this study:

1. There is no significant difference in attitude towards science as measured by the sub-test scores of the SATS test between the A, B, and C groups of students.
2. There is no significant difference in achievement in science as measured by the sub-test scores of the TOUS test between the A, B, and C groups of students.

In addition, a computer program was utilized which produced:

A. Correlation matrices for the total group and each of the three sub-groups comprising the study on the basis of the sixteen variables.

1. Grade nine science achievement scores.
2. Grade nine mathematics achievement scores.
3. Intelligence quotients.
4. TOUS 1 - The scientific enterprise.
5. TOUS 2 - The scientists.
6. TOUS 3 - The aims and methods of science.
7. Total score on the TOUS instrument.
8. SATS 1 - Test materials.
9. SATS 2 - Course content.
10. SATS 3 - Student interest.
11. SATS 4 - Student needs.
12. SATS 5 - Laboratory work.
13. SATS 6 - Student involvement.
14. Total score on the SATS instrument.
15. Age.
16. Sex.

B. The means and standard deviations for all sixteen variables for each group, and for the total sample.

C. A multiple regression analysis of each of the eleven dependent variables on the five independent variables.

Using the means of the sixteen variables for each group and pooled standard deviation, t-tests of differences between means of each group were also calculated to determine if differences in the groups exist because of the courses followed.

CHAPTER II

REVIEW OF THE LITERATURE

A Brief History of the Development of Grade Ten Science Programs in Manitoba

All students enrolled in the grade ten level of the University Entrance Course program in Manitoba have as a compulsory part of their program a course called General Science 100. Although referred to as General Science, traditionally it has been a form of physical science. In the early 1960's criticism of this feature was voiced by some teachers within the province who felt that provision should be made at this level for a course in biological science. However, in August 1963 the traditional view of the advisability of teaching physical science was upheld by the report of the University Entrance Course Seminar which stated:

> It is 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 pre-requisite for grade eleven Chemistry and Physics courses.[1]

---

[1] Initial Report University Entrance Course Seminar Manitoba Teachers College 22 July - 2 August, 1963, p. 12 (mimeographed).

Until September 1964 there was only one textbook authorized for use with the General Science 100 program and that textbook was Everyday Problems in Science by Beauchamp, Mayfield and West, published in Canada in 1948 by W. Gage and Company. Examples of the units of work covered in the program were: Unit 1 - "How Do Scientists Work?"; Unit 4 - "How Do We Use and Control Power?"; and Unit 9 - "How Do We Control Heat?"

Although the general objectives of the program were as stated in the program of studies,

> 1. To lead the learner to search for truth by building well-organized patterns of knowledge.
> 2. To develop relevant skills and habits both mental and physical, so that they can be satisfactorily utilized by the learner.
> 3. To inculcate healthy moral and social attitudes for living in a democratic society.[2]

an investigation of the actual content of the textbook disclosed a technological orientation. This facet together with the fact that the technology outlined was fifteen years behind current knowledge combined to create a general feeling of dissatisfaction and growing rejection of the program by students and teachers alike.

The Department of Education in Manitoba was aware of the need for change in a curriculum pattern which had remained essentially static for twenty years. In sponsoring the University Entrance Course Seminar in the summer of 1963 composed of eminent local educators the Curriculum Branch was able to obtain the necessary public support to

---

[2] Programme of Studies for the Schools of Manitoba, Senior High Schools 1963-64 (Winnipeg: Queen's Printer, 1963) p. 50.

initiate a major curriculum revision in all subject areas. As a result of the additional recommendations for Science programs made by the Seminar; namely,

> 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 courses 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 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 of principles.[3]

curriculum committees were appointed in October 1963 in the subject areas of Chemistry and Physics. The recommendations made by these committees in the spring of 1964 were to the effect that sections of the new science programs recently developed in the U.S.A. known as P.S.S.C. Physics and CHEMS be combined to form the science course for those students in the tenth grade who were enrolled in the University Entrance Course program.

Acting upon these recommendations the Department of Education authorized a number of classes, where teachers with the necessary training were available, to follow the recommended program for the school year 1964-65. Early in 1965 the Department of Education informed the joint Physics and Chemistry Curriculum Revision Committee that for various reasons, mainly administrative, the pilot program was not proving to be one which could be generally implemented at the Grade ten

[3]Initial Report University Entrance Course Seminar Manitoba Teachers College 22 July - 2 August, 1963, p. 12.

level in the Province. Although the program would be allowed to continue for 1965-66 only in those schools which had already become committed, the Committee was asked to make other recommendations for possible implementation in September 1966, or as soon as feasible thereafter.

Of necessity, serious attention was now focussed upon a new project, entitled "Introductory Physical Science", which was being developed by Educational Services Incorporated of Boston, Massachusetts with the support of the National Science Foundation. This project was to be a one year program in introductory physical science based on the theme of the development of evidence for an atomic model of matter. The evidence available suggested that this program might be compatible with the philosophy of the Curriculum Committee as the method employed to achieve the stated goals was supposed to be one of student experimentation. Further evidence that this program might prove satisfactory for use at the grade ten level in Manitoba was found in the statements made by Haber-Schaim, director of the project, concerning the reasons why the project was originated.

> The greatest handicap faced by science teachers in the new curricula, such as the Physical Science Study Committee, the Chemical Education Materials Study, and the Biological Sciences Curriculum Study, is that most students in senior high school have little experience in observation, few basic laboratory skills, a very limited knowledge of how to apply elementary mathematics to experimental results, and little ability to correlate an abstract idea with a concrete situation. Often they have no idea of orders of magnitude, no feeling of approximation, and no ability to judge what is important and what is not.

> Students need time to digest knowledge. Teachers have repeatedly said that if we could put into the earlier grades some of the basic ideas and skills which are needed so badly in latter science courses, it would make those courses much easier to teach and give the students much more time to digest the materials.[4]

Identical complaints were being voiced frequently to the Curriculum Revision Committees in feedback from those teachers of senior high school science in Manitoba who were conducting classes in the newly recommended science programs. In February 1966 the joint Physics and Chemistry Curriculum Revision Committee made the recommendation:

> that a well chosen and carefully controlled pilot program in Introductory Physical Science be conducted at the Grade ten level in 1966-67.[5]

Plans were immediately implemented to provide for the necessary in-service training of teachers so that a reasonable number of pilot classes could be conducted. As a result thirty classes were able to commence the program in September 1966.

However, because of the increasing pressure being brought to bear on the Department of Education to remove the textbook Everyday Problems in Science from the list of authorized textbooks and because of the possibility that the pilot program using the textbook Introductory Physical Science might prove unacceptable as had the previous pilot program, it was felt necessary to make available to the high schools an additional program which could be used, even on a temporary basis, in

---

[4]Uri Haber-Schain, "A New Physical Science Course," IPS Newsletter, Prentice Hall, Incorporated, February 1966, p. 1.

[5]Minutes, Joint Physics-Chemistry Curriculum Revision Committee, February 1, 1966, (mimeographed), p. 1.

the University Entrance Course in lieu of the authorized program based on Everyday Problems in Science. Another grade ten physical science program was currently in use in the high schools of the province. This was the program known as General Science 101 or the General Course science program and the suggestion was put forward that this program be utilized on a temporary basis. This course had been developed, on the recommendation of the General Course Seminar of 1960, by a committee known as the General Course Science Committee. It made use of the textbook An Introduction to Physical Science by R.L. Hedley who wrote the textbook specifically for use with this program because there was no single text available on the market which adequately covered the topics desired.

Although this program had been relatively popular with the stream of students for which it was designed, some reservations were expressed about the advisability of allowing this program to be used in the University Entrance Course. The main objection to its use lay in the fact that it took a somewhat traditional approach to the study of Chemistry which it was felt might have a deleterious effect on the introduction to this subject in grade eleven where it was desired to use the CHEMS material and program. However, the aims and objectives for the General Science program as listed in the course outline were compatible with those of the senior high science courses.

> 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 for the methods and procedures of science.
6. A disposition to use the knowledge and methods of science appropriately.
7. The development of skills and abilities normally associated with science.[6]

Another point in favour of the utilization of this program was the fact that it tried to develop scientific literacy by the use of a relatively strong laboratory program. The absence of a worthwhile laboratory program was one of the major complaints listed against the authorized program using Everyday Problems in Science.

In May 1966 an announcement was made by the Department of Education to the effect that as a temporary measure, those schools who wished to offer General Science 101 in lieu of General Science 100 would be authorized to do so. Thus in September 1966 three courses in science were available for use at the grade ten level of the University Entrance Course program.

A Review of Evaluative Investigations

There has been to date no major appraisal of the Introductory Physical Science program carried out in the United States. The project evaluation carried out by Educational Services Incorporated during the

---

[6]Course outline, General Course Science 101, Province of Manitoba, Department of Education, undated, mimeographed, p. 2.

life of the project, made use only of achievement and laboratory tests, observations of pilot teachers and feedback from pilot teachers. In the "Report of the International Clearinghouse n Science and Mathematics Curricula Developments 1967" the feedback process for project evaluation is described by the project Introductory Physical Science as follows:

> Feedback process; During the last three years the pilot teachers (about 55 each year) have submitted regular written comments on all aspects of the course, such as text, teacher's guide, experiments, equipment, and quizzes. These reports have been carefully reviewed and used as a basis for the revisions of the text and teacher's guide.[7]

[7] J. David Lockard, editor, Report of the International Clearinghouse On Science and Mathematics Curricula Developments 1967. A Joint Project of the Commission on Science Education of the American Association for the Advancement of Science and the Science Teaching Center, University of Maryland (University of Maryland, College Park, Maryland) p. 264.

CHAPTER III

EXPERIMENTAL DESIGN

For the school year 1966-67, there existed a rather unique situation as far as the science programs authorized for use at the grade ten level of the University Entrance program in the secondary schools of Manitoba were concerned. Instead of the single authorized textbook which was the normal pattern, for this year a total of three different textbooks were authorized for use in the schools. The design of this experiment was predicated on this unique feature.

As the program known as I.P.S. was of prime concern in this study and also as the smallest number of schools were using this program due to its experimental nature, the initial selection of schools that were asked to participate in the study was made from this group. The basis for selection was the geographical area and the size of the school, so that the sample population would be fairly representative of the student population in the Province. The sampling, six schools from the twenty-three schools offering this program, included those from the City of Winnipeg proper, from the surrounding suburban municipalities and from towns in rural Manitoba.

Next the selection was made of additional schools to be asked to participate in the study from those where programs based on the other authorized textbooks, An Introduction to Physical Science and Everyday Problems in Science were being taught. The prime consideration in making these selections was that the schools chosen should match the schools chosen in the initial group as much as possible for size of school, geographic location, i.e. rural, suburban or urban, and the general socio-economic background of the students attending. In this way an attempt was made to reduce bias which would be unavoidably present due to the inability to select schools on a random basis. Also, in an attempt to produce uniformity in the student populations, all the grade ten University Entrance Course students from each participating school were incorporated into the study.

The principals of the eighteen schools selected for participation were contacted by letter asking for their cooperation in conducting the study by assisting in the carrying out of the testing necessary for the evaluation of the programs. Without exception, all principals agreed to cooperate.

In June 1966 all students enrolled at the grade nine level of the public school system in Manitoba were required to write examinations administered under Department of Education regulations in five academic subject areas. These examinations in English Literature, English Language, Social Studies, Mathematics and Science were externally set by a committee of examiners appointed by the Department of Education and scored in committee by teachers who had taught the course. In addition a mental abilities test, the Lorge-Thorndike test, level 5 form A verbal, was administered as part of the examination proceedings. It was decided to use the data available from these common mathematics and science examinations as well as the Intelligence Quotients calculated from the results of the Lorge-Thorndike Intelligence test as indicators of prior knowledge possessed by the pupils participating in the study.

Each participating school was asked to provide a list of all their students currently enrolled in University Entrance Course together with the name of the school at which each student wrote his or her grade nine external examinations and the year in which these examinations were written. For the purposes of this study the students were grouped according to the grade ten science program being taken with Group A being those students following a program based on the textbook Introductory Physical Science; Group B those students following a program based on the textbook An Introduction to Physical Science and Group C being those students following a program based on the textbook Everyday Problems in Science. From each group of students the names of all students who did not write grade 9 examinations in Manitoba in June 1966 were deleted. This procedure removed from the samples any students who might be repeating their grade ten year or who did not take their grade nine schooling in Manitoba. The scores obtained on the external examinations in mathematics, science as well as the Intelligence Quotients, were then obtained from the files of the Registrar, Department of Education for the remainder of the students in the three groups. If, for any reason, it was not possible to obtain all three scores for any student, this student's name was also removed from the list of participants.

Two criterion tests were selected for administration to all students to determine what, if any, understanding and attitudes were being developed as a result of the science programs under study. The first criterion test chosen was entitled Test On Understanding Science and was developed by Leopold E. Klopfer and William W. Cooley in the course of research at the Graduate School of Education, Harvard University, Cambridge, Massachusetts. This instrument, abbreviated TOUS, was developed around three major themes: understanding about the scientific enterprise; understanding about scientists; and understanding about the methods and aims of science.

In making reference to the instrument, its authors noted:

> New teaching methods and improved instructional materials are generally devised to achieve certain specific objectives. In conducting developmental research which inquires into the effects of new methods, we must include, as an integral part of that research, the selection or design of testing instruments which will evaluate those specific objectives![1]

Also, the following comments, contained in the manual accompanying the TOUS instrument, were felt to be appropriate and applicable to the present study:

> 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 career fields. However, while a large variety of tests has been prepared to measure student achievement in the facts and principles of science, no adequate instrument has yet been constructed 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 that a particular technique or procedure has contributed

---

[1]William W. Cooley and Leopold M. Klopfer, "The Evaluation of Specific Education Innovations," Journal of Research in Science Teaching, 1:73 (1963).

> 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.[2]

In addition the following comment from the same source supported the choice of this instrument as a criterion test:

> Turning to the possible applications of TOUS in curriculum development, the most obvious use of this instrument is in the direct testing of high school students to determine to what extent a realistic understanding of science and scientists has been attained as a result of taking science courses. Such testing would provide teachers and curriculum workers with comparative objective evidence on the extent to which these important objectives of instruction are being achieved. At present, only subjective testimony is available as a guide in this area. If deficiencies in student understanding of science and scientists can be demonstrated by a reliable test, corrective measures may then be proposed to bring about the desired improvements.[3]

The second criterion test chosen to be administered was entitled the Student Attitude Toward Science, abbreviated SATS. This instrument was developed by R.L. Hedley in the course of research at the College of Education, Michigan State University, East Lansing, Michigan. The instrument investigates student attitude toward six separate areas of concern in science teaching: the textbook; the course content; interest in the course being taken; student needs, i.e. how useful the student felt the course to be to him; laboratory work; and student involvement. There are seventy-two statements in all and the students respond to each on a five point Likert scale of summated ratings.

---

[2] William W. Cooley and Leo E. Klopfer, Manual for Administrating, Scoring and Interpreting Scores on Test On Understanding Science, Form W (Princeton: Educational Testing Service, 1961), p. 1.

[3] Ibid., p. 9.

During the last two weeks of May 1967, the Test On Understanding Science Form W and the Student Attitude Towards Science instruments were mailed or delivered to all participating schools. This particular time was chosen as it was not feasible to conduct a testing program in the high schools anytime during the month of June because of interference with scheduled end of year activities including preparations for field days, closing exercises and final examinations. By the latter part of May it was determined that the participating schools would have completed ninety percent or more of the course work and so that formation of any understanding or attitudes that were likely to take place could be deemed to have occurred.

The science teachers in the schools concerned administered the criterion tests and returned the student papers to the writer for scoring. It was possible to score the answer sheets from the TOUS instrument by machine but because of the nature of the SATS instrument which utilized the Likert scale it was necessary to score the answer sheets from this instrument by hand. Any student who did not complete either of the criteria tests, for any reason, was removed from the list of participating students. In addition the score sheets from one small rural school were lost and the names of these students had to be withdrawn from the experiment as well. As a result of the removal of names of students from the list of participants for one reason or another the original number of 2,027 students dwindled to 1,396 by the time the final tabulations were made.

Consequently, the final populations were as follows:

Group A - 455 students using the textbook
<u>Introductory Physical Science</u>

Group B - 496 students using the textbook
<u>An Introduction to Physical Science</u>

Group C - 445 students using the textbook
<u>Everyday Problems In Science</u>

For each student the following information was recorded on tabulation sheets and transferred to punch cards for processing by a computer:

Experimental Group Number

Score from grade nine Mathematics test - June 1966

Score from grade nine Science test - June 1966

The mental ability of the student as an Intelligence Quotient - June 1966

Age in years and months as of May 30, 1967

Sex

Score on TOUS sub-test #1

Score on TOUS sub-test #2

Score on TOUS sub-test #3

Total score on TOUS test

Score on SATS sub-test #1

Score on SATS sub-test #2

Score on SATS sub-test #3

Score on SATS sub-test #4

Score on SATS sub-test #5

Score on SATS sub-test #6

Total score on SATS test

Consultations with a statistician on the computer staff resulted in the development of a computer program which produced:

a) the means and standard deviations for all sixteen variables for each group, and for the total sample

b) a correlation matrix for each group and the total sample

c) a multiple regression analysis of each of the eleven dependent variables on the five independent variables, i.e. Mathematics and Science scores, I.Q., Age and Sex, for each group together with an analysis of variance.

Using the means of the sixteen variables for each group and pooled standard deviation, t-tests of differences between means of each group were then calculated by the writer. The investigation of these results suggested that an additional statistical analysis be done, to modify the composition of the initial groups so that a slight difference in prior knowledge of mathematics which was evident would be overcome. Accordingly the data punch cards for each group of students were rearranged in ascending order of mathematics scores and a selection of cards made so that each group would contain only cards showing mathematics scores which were duplicated in both other groups. Upon the completion of this manoeuvre 316 students were left in each group and the means and standard deviations were again calculated for each of the sixteen variables. Then utilizing the new means and standard deviations, t-tests of differences between means for each of the sixteen variables of each group were again calculated.

CHAPTER IV

ANALYSIS OF DATA

It is the purpose of this chapter to examine (1) the means and standard deviations of the sixteen criteria variables used in the study, (2) the t-tests of differences between the means of each group, (3) the means and standard deviations of the sixteen criteria variables used in the study for the samples modified on the basis of prior mathematics scores, (4) the t-tests of differences between the means of each modified group, (5) the correlation coefficients for levels of significance between the sixteen criteria variables and (6) a multiple regression analysis of each of the eleven dependent variables on the five independent variables together with an analysis of variance.

Analysis of the Criteria Variables

Table 1 shows the mean scores and the standard deviation for the sixteen variables of the students involved in each of the three groups under consideration. The variable listed in this table as I.Q. and interpreted to mean mental ability, together with the variables listed as Mathematics and Science constitute the indicators of prior knowledge possessed by the pupils participating in the study.

TABLE 1. MEANS AND STANDARD DEVIATIONS OF CRITERIA VARIABLES

VARIABLE	TOTAL GROUP		GROUP A		GROUP B		GROUP C	
	MEAN N 1396	STANDARD DEVIATION	MEAN N 455	STANDARD DEVIATION	MEAN N 496	STANDARD DEVIATION	MEAN N 445	STANDARD DEVIATION
MATHEMATICS	76.8	13.9	78.0	14.1	74.7	14.7	77.7	12.5
SCIENCE	72.1	12.0	72.8	12.1	71.9	11.7	71.8	12.4
I.Q.	121.7	13.5	123.1	15.1	120.9	13.8	121.3	11.2
TOUS 1	9.9	2.4	10.2	2.5	9.7	2.3	9.8	2.4
TOUS 2	11.0	3.2	11.1	2.3	11.0	4.3	10.9	2.3
TOUS 3	10.4	3.0	11.0	3.1	10.1	2.9	10.0	2.8
TOUS TOTAL	31.2	5.8	32.4	6.0	30.5	5.6	30.6	5.6
SATS 1	43.5	9.4	45.6	9.7	44.9	8.8	39.9	8.7
SATS 2	39.6	6.7	41.1	7.1	39.2	6.6	38.6	6.2
SATS 3	41.3	6.6	41.8	6.5	40.2	6.4	42.2	6.8
SATS 4	53.8	11.6	55.0	11.7	55.3	11.2	51.0	11.6
SATS 5	37.9	5.0	39.2	5.2	37.7	5.0	36.8	4.6
SATS 6	15.6	3.4	16.8	3.2	15.4	3.3	14.7	3.3
SATS TOTAL	231.8	32.2	239.5	33.3	232.6	30.8	223.0	30.6
AGE	191.5	6.2	192.1	5.8	191.2	6.6	191.3	6.1
SEX	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5

Table 2 shows the t-tests of differences between the means of the variables for the students in the three Groups A, B and C. It is interesting to note that there is no significant difference between the mean science scores of any of the groups. Thus any differences which might arise between the groups on the criterion tests cannot be attributed to difference in prior science knowledge possessed by the different groups. It is also evident that there is a significant difference at the five percent level in the I.Q. scores of one of the groups, namely Group A. However, an examination of the means of the three groups as shown in Table 1 indicates that the maximum difference in means is 2.2 units. The Standard Error Measurement associated with the Lorge-Thorndike Intelligence Test, which was the instrument used in obtaining the scores, is 5.1 I.Q. units as indicated in the Technical Manual, revised edition, which accompanies the tests. Consequently, to interpret that a difference of 2.2 units is statistically significant when the Standard Error of Measurement is 5.1 units is not justifiable as this would require the assumption that the means in question are much more accurate and absolute than they are alleged to be by the publishers of the measuring instrument. Thus, for the purposes of this study it is assumed that there is no essential difference in the Intelligence Quotients of the three groups.

Table 1 also shows that the prior knowledge of mathematics was less for the students of Group B than for either of the other two groups. In Table 2 this difference is shown to be significant at the one percent level and consequently this discrepancy could be a factor if the criteria tests indicate any differences between the groups. In addition when we examine the other independent variables, Age and Sex, in Tables 1 and 2 we find that the distribution by sex in each of the groups is very similar but that the mean age of Group A does differ from the mean ages of Groups B and C. However, as the maximum difference between groups is 0.9 months, even though this difference is statistically significant at the five percent level, it does not seem likely that this amount of difference would materially affect the results of the criteria tests.

TOUS 1, TOUS 2, and TOUS 3 in Tables 1 and 2 refer respectively to Understanding About the Scientific Enterprise, Understanding About the Aims and Methods of Science. The heading TOUS TOTAL refers to the total score on the instrument. The tentative norm reported for the TOUS instrument for the tenth grade level is a mean of 28.58 with a standard deviation of 7.66 based on 1,064 students. An examination of Table 1 shows a mean value of 31.2 with a standard deviation of 5.8 based on 1,396 students. Thus the students involved in this study performed significantly better than could be expected for the average group.

However, examination of Table 2 shows that Group A performed significantly better than either Groups B or C on TOUS 1 Understanding About the Scientific Enterprise, TOUS 3 Understanding About the Aims and Methods of Science and TOUS TOTAL. Other factors being equal this would be an indication that the course being taken

TABLE 2

t-TESTS OF DIFFERENCES BETWEEN MEANS OF VARIABLES

(EXPERIMENTAL AND CONTROLLED) FOR GROUPS A, B AND C

VARIABLE	$t_{A,B}$	$t_{A,C}$	$t_{B,C}$
PRIOR KNOWLEDGE - MATHEMATICS	3.71**	0.33	-3.35**
PRIOR KNOWLEDGE - SCIENCE	1.15	1.19	0.07
I.Q.	2.52*	1.96*	-0.51
TOUS 1 SCIENCE ENTERPRISE	3.53**	2.68**	-0.77
TOUS 2 SCIENTISTS	0.67	1.14	0.49
TOUS 3 AIMS AND METHODS OF SCIENCE	4.53**	4.98**	0.57
TOUS TOTAL	4.93**	4.55**	-0.25
SATS 1 TEXT MATERIALS	1.30	9.53**	8.44**
SATS 2 COURSE CONTENT	4.49**	5.59**	1.25
SATS 3 INTEREST	3.75**	-0.85	-4.60**
SATS 4 STUDENTS' NEEDS	-0.40	5.20**	5.70**
SATS 5 LABORATORY WORK	4.86**	7.36**	2.68**
SATS 6 INVOLVEMENT	6.56**	9.64**	3.31**
SATS TOTAL	3.36**	7.82**	4.64**
AGE	2.36*	2.12*	-0.18
SEX	0.00	0.00	0.00

* Statistic significant at 5% level.

** Statistic significant at 1% level.

by Group A was doing more to achieve an objective not being achieved by the other programs, namely, developing an understanding about science.

The remaining variable considered in Tables 1 and 2 refer to the scores obtained on the Student Attitude Toward Science instrument. The first of the six sub-tests of this instrument is designed to obtain a reaction to statements made about the texts used in the different courses. As there are thirteen statements in this scale and a neutral position has a value of three, a total value of thirty-nine indicates a neutral or "doesn't matter" attitude. While there is no negative attitude evidence in any of the groups and while there is no significant difference in the attitude shown towards their textbooks by either Groups A or B, both Groups A and B show a significantly more positive attitude towards the textual material than do the students from Group C.

Student attitude toward the content of the course is measured by SATS 2. Here a value of thirty-six would indicate a neutral or "don't care" position. It should be noted that all three groups report a positive position on this scale but that the value recorded for Group A is significantly more positive than those of the other two groups. The content of the program followed by the students in Group A is heavily laboratory oriented with a distinct "discovery" flavour not present in the other two programs under study. It apparently satisfied some students as a score of 41.1 indicates a strong positive position.

SATS 3 sub-test refers to the student's assessment of his interest in science courses, as measured by his reactions to statements about science courses. A neutral position would have a value of forty-two. An examination of this item in Table 1 indicates an overall negative interest in science by the entire group. This value seems to be contributed mainly by the students of Group B. Table 2 shows that the values from this group are significantly lower than the values from either Group A or Group C and although the values of Groups A and C are on opposite sides of the neutral value, the differences between them is not significant. There does not seem to be any particular reason for the negative results of this sub-test especially in view of the predominantly positive responses to all other sub-tests.

SATS 4 refers to those statements pertaining to students' needs in science. A value of fifty-one indicates a neutral position on this scale. These students of Group A and of Group B score about equally well on this scale with a positive value about their course satisfying their needs. The students from Group C score significantly lower values on this sub-test, registering a neutral position.

SATS 5 scale uses a number of statements concerning laboratory work to determine how students feel about this aspect of science. A value of thirty-three indicates a neutral position. Each group replied with positive values for this sub-test but it is interesting to note that the degree of positive response increases significantly as we examine first the responses of Group C, then those of Group B and then those of Group A. This pattern coincides with the degree of laboratory orientation of the three programs.

SATS 6 scale was developed to determine the extent of involvement of students in their science courses. A value of fifteen would indicate a neutral position. An examination of Table 1 shows that the scores range from positive for Group A, to close to neutral for Group B to very slightly negative for Group C. Table 2 indicates that the differences in the scores registered are significant at the one percent level and that they follow the same pattern as did the scores for SATS 5 on laboratory work.

In general the SATS instrument as shown by the scores of the variable SATS TOTAL indicates that the attitudes of the students of Group A are significantly more positive toward their program than are the attitudes of the students of Group B. In turn, the attitudes of the students of Group B are significantly more positive towards their program than are the attitudes of the students of Group C towards their program.

The study subsequently led to a modification of Groups A, B and C to remove the possibility of the slight but significant difference in prior knowledge in mathematics existing for the Group B students.

TABLE 3. MEANS AND STANDARD DEVIATIONS OF CRITERIA VARIABLES

VARIABLE	GROUP A'		GROUP B'		GROUP C'	
	MEAN N 316	$(\text{STANDARD DEVIATION})^2$	MEAN N 316	$(\text{STANDARD DEVIATION})^2$	MEAN N 316	$(\text{STANDARD DEVIATION})^2$
MATHEMATICS	78.2	135.4	78.2	135.4	78.2	135.4
SCIENCE	72.8	133.9	73.2	137.2	71.6	167.2
I.Q.	122.4	157.4	121.8	200.7	120.9	127.8
TOUS 1	10.2	6.0	9.8	5.1	9.8	5.7
TOUS 2	11.1	5.4	11.1	25.7	10.8	5.4
TOUS 3	11.1	9.7	10.2	8.8	10.0	7.7
TOUS TOTAL	32.3	35.7	30.8	31.9	30.6	31.3
SATS 1	45.5	97.0	44.7	74.0	40.5	79.5
SATS 2	41.1	49.4	39.4	43.6	38.8	43.4
SATS 3	41.7	43.7	39.9	39.9	41.9	43.9
SATS 4	55.2	136.3	55.5	125.8	51.2	139.0
SATS 5	39.5	27.3	37.2	25.7	37.3	19.3
SATS 6	16.8	10.4	15.4	11.3	14.6	10.9
SATS TOTAL	239.6	1,086.9	232.2	922.7	224.1	978.1
AGE	192.0	35.7	190.9	35.4	191.3	41.2
SEX	0.5	0.4	0.5	0.2	0.5	0.2

TABLE 4

t-TESTS OF DIFFERENCES BETWEEN MEANS OF VARIABLES

(EXPERIMENTAL AND CONTROLLED) FOR GROUPS A', B' AND C'

VARIABLE	$t_{A',B'}$	$t_{A',C'}$	$t_{B',C'}$
PRIOR KNOWLEDGE - MATHEMATICS	0.00	0.00	0.00
PRIOR KNOWLEDGE - SCIENCE	-0.37	1.33	1.70
I.Q.	0.60	1.51	0.91
TOUS 1 SCIENCE ENTERPRISE	2.13*	2.13*	0.00
TOUS 2 SCIENTISTS	0.00	1.15	1.15
TOUS 3 AIMS AND METHODS OF SCIENCE	3.54**	4.51**	0.97
TOUS TOTAL	3.45**	3.83**	0.38
SATS 1 TEXT MATERIALS	1.04	6.94**	5.91**
SATS 2 COURSE CONTENT	3.09**	4.37**	1.28
SATS 3 INTEREST	3.43**	-1.53	-3.80**
SATS 4 STUDENTS' NEEDS	-0.39	4.24**	4.64**
SATS 5 LABORATORY WORK	5.85**	5.59**	-0.26
SATS 6 INVOLVEMENT	5.58**	8.46**	2.88**
SATS TOTAL	2.95**	6.17**	3.21**
AGE	2.36*	1.54	-0.82
SEX	0.00	0.00	0.00

* Statistic significant at 5% level.

** Statistic significant at 1% level.

Examination of Tables 3 and 4 shows that the modification procedure applied to remove the mathematical bias which existed in one group had the net result of producing three groups of students between which there are no significant differences in any of the three variables indicative of prior knowledge, i.e. Mathematics, Science and I.Q. Also it should be noted that this procedure did not affect the distribution of sex in the groups and reduced the slight discrepancy which had existed in the age factor. When the remaining variables are examined it is evident that the adjustment made in the groups did not affect the manner in which the students of each group reacted to the criteria tests. The trends noted in Table 2 concerning the significant differences between the three groups in the development of understanding and attitude remain the same.

Analysis of the Correlation Coefficients

Table 5 gives the inter-correlations of the sixteen variables used in the study for the total sample population and as the matrix is symmetrical, only the upper triangle is shown. The correlation coefficients for one variable relating to the others can be found by locating the intersection of the row and column containing the variables in question. The element at the point of intersection is the correlation coefficient desired. In this table, the results of the total sample population are considered. For those correlations coefficients greater than

TABLE 5. CORRELATION COEFFICIENTS FOR SIXTEEN VARIABLES IN TOTAL GROUP

	PRIOR SCIENCE	I.Q.	TOUS 1	TOUS 2	TOUS 3	TOUS TOTAL	SATS 1	SATS 2	SATS 3	SATS 4	SATS 5	SATS 6	SATS TOTAL	AGE	SEX
RIOR ATHE- ATICS	.487**	.286**	.202**	.151**	.282**	.301**	.115*	.236**	-.005	.087	-.008	-.003	.110*	-.123**	-.044
RIOR CIENCE		.338**	.272**	.152**	.344**	.373**	.105*	.203**	.053	.125**	.049	.022	.138**	-.153**	-.001
.Q.			.255**	.205**	.389**	.433**	.070	.188**	.007	.074	.005	-.033	.085	-.305**	.043
OUS 1				.222**	.351**	.712**	.078	.152**	.070	.096	.074	.035	.117*	-.094	.003
OUS 2					.196**	.494**	.044	.110*	.012	.024	.006	-.023	.046	-.072	-.034
OUS 3						.780**	.117*	.210**	.084	.118*	.034	.041	.146*	-.124**	.127**
OUS OTAL							.120*	.233**	.086	.116*	.057	.030	.154**	-.135**	.066
ATS 1								.595**	.342**	.672**	.457**	.374**	.832**	.006	.106*
ATS 2									.276**	.519**	.345**	.202**	.690**	-.075	.177**
ATS 3										.587**	.337**	.430**	.666**	.068	.149**
ATS 4											.413**	.468**	.892**	.033	.236**
ATS 5												.377**	.609**	.036	.053
ATS 6													.566**	.022	.029
ATS OTAL														.019	.195**
GE															.065

* Statistic significant at 5% level r $>$ .105.
** Statistic significant at 1% level r $>$ .122.

0.105 the correlations are considered significant at the five percent level, while for coefficients greater than 0.122, the correlations are considered significant at the one percent level.

The product-moment correlations reported in the _Manual for Administrating, Scoring and Interpreting Scores for TOUS_ indicate a value of 0.69 between I.Q. and TOUS TOTAL score. This study shows a value of 0.43 for the same relationship while the correlation of these two variables is somewhat lower than that reported by the test authors, it is still a significant relationship at the 0.1 percent level.

Further examination of Table 5 shows that there is little relationship as determined by correlation coefficients reported therein between the elements of the TOUS instrument and the subtests of the SATS instrument. However, low but significant correlation coefficients are reported between SATS 2, _The Content of the Course_, and each of the elements of the TOUS instrument. Also coefficients significant at the five percent level are reported between TOUS, _Understanding About the Aims and Methods of Science_, and SATS 1 and 4, _Textual Materials_, and _Student Needs_. These significant correlations would seem to be due to the higher responses of Group A. One interpretation is that the textual materials, the needs of the students and the content of the course for the program followed by students of Group A are oriented toward the objectives being measured by the TOUS instrument.

TABLE 6. CORRELATION COEFFICIENTS FOR SIXTEEN VARIABLES IN GROUP A.

	PRIOR SCIENCE	I.Q.	TOUS 1	TOUS 2	TOUS 3	TOUS TOTAL	SATS 1	SATS 2	SATS 3	SATS 4	SATS 5	SATS 6	SATS TOTAL	AGE	SEX
PRIOR MATHEMATICS	.539**	.225**	.286**	.274**	.321**	.379**	.204**	.265**	.079	.134	.026	.044	.187**	-.151	-.054
PRIOR SCIENCE		.252**	.363**	.322**	.387**	.461**	.186**	.226**	.093	.167*	.123	.168*	.223**	-.209**	-.021
I.Q.			.217**	.274**	.377**	.435**	.218**	.304**	.126	.207**	.106	.069	.252**	-.286**	.060
TOUS 1				.319**	.379**	.725**	.232**	.250**	.180*	.225**	.138	.070	.265**	-.060	.008
TOUS 2					.347**	.703**	.144	.237**	.083	.105	.067	.071	.164*	-.090	.020
TOUS 3						.815**	.229**	.285**	.155	.220**	.105	.094	.259**	-.118	.110
TOUS TOTAL							.275**	.348**	.189**	.252**	.141	.106	.313**	-.122	.070
SATS 1								.692**	.379**	.677**	.453**	.303**	.845**	-.102	.033
SATS 2									.313**	.584**	.387**	.239**	.752**	-.136	.080
SATS 3										.619**	.377**	.486**	.683**	-.036	.060
SATS 4											.418**	.445**	.894**	-.098	.126
SATS 5												.331**	.607**	-.096	-.009
SATS 6													.525**	-.088	-.015
SATS TOTAL														-.126	.085
AGE															.075

* Statistic significant at 5% level $r \geq .157$.
** Statistic significant at 1% level $r \geq .182$.

Table 5 also shows that both instruments have a high correlation between the sub-tests and the total test. Values ranging from 0.566 to 0.892 are shown for the SATS instrument, which indicates a highly significant relationship while values from 0.494 to 0.780 indicate a high correlation between the sub-tests of the TOUS instrument. The lower correlation coefficient of TOUS 2, Understanding About Scientists, with the total TOUS test would seem to be due to the low response of one group, the students in Group B, to this test.

Table 6 shows the correlation coefficients for the variables used with the students in Group A. There is a positive correlation significant at the one percent level shown between the tests for prior knowledge in Mathematics and Science, I.Q., the three elements of the TOUS instrument and the first two sub-tests of the SATS instrument, Textual Materials and Course Content. One explanation for this relationship would be that the program followed by the students of Group A built upon the knowledge that students brought with them to the course. There is a reasonable significant relationship shown between the TOUS sub-tests and the SATS sub-tests for this group of students. Eight of the eighteen correlation coefficients are significant at the one percent level and with one exception these are all to be found in SATS sub-tests dealing with Textual Materials, Course Content, and Satisfying Student Needs. One explanation is that these areas for this group of

TABLE 7. CORRELATION COEFFICIENTS FOR SIXTEEN VARIABLES IN GROUP B.

	PRIOR SCIENCE	I.Q.	TOUS 1	TOUS 2	TOUS 3	TOUS TOTAL	SATS 1	SATS 2	SATS 3	SATS 4	SATS 5	SATS 6	SATS TOTAL	AGE	SEX
RIOR ATHE- ATICS	.536**	.340**	.156*	.097	.283**	.258**	.089	.230**	-.059	.096	-.042	.041	.096	-.206**	-.076
RIOR CIENCE		.394**	.211**	.087	.400**	.379**	.041	.198**	.039	.115	-.061	-.022	.090	-.159*	.012
.Q.			.235**	.140	.412**	.413**	.021	.160*	-.042	.060	-.098	-.116	.021	-.310**	.027
OUS 1				.128	.312**	.671**	.017	.109	.036	.086	.019	-.013	.068	-.101	.045
OUS 2					.093	.334**	.020	.042	-.003	.005	-.020	-.051	.006	-.055	-.100
OUS 3						.748**	.038	.142	.040	.078	-.074	-.029	.060	-.147	.129
OUS OTAL							.046	.142	.041	.085	-.039	-.044	.069	-.143	.053
ATS 1								.544**	.381**	.687**	.399**	.406**	.834**	.055	.107
ATS 2									.231**	.528**	.264**	.175**	.655**	-.076	.265**
ATS 3										.613**	.305**	.397**	.682**	.150*	.119
ATS 4											.357**	.439**	.900**	.069	.245**
ATS 5												.359**	.562**	.106	.040
ATS 6													.566**	.058	-.004
ATS OTAL														.084	.206**
GE															.069

* Statistic significant at 5% level, r>.148.
** Statistic significant at 1% level, r>.172.

students are oriented towards the same objectives being measured by the TOUS instrument.

Again both instruments have a high correlation between the sub-tests and the total test. For the TOUS instrument values range from 0.703 to 0.815 which indicates a highly significant relationship and the value of 0.525 to 0.894 recorded for the SATS instrument are only slightly less significant.

It should also be noted that there is a negative correlation, although only significant in two instances, between Age and all other variables under consideration. One possible interpretation is that the older students may have experienced failure on previous occasions in school and may experience difficulty in understanding concepts. This in turn would influence their attitudes towards the subject field in a negative manner.

The correlation coefficients for the same sixteen variables for the students of Group B are found in Table 7. There are not as many strong significant relationships to be found for this group as there were for the students of Group A. There is still a highly significant relationship shown in between sub-tests of the SATS instrument and the total test with values ranging from 0.562 to 0.900. However, this type of relationship is not to be found for the TOUS instrument. The second element of the TOUS instrument, Understanding About Scientists, does not show a significant correlation value with any of the sixteen variables except for the TOTAL TOUS test.

Even in this instance the value dropped to 0.334, which although significant at the one percent level is considerably less than the values of 0.703 and above found in Table 6. It would seem that the program followed by the students of Group B did nothing in the minds of the students to relate to an understanding of role played by scientists in society.

For this group there is no evidence of any significant correlation between the TOUS instrument and the SATS instrument. In fact some negative values are to be found, especially in the relationship between the elements of the TOUS test and SATS subtest #6, Involvement and SATS #5, Laboratory Work. One explanation here is that the students in Group B see no relationship between what they are doing in the laboratory and understanding the course content.

The negative trend in the relationship between the variable Age and other variables previously noted in Table 6 is again evident. However, for this group of students the negative relationship does not extend to the same extent into the sub-tests of the SATS instrument. This would indicate that the older students involved in this program developed the same attitudes as did the rest of the student population.

Also although the correlation coefficient between prior knowledge in science and prior knowledge in mathematics for this group is practically identical with the correlation coefficient between the same two variables for the students of the previous

TABLE 8. CORRELATION COEFFICIENTS FOR SIXTEEN VARIABLES IN GROUP C.

	PRIOR SCIENCE	I.Q.	TOUS 1	TOUS 2	TOUS 3	TOUS TOTAL	SATS 1	SATS 2	SATS 3	SATS 4	SATS 5	SATS 6	SATS TOTAL	AGE	SEX
PRIOR MATHE-MATICS	.378**	.284**	.141	.165*	.220**	.254**	.091	.197**	-.079	.060	-.026	-.140	.044	.002	.011
PRIOR SCIENCE		.387**	.236**	.136	.233**	.270**	.076	.174*	.024	.091	.075	-.097	.086	-.104	.032
I.Q.			.322**	.319**	.361**	.447**	-.110	.016	-.103	-.098	-.049	-.119	-.106	-.360**	.039
TOUS 1				.352**	.335**	.731**	-.066	.044	-.026	-.038	.011	-.012	-.035	-.146	-.049
TOUS 2					.279**	.708**	-.034	.117	-.026	-.032	-.036	-.100	-.015	-.110	.029
TOUS 3						.762**	-.004	.135	.046	.016	-.016	-.050	.033	-.143	.148
TOUS TOTAL							-.041	.141	.007	-.021	-.017	-.075	-.002	-.180*	.074
SATS 1								.522**	.378**	.618**	.465**	.312**	.797**	.034	.208**
SATS 2									.298**	.429**	.322**	.089	.632**	-.045	.211**
SATS 3										.616**	.366**	.468**	.720**	.064	.290**
SATS 4											.445**	.497**	.886**	.111	.367**
SATS 5												.346**	.619**	.051	.154
SATS 6													.546**	.032	.114
SATS TOTAL														.058	.335**
AGE															.050

* Statistic significant at 5% level, $r \geq .157$.
** Statistic significant at 1% level, $r \geq .182$.

group the relationship between these two variables and all other variables is significantly less than for the previous group. One interpretation for this is that the program followed by the students of Group B did not relate to the prior knowledge held by the students when they commenced the program.

Table 8, which shows the correlation coefficients for the same variables for the students of Group C, is characterized by the high number of negative coefficients existing between the sub-test of the SATS instrument and the other variables. While these negative coefficients are not at a significant level they would seem to indicate a general dissatisfaction on the part of the students for the program being followed.

Again, it is noted, there is a high correlation between the sub-tests and the total test for both the TOUS and SATS instruments.

Another significant difference between the values found on this chart and the values on charts 6 and 7 is the relationship between the variable Sex and the SATS instrument. Five of the seven coefficients show a positive correlation significant at the one percent level. For the students of Group B three of the seven coefficients were positive and significant at the one percent level while for the students of Group A there was no significant correlation with the variable Sex. This relationship might be interpreted to mean that the program followed by the students of Group C had a greater appeal to one sex, male, than the other. This discrepancy was not noticeable in the program followed by the students in Group A.

When Tables 6, 7 and 8 are examined one after another, the gradation from positive to negative coefficients and also the decrease in significant correlation coefficients is very noticeable. A general explanation which could be attributed to the situation is a decrease in general student acceptance of the program being followed as you move from the program followed by Group A to the program followed by Group B and then to that followed by Group C.

Analysis of Variance

Tables 9 to 14 bring together the results of F and T scores as well as multiple correlation figures. The F test is a measure of the significance of the five predictor variables Mathematics, Science, I.Q., Age and Sex when used together to predict the various criteria variables. The T scores indicate the relative order of significance of each of the predictor variables in predicting the outcome of the sub-test. The multiple correlation figure indicates the percentage of the variance of the criterion variable accounted for by the five predictor variables while the correlation figures indicate the correlation between the criterian variable and the given predictor variable which have just been discussed.

TABLE 9

PREDICTION OF TOUS SUB-TEST AND TOTAL SCORES

FOR GROUP A USING

PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT

AS WELL AS AGE AND SEX AS PREDICTORS

N 455

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
TOUS SUB-TEST #1 SCIENCE ENTERPRISE	MATHEMATICS	.29**		2.20*	
	SCIENCE	.32**		5.31**	
	I.Q.	.22**		2.93**	
	AGE	-.06		1.18	
	SEX	.01		0.17	
			.40		17.089**
TOUS SUB-TEST #2 SCIENTISTS	MATHEMATICS	.27**		2.31*	
	SCIENCE	.32**		4.05**	
	I.Q.	.27**		4.28**	
	AGE	-.09		0.62	
	SEX	.02		0.38	
			.39		16.347**
TOUS SUB-TEST #3 AIMS AND METHODS OF SCIENCE	MATHEMATICS	.32**		2.67**	
	SCIENCE	.39**		5.14**	
	I.Q.	.38**		6.53**	
	AGE	-.12		0.67	
	SEX	.11		2.51*	
			.51		30.848**
TOUS TOTAL	MATHEMATICS	.38**		3.23**	
	SCIENCE	.46**		6.70	
	I.Q.	.44**		8.17**	
	AGE	-.12		1.40	
	SEX	.07		1.57	
			.59		46.888**

* Statistic significant at 5% level.

** Statistic significant at 1% level.

TABLE 10

PREDICTION OF TOUS SUB-TEST AND TOTAL SCORES

FOR GROUP B USING

PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT

AS WELL AS AGE AND SEX AS PREDICTORS

N 496

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
TOUS SUB-TEST #1 SCIENCE ENTERPRISE	MATHEMATICS	.16*		0.59	
	SCIENCE	.21**		2.34*	
	I.Q.	.23**		3.33**	
	AGE	-.10		-0.58	
	SEX	.04		1.05	
			.27		7.924**
TOUS SUB-TEST #2 SCIENTISTS	MATHEMATICS	.10		0.70	
	SCIENCE	.09		0.32	
	I.Q.	.14		2.43*	
	AGE	-.05		0.02	
	SEX	-.10		-2.25*	
			.18		3.292**
TOUS SUB-TEST #3 AIMS AND METHODS OF SCIENCE	MATHEMATICS	.28**		1.15	
	SCIENCE	.40**		5.39**	
	I.Q.	.41**		6.36**	
	AGE	-.15		-0.38	
	SEX	.13		3.31**	
			.50		33.506**
TOUS TOTAL	MATHEMATICS	.26**		0.53	
	SCIENCE	.38**		5.02**	
	I.Q.	.41**		6.69**	
	AGE	-.14		-0.20	
	SEX	.05		1.26	
			.48		29.012**

* Statistic significant at 5% level.

** Statistic significant at 1% level.

TABLE 11

PREDICTION OF TOUS SUB-TEST AND TOTAL SCORES

FOR GROUP C USING

PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT

AS WELL AS AGE AND SEX AS PREDICTORS

N 445

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
TOUS SUB-TEST #1 SCIENCE ENTERPRISE	MATHEMATICS	.14		0.42	
	SCIENCE	.24**		2.51*	
	I.Q.	.32**		4.84**	
	AGE	-.15		-0.78	
	SEX	-.05		-1.37	
			.35		12.405**
TOUS SUB-TEST #2 SCIENTISTS	MATHEMATICS	.17*		1.72	
	SCIENCE	.14		-0.24	
	I.Q.	.32**		5.59**	
	AGE	-.11		-0.12	
	SEX	.03		0.38	
			.35		10.677**
TOUS SUB-TEST #3 AIMS AND METHODS OF SCIENCE	MATHEMATICS	.22**		2.33*	
	SCIENCE	.23**		1.48	
	I.Q.	.36**		5.48**	
	AGE	-.14		-0.88	
	SEX	.15		3.10**	
			.41		17.888**
TOUS TOTAL	MATHEMATICS	.25**		2.39*	
	SCIENCE	.27**		1.68	
	I.Q.	.45**		7.39**	
	AGE	-.18*		-0.94	
	SEX	.07		1.38	
			.47		25.433**

* Statistic significant at 5% level.

** Statistic significant at 1% level.

An examination of the F scores in Table 9 shows that for the students of Group A the predictor variables, used together, are very highly significant in predicting the outcome of the TOUS sub-test as a score of 4.10 denotes significance at the 0.1 percent level of confidence. The T scores show that the I.Q., and prior knowledge in Mathematics and Science are the most significant of the variables in predicting the TOUS scores. The Age variable was generally the least significant of all the predictors, followed very closely by Sex. The multiple correlation coefficient of 0.59 between the TOUS TOTAL score and the five predictor variables indicates that 59% of the variance of the score is accountable by the independent variables. While this is a satisfactorily high value it indicates that there are still other undefined factors which are affecting the students' responses.

Table 10 displays the same tables but for the students in Group B. Although the F scores are not as high as those for Group A nevertheless they are significant for all sub-tests. Again the predictor variable I.Q. is the most significant of the variables followed by prior knowledge in Science. However, for this group the T score for the variable prior knowledge in Mathematics, never reaches a significant level. Also, although the scores are not at significant levels, we have negative T scores for the variable Age appearing.

The scores for students of Group C are found in Table 11. Again the high F scores show that the five predictor variables are very significant in the determination of the criteria variables as long as they are used together. The most significant and influential of the predictor variables for this group is also shown to be the I.Q.

A comparison of the three charts just described shows that the prime variable in predicting the outcome of the TOUS sub-tests is I.Q. This is to be expected as a subjective analysis of the basis for understanding would arrive at the same conclusion. Although the variables prior knowledge in Science and prior knowledge in Mathematics prove to be key variables for the students of Group A, they do not assume the same importance for the students of Groups B and C. This would seem to indicate that the program followed by the students in Group A builds upon the knowledge that the student brings to the course whereas the programs followed by Groups B and C do not display this relationship to the same extent.

Table 12 again refers to the students comprising Group A but this time the tables refer to the ability of the predictor variables to determine the SATS sub-test and total scores. All of the F scores are at significant levels except the one for SATS sub-test 3 but at the same time are considerably lower than they were when TOUS scores were being considered. Again the I.Q. variable is the most significant of the predictor variables

TABLE 12
PREDICTION OF SATS SUB-TEST AND TOTAL SCORES
FOR GROUP A USING
PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT
AS WELL AS AGE AND SEX AS PREDICTORS
N 455

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
SATS SUB-TEST #1 TEXT MATERIALS	MATHEMATICS	.20**		2.34*	
	SCIENCE	.19**		1.33	
	I.Q.	.22**		3.32**	
	AGE	-.10		-0.50	
	SEX	.03	.28	0.73	7.633**
SATS SUB-TEST #2 COURSE CONTENT	MATHEMATICS	.27**		3.35**	
	SCIENCE	.23**		1.28	
	I.Q.	.30**		4.96**	
	AGE	-.14		-0.75	
	SEX	.08	.38	1.80	15.070**
SATS SUB-TEST #3 INTEREST	MATHEMATICS	.08		0.57	
	SCIENCE	.09		0.92	
	I.Q.	.13		2.06*	
	AGE	-.04		.09	
	SEX	.06	.15	1.20	2.179
SATS SUB-TEST #4 STUDENT NEEDS	MATHEMATICS	.13		0.88	
	SCIENCE	.17*		1.77	
	I.Q.	.21**		3.14**	
	AGE	-.10		-0.75	
	SEX	.13	.27	2.71**	7.130**
SATS SUB-TEST #5 LABORATORY WORK	MATHEMATICS	.03		-1.25	
	SCIENCE	.12		2.30*	
	I.Q.	.10		1.46	
	AGE	-.10		-1.17	
	SEX	-.01	.17	-0.21	2.530*
SATS SUB-TEST #6 INVOLVEMENT	MATHEMATICS	.04		-1.30	
	SCIENCE	.17*		3.38**	
	I.Q.	.07		0.47	
	AGE	-.09		-1.04	
	SEX	-.01	.19	-0.26	3.252**
SATS TOTAL	MATHEMATICS	.19**		1.39	
	SCIENCE	.22**		2.39*	
	I.Q.	.25**		3.86**	
	AGE	-.13		-0.86	
	SEX	.08	.32	1.86	10.188**

* Statistic significant at 5% level.
** Statistic significant at 1% level.

TABLE 13
PREDICTION OF SATS SUB-TEST AND TOTAL SCORES
FOR GROUP B USING
PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT
AS WELL AS AGE AND SEX AS PREDICTORS
N 496

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
SATS SUB-TEST #1 TEXT MATERIALS	MATHEMATICS	.09		2.14*	
	SCIENCE	.04		-0.19	
	I.Q.	.02		0.10	
	AGE	.05		1.50	
	SEX	.11		2.47*	
			.16		2.586*
SATS SUB-TEST #2 COURSE CONTENT	MATHEMATICS	.23**		3.70**	
	SCIENCE	.20**		1.48	
	I.Q.	.16*		1.04	
	AGE	-.07		-0.65	
	SEX	.26**		6.66**	
			.38		16.295**
SATS SUB-TEST #3 INTEREST	MATHEMATICS	-.06		-1.39	
	SCIENCE	.04		2.03*	
	I.Q.	-.04		-0.40	
	AGE	.15		2.95**	
	SEX	.12		2.37*	
			.21		4.384**
SATS SUB-TEST #4 STUDENT NEEDS	MATHEMATICS	.10		1.60	
	SCIENCE	.11		1.48	
	I.Q.	.06		0.44	
	AGE	.07		1.93	
	SEX	.25**		5.64**	
			.29		9.067**
SATS SUB-TEST #5 LABORATORY WORK	MATHEMATICS	-.04		0.32	
	SCIENCE	-.06		-0.55	
	I.Q.	-.10		-1.31	
	AGE	.11		1.72	
	SEX	.04		0.82	
			.13		1.785
SATS SUB-TEST #6 INVOLVEMENT	MATHEMATICS	.04		1.93	
	SCIENCE	-.02		-0.36	
	I.Q.	-.12		-2.62**	
	AGE	.06		0.73	
	SEX	-.00		0.11	
			.15		2.229*
SATS TOTAL	MATHEMATICS	.10		2.00*	
	SCIENCE	.09		1.05	
	I.Q.	.02		-0.25	
	AGE	.08		2.09*	
	SEX	.21**		4.74**	
			.26		6.941**

* Statistic significant at 5% level.
** Statistic significant at 1% level.

TABLE 14
PREDICTION OF SATS SUB-TEST AND TOTAL SCORES
FOR GROUP C USING
PRIOR KNOWLEDGE SCORES IN MATHEMATICS, SCIENCE, INTELLIGENCE QUOTIENT
AS WELL AS AGE AND SEX AS PREDICTORS
N 445

CRITERION VARIABLE	PREDICTOR VARIABLE	CORRELATION	MULTIPLE CORRELATION	T	F
SATS SUB-TEST #1 TEXT MATERIALS	MATHEMATICS	.09		2.14*	
	SCIENCE	.08		1.98*	
	I.Q.	-.11		-3.78**	
	AGE	.03		-0.80	
	SEX	.21**		4.67**	
			.29		7.986**
SATS SUB-TEST #2 COURSE CONTENT	MATHEMATICS	.20**		3.59**	
	SCIENCE	.17*		2.74**	
	I.Q.	.02		-2.44**	
	AGE	-.04		-1.81	
	SEX	.21**		4.74**	
			.33		10.512**
SATS SUB-TEST #3 INTEREST	MATHEMATICS	-.08		-1.67	
	SCIENCE	.02		1.84	
	I.Q.	-.10		-2.30*	
	AGE	.06		0.32	
	SEX	.29**		6.45**	
			.33		10.517**
SATS SUB-TEST #4 STUDENT NEEDS	MATHEMATICS	.06		1.12	
	SCIENCE	.09		2.53*	
	I.Q.	-.10		-3.09**	
	AGE	.11		1.03	
	SEX	.37**		8.39**	
			.41		17.969**
SATS SUB-TEST #5 LABORATORY WORK	MATHEMATICS	-.03		-1.01	
	SCIENCE	.07		2.30*	
	I.Q.	-.05		-1.40	
	AGE	.05		0.55	
	SEX	.15		3.24**	
			.20		3.571**
SATS SUB-TEST #6 INVOLVEMENT	MATHEMATICS	-.14		-2.07*	
	SCIENCE	-.10		-0.52	
	I.Q.	-.12		-1.55	
	AGE	.03		-0.15	
	SEX	.11		2.55*	
			.20		3.764**
SATS TOTAL	MATHEMATICS	.04		0.91	
	SCIENCE	.09		2.57*	
	I.Q.	-.11		-3.57**	
	AGE	.06		-0.26	
	SEX	.34**		7.65**	
			.38		14.943**

* Statistic significant at 5% level.
** Statistic significant at 1% level.

followed by prior knowledge in Science. The multiple correlation scores which are also considerably less than they were for the TOUS scores of these same students reinforce the evidence that the five predictor variables do not play as large a part in the determination of the SATS scores as they do for TOUS scores.

A similar situation is noted on the examination of Table 13. Again all the F scores, with the exception of one, are significant but at somewhat lower levels than they were for the TOUS scores on the same group of students. The T scores, showing the relative significance of the predictor variables in predicing the outcome of the sub-test, indicate a marked change from previous patterns. The I.Q. variable which has been dominant is shown to be significant in only one of the seven tests while the variable Sex is the most significant variable in five of the seven tests. Because of the positive correlation shown between the variable Sex and the criteria variables it would seem to indicate that the program appealed more to the male participants that it did to the females.

An examination of the scores in Table 14 shows that the F scores, for the students in Group C, are all significant at the one percent level with most being significant at the 0.1 percent level. Although the variables I.Q. and prior knowledge in Science are again very significant, the most significant variable was Sex. With a positive correlation existing between Sex and the various criteria variables it would seem to indicate that the program followed by this group like the program followed by the students in Group B had a greater appeal to the male participants.

Examining Tables 12, 13 and 14 together it would seem that the predictor variables chosen do not play as significant a role in the prediction of the scores obtained on the SATS sub-tests as they did for the TOUS sub-tests. However, this would seem logical as one would expect understanding to be much more dependent on I.Q. and prior knowledge than would be the case for attitudes. However, it does seem that the programs followed by Groups B and C appealed more to the male participants whereas the program followed by the students of Group A found equal favour with both sexes.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

In this investigation, 1,396 students enrolled in grade ten science courses in Manitoba schools were given a Test On Understanding Science, and a Student Attitude Toward Science test. The students were enrolled in three different science courses, 455 were following a program based on the textbook Introductory Physical Science, 496 were taking a program based on the textbook An Introduction to Physical Science, and 445 were following a program based on the textbook Everyday Problems in Science. All students involved had previously written in June 1966 common, externally set and marked tests in Mathematics, Science and mental ability.

In general, the purpose of the study was to examine pupil achievement in and pupil attitude toward three grade ten Science programs authorized for use in Manitoba high schools. To this end the Student Attitude Toward Science instrument was chosen to measure the acceptance by the students of the text material, the content of the course and the laboratory work. It also measured student interest in the course, student involvement in the course and the extent to which the students perceived that the course was meeting their needs. The Test On Understanding Science was used to obtain a measure of student understanding of the aims and methods of science, of the nature of the scientific enterprise, and of the role of the scientist.

The study used statistical techniques to test pupil achievement in the three different programs as measured by the Test On Understanding Science. The test items were not course specific, but were of a general knowledge nature. Statistical techniques were applied to the results of the Student Attitude Toward Science instrument to determine student acceptance of the science course being taken.

The hypotheses tested were given in Chapter I and are reproduced here with the results of the testing.

I There is no significant difference in attitude toward science as measured by the sub-test scores of the SATS test between A, B and C groups of students.

The scores of the students in Group A were consistently and significantly higher, at the one percent level, than the scores obtained by the students in Groups B and C. Also, in general, the scores of the students in Group B were significantly higher than the scores obtained by the students in Group C.

II There is no significant difference in the achievement in science as measured by the sub-test scores of the TOUS test between the A, B, and C groups of students.

For one sub-test only, Understanding of the Role of Scientists in Society, there was no significant difference in the scores obtained by the three groups. For the other two sub-tests and the total TOUS test the scores from the students in Group A were significantly higher at the one percent level, than the scores of the students from Groups B and C. There was no significant difference found between the scores of the students in Groups B and C for any of the sub-tests.

In addition, on examination of the correlation matrices computed for the total group and for each of the three sub-groups on the basis of sixteen variables, significant correlations were found between the sixteen variables used in this study. There was a highly significant correlation between the sub-tests of SATS and the total score on SATS, indicating that the instrument was a consistent measure. There were also highly significant correlations between the sub-tests of TOUS and the total score on TOUS, indicating that this instrument was also measuring consistently. However, when the matrices were examined for correlations between the sub-tests of the SATS instrument and the sub-tests of the TOUS instrument, two patterns emerged. For Groups B and C there were no significant correlations between the sub-tests of the two instruments indicating that the two instruments were measuring different attributes of students' responses. The matrix for the students of Group A, however, showed a reasonable number of significant correlations between the two instruments. These correlations significant at the one percent level, existed principally between the TOUS sub-tests concerned with Understanding of the Scientific Enterprise and Understanding the Aims and Methods of Science and the areas of the SATS tests concerned with Text Materials, Course Content, and Student Needs. One interpretation of this result could be that the program using the textbook Introductory Physical Science which was followed by the students in Group A somehow develops in the students an interdependence of understanding and attitude which does not take place in the students who followed the other two programs.

The excessive number of negative correlation coefficients shown in the responses to the SATS instrument of the students of Group C indicated a pronounced dissatisfaction with the program using the textbook Everyday Problems in Science. This dissatisfaction was evident in the negative relationships with regard to text materials, student interest, student needs, laboratory and student involvement in the program. It would be a fair assessment to state that this program has been rejected by the students as far as meeting their requirements.

Negative correlation coefficients were also found in the responses to the SATS instrument by the students of Group B. However, the frequency of distribution was not so pronounced and was limited to the areas of laboratory and student involvement. This would indicate that although the program was not entirely acceptable it was by no means rejected by the students.

The students of Group A, using the textbook Introductory Physical Science, had very positive and significant correlation coefficients indicating a general acceptance of the program being followed. This was in marked contrast to the results obtained from the other two programs.

The results of the multiple regression analysis and the analysis of variance indicated that the five predictor variables chosen-prior knowledge in Mathematics and Science, I.Q., Age and Sex, are very significant when used together, in predicting the results of the TOUS sub-tests for all groups. The dominant variable was shown to be I.Q. followed by prior knowledge in Science and Mathematics. Although the significance of this test was very high other undetermined variables were affecting the results as shown by the fact that the maximum percentage of the variance predictable was fifty-nine percent.

When the same analysis was applied to the results of the SATS sub-tests the results, although significant, were not of the same degree. For many of the tests Sex became the dominant variable although I.Q. was still of significant importance. This aspect was especially noticeable in the scores of the students from Groups B and C. The variable Sex did not arise as a significant variable in the program followed by the students of Group A using the textbook Introductory Physical Science. This would indicate that this program appealed equally well to both boys and girls.

Conclusions

It has been shown that significant differences in attitude towards science as measured by the sub-test scores of the SATS test do exist between the A, B, and C groups of students. The differences ranged from very positive for the students of Group A to very negative for the students of Group C with the students of Group B showing generally positive with some negative aspects.

It has also been shown that significant differences in achievement in science as measured by the sub-test scores of the TOUS test do exist between the A, B, and C groups of students. The students of Group A have a significantly better understanding about the scientific enterprise and about the aims and methods of science than do the students of either Group B or Group C.

Although there is no significant difference discernible between the students of Group B and the students of Group C, in respect to their scores on the TOUS sub-tests, nevertheless it has been shown that the students of Group B following the program based on the textbook An Introduction to Physical Science do accept the textbook and the content of their course more readily than do the students of Group C. In addition the students of Group B indicated that their program satisfied their interest and felt needs much more so than did the students of Group C.

It should also be concluded that this study has shown again that it is possible to evaluate different science courses on other than a subjective basis, to show which are effective and acceptable to students. The statistical techniques which have been used in this study could be used in curriculum research in other subject areas.

Recommendations

Certain areas of concern were not covered in this study which should be investigated. Possibly the most important of these is the possible effect of many different teachers being involved in the program. It was hoped that the distribution of the sampling would tend to remove teacher influence but the true effect may have been just the opposite. Also the possible or even probable effect of other prior knowledge factors such as achievement scores in English or reading comprehension ability might play a major part in determining a student's attitude and his understanding of a given program. It was noted that although up to fifty-nine percent of the scores on the TOUS test were statistically predictable by means of the variables used it was not possible to exceed a value of thirty-eight percent for similar predictions on the SATS scores.

It is recommended that further investigation be undertaken to include the relationship between teacher factors of knowledge, sympathy, warmth, expectations and motivational techniques, student understanding of science and student attitude toward science courses.

It is also recommended that a further study be conducted using the same student populations as were involved in this study to determine if the difference in attitudes and understanding found in these students at the end of their grade ten program continued to exist at the end of their high school science program.

A further recommendation stems from the reactions of the students in Group B to the program based on the textbook <u>An Introduction to Physical Science</u>. As the student reactions were not wholly positive to this program and as this program is the only program authorized for use in the General Course Science curriculum in grade ten it would seem advisable that curricular revision be undertaken to create a science program which would do more to meet the objectives of developing positive attitudes and understanding towards the place of science in our society. Such a revision, if undertaken, could profit from an examination of those aspects of the program based on the textbook Introductory Physical Science which produced strong positive student reaction.

BIBLIOGRAPHY

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

Cooley, William W., and Leopold M. Klopfer, "The Evaluation of Specific Educational Innovations," Journal of Research in Science Teaching, 1:73 (1963).

Course Outline, General Course Science 101, Province of Manitoba Department of Education, undated, mimeographed.

Haber-Schaim, Uri, "A New Physical Science Course," IPS Newsletter, Prentice Hall, Incorporated February 1966.

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

Lockard, J. David, ed., Report of the International Clearinghouse On Science and Mathematics Curricular Developments 1967. A Joint Project of the Commission on Science Education of the American Association for the Advancement of Science and the Science Teaching Center, University of Maryland (University of Maryland, College Park, Maryland).

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

Programme of Studies for the Schools of Manitoba, Senior High Schools 1963-64. Winnipeg: Queen's Printer, 1963.

APPENDIX A

DIRECTIONS FOR ADMINISTERING SATS

THE SATS INSTRUMENT

DIRECTIONS FOR ADMINISTERING SATS

This instrument is experimental in nature. It has been devised in an attempt to determine how students react to the course of study they are taking this year. In this preliminary edition seventy five statements are made and the students are asked to react to these statements on a five point scale going from A (strongly agree) to C (indifferent, or don't know) to E (strongly disagree) with B and D being inbetween statements. The items are broadly categorized into Interest, Student Needs, Content of Course, Text, Laboratory Work and Student Involvement. No attempt is made or implied to use this device as a measurement of teacher efficiency or competency. Even those statements which appear to be slanted towards teaching techniques are selected on the basis of what students find interesting and useful to them.

In order to have confidence in the comparability of their attitude to the course, it is important to follow the procedure outlined below. This includes reading aloud the directions on the back cover of the test booklet.

ASSEMBLING MATERIALS BEFORE TESTING

The following should be used as a check list by the tester in determining that all necessary materials are available before any students are to be tested.

1. The same number of SATS booklets as the number of students to be tested - plus a few extra copies for emergencies.

2. The same number of answer sheets as number of students to be tested - plus a few extra copies for emergencies.

3. This direction sheet.

4. Pencils - students should not use ink, as it would be difficult to change an answer if desired. Some extra pencils should be kept on hand for emergencies.

ARRANGEMENTS TO BE MADE BEFORE TESTING

The following points should be considered as a check list for the examiner. The instructor should be sure that all details are taken care of before any students are tested.

1. Study of the SATS materials. It will pay the examiner in terms of smooth test administration to study carefully the SATS booklet to be given to the students, the answer sheet and all of the directions given on these pages before testing.

2. Practice administration. The examiner can more nearly assure uniformity in testing if he gives the opinionnaire to a small group of students who will not be included in the actual testing. It would be satisfactory if he completes the test himself.

3. Time scheduling. There is no time limit on the test but it is expected that students can be tested in one session of approximately 50 minutes. If larger groups are being used, more time may be needed for distributing materials, having students fill in information on answer sheets and for answering student's questions.

4. Room scheduling. If possible this test should be given in a room that does not crowd the examinees. Good lighting, and ventilation and freedom from noise

and interruption are other factors to be considered in selecting a testing place.

5. Seat and desk arrangement. Students should be provided with reasonably comfortable seats and smooth hard writing surfaces. Writing surfaces should be large enough to accommodate a folded test booklet and an answer sheet.

6. Information on students. The answer sheet provides space for each student to write in name, date of test, age, sex, School, city, grade, instructor and name of test. In space labelled No. 1, ask the students to give the name of the course they are taking in science and in No. 2 the name of the textbook they are using.

AT THE TIME OF, AND DURING, THE TESTING SESSION

1. Read the directions on the back page of the booklet to the students word for word.

2. In answering questions raised by students, it is essential that the examiner obtains the cooperation of the students in giving their honest opinions to the statements. There will be no penalty for any statements made. All questions must be answered. If they have no opinion, they should score the C response.

Instructions which are to be read aloud to the students are underlined and double spaced. Instructions, printed in single space, without underlining, are intended only for the examiner.

TEST INSTRUCTIONS

When the students are assembled in the examination room and seated

SAY:

The testing period has begun. There should be no talking among you until you have been dismissed.

We shall now pass out test materials. Do not open your booklet or turn it over until you are told to do so.

Distribute test booklets, answer sheets and pencils. Then SAY: Do not open your booklet until I tell you to. Take your answer sheet and turn it so you can PRINT your name on it. Fill in today's date. (Examiner should give the correct date). On the next line write in the name of your school, city or town. Under No. 1 write the name of the course you are taking. (Examiner should indicate general course, matriculation, or University entrance or whatever). Under No. 2 write the name of the text you are using. Now fill in the date of your birth giving day, month and year. (Examiner should illustrate as 17/3/52 your age in years and sex, grade and the name of your science teacher. Fill in the name of the test as SATS. Do not write anything under scores or part.

Pause to make sure there are no questions about the information to be filled in on the answer sheets. Then SAY:

> Please turn your test booklet to DIRECTIONS, on the back cover.
>
> Read these directions silently while I read them aloud.

Read the directions from a copy of the test booklet. After you finish reading the directions, SAY:

Are there any questions?

Be sure that every student understands the general directions. Emphasize any points that need emphasis and explain the points of A to D meaning going from strongly agree to strongly disagree. All the items on the answer sheet are noted as A B C D E and no reference is made on the answer sheet as to the interpretation. Then SAY:

If you forget what A or any item means, you can refer back to your directions. There are 75 statements on this paper and you will be allowed 40 minutes to complete it. You will have to work rapidly but do try to complete all the answers.

Answer any questions. Then SAY:

Open your booklet and begin working. If you finish before I call time go back over the test and check your answers. Be sure that you mark your answers in the proper spaces on the answer sheet. Make only one mark for each statement.

Allow the students enough time to finish the test. It is not critical to follow an exact time scale but encourage students to complete the answers as rapidly as possible. This should indicate a more reliable attitude toward the statements. Collect the answer sheets, then the test booklets. Package the answer sheets separately and forward them to the following address:

K. H. Charlesworth
Curriculum Branch
Department of Education
Room 411, 1181 Portage Avenue
Winnipeg 10, Manitoba

The test booklets are required for use with classes in other schools. These should be packaged together and returned to the same address as the answer sheets.

S A T S

S T U D E N T   A T T I T U D E   T O W A R D S   S C I E N C E

F O R M   A - (Revised)

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

DIRECTIONS

The following statements are related to your work in the science course you are taking this year. These statements are presented as generalizations and represent opinions rather than facts. As opinions, they are neither right nor wrong. This is not a test but a device to determine how you feel about your course of study. In the items that follow you are asked to give your honest opinion by scoring the appropriate section with the special pencil provided. Score the appropriate section as it first impresses you. Indicate what you believe rather than what you think you should believe.

Example: I like to watch NHL hockey broadcasts on TV.

A	B	C	D	E
//	//	//	//	//
strongly agree		neutral		strongly disagree

If you score the A response this would indicate that you are very interested in hockey and watch the televised programs most of the time.

If you score the B response, this would indicate that you watch the TV hockey broadcasts frequently but on some nights you would watch competing programmes.

If you score the C response, this would indicate that you really didn't care one way or another. You would watch hockey sometimes and just as often you would do something else.

If you score the D response, this would indicate that you watch other programmes or do something else more often than you watched hockey. It would also indicate that you did watch the programme once in a while.

If you score the E response, this would indicate that you do not watch hockey at all. In fact you have no interest in the hockey programmes.

Of course, all of these responses presume that you have a TV set and that NHL hockey broadcasts are available to you. Furthermore, the statement assumes the response is true for the hockey season.

Now try this statement by scoring the appropriate section of item 150.

Example: The assignments my teacher gives me in science are usually too difficult.

Remember that A means that you strongly agree with the statement, C means that you neither agree or disagree or can't decide and E means that you strongly disagree with the statement, B and D are simply degrees of agreement or disagreement. The purpose of this test is to obtain your opinion. There is no right or wrong answer. All statements refer to the science course you are currently taking.

If you have had no laboratory work this year or if you are undecided as to your feelings on a statement, score section C.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

1. Much of the material of the science course I have already covered in Junior High school, so it is not new to me.

2. I can read the text with no difficulty. Most of the technical terms are clearly explained.

3. I would like to study many topics in the science course more deeply but there is not enough class time.

4. The topics I have studied this year in my science course are of little use to me in the work that I plan on doing after I leave school.

5. Much of the information given in my science textbook is out-of-date.

6. I like to see demonstrations of scientific principles carried out in class as it makes the text easier to understand.

7. Little consideration is given in my science course to the topics in science that I think are the important or big problems in science.

8. I think the science course I am taking is useful to me because it shows recent applications of science.

9. We have charts, clippings and other interesting materials on display in our science classroom.

10. I pay more attention in science classes than in other classes because I am interested in the topics we are studying in science.

11. Many of the laboratory exercises we performed this year were too long to be done in the allotted time.

12. In my science classes we use interesting apparatus and materials, either in the laboratory or in the classroom.

13. I think that my laboratory manual gives adequate direction so I know how to carry out the experiment.

14. I seldom know the result of an experiment before I carry out the laboratory exercise. Most of the experiments cause me to think.

15. I would rather have taken a biological science course this past year than the course of study we had.

16. I think our laboratory was well enough equipped to do all the experiments suggested in our work this year.

17. When I study a topic or a unit in my science course, I can usually see why it is important for me to study it.

18. I have done only a few of the laboratory experiments on my own or with groups of fellow students this past year. Most of the work is demonstrated by the teacher.

19. I find the questions at the end of the chapters of the text that involve mathematical calculations too difficult.

20. I am interested in performing experiments in the laboratory but do not like having to write up the experiment in detail.

21. I am not interested in taking a science course like this one next year but would rather take almost any subject other than science.

22. I think we spent too much time in class on some topics in the science course this year and rushed too quickly over other topics.

23. Experiments relating to the topic I was studying in class were performed at approximately the same time as the work was studied in the regular class periods.

24. I would prefer to work on experiments I invented and devised rather than the ones I have done this year.

25. I spent too much time on learning trivial laboratory techniques which were not important to getting my experiments done.

26. Too much time is devoted to the study of science and not enough time to the study of other subjects.

27. I prefer to handle the equipment myself in doing experimental work rather than watching someone else do the experiment.

28. Because of my interest in science, I normally spend more time on my science home work than in other subjects.

29. Because of the difficulty of this science course, I find that I have to spend more time on science homework than in other subjects.

30. I wish those who develop courses and select texts would ask me what I thought I needed to learn in science. I think I know what I would like to study for the job I want after I leave school.

31. Too much mathematics is needed to do this course in science.

32. I think the course I am studying in science is too difficult for me.

33. In general I think I am learning things from my science course that I can use.

34. I think the experiments that I have done this year have begun to make me think as I imagine a scientist thinks.

35. I am confused over such technical terms as scientific model, scientific problems, hypothesis, conclusions, laws and theories.

36. I think I can read popular articles in the general area of science with better understanding because of the information I have obtained from my science course.

37. I have read more articles in popular science books and magazines this year than I have in any single year before.

38. I like to do the extra science investigations or activities suggested in the text.

39. I find the questions at the end of the chapter challenging. They make me think.

40. Most of the topics I am taking in my science course are those I would like to study more deeply at some future time.

41. This course has helped me in some of the other courses I am taking this year.

42. I spend more time studying science than I do any other subject.

43. I think my powers of observation have improved through the work I have taken in science this year.

44. The science course covers too much material. We do not spend enough time on any one topic for me to understand it.

45. I would like to help present demonstrations to my classmates on the topics we study in science.

46. When we see demonstrations in class I find that I become more attentive and interested in the work.

47. I have to be forced to do my science homework.

48. I have to be forced to do any kind of homework. I just don't like doing any kind of assignment.

49. The text is very informative. Enough information is given on most topics so that I can understand the main ideas.

50. I would like to construct in the laboratory simple machines and simple apparatus to carry out experiments. I think this would be useful in making me think like a scientist.

51. The problems at the end of the chapter are useful and beneficial to me. They help me understand the course.

52. The author(s) of my textbook has made the content interesting, easily understood, concise and clear.

53. The science course that I am taking is more difficult than the science courses that other students in this school are taking.

54. I think the text is too compact and too congested, making for heavy reading.

55. I think there are sufficient illustrations of applications of scientific principles, in examples or in diagrams, in the text of the various topics in the course we are studying.

56. I often notice in things around me application of some of the scientific principles I have studied this year.

57. I think the exercises in the text serve no useful purpose and are merely busy work.

58. I frequently read other texts and reference books in order to understand the material in my science course.

59. I like experiments for which there is a right answer so that I know the results I get are right or wrong.

60. The demonstrations I have seen this year usually have worked as I expected them to work.

61. I usually know what I am supposed to do in the laboratory.

62. I would like to have my science course organized so I could do more experimental work.

63. The knowledge I have gained in my science course gives me a feeling of accomplishment.

64. I usually look forward to my science classes.

65. In my classes, the laboratory period is a play period.

66. I believe the information I am learning in my science course is useful to me now and will be useful in later life after I finish school.

67. I can't follow the directions for doing experiments in the laboratory. They are not clear enough for me to see what I am supposed to do.

68. The text usually refers to everyday applications in science that I can understand.

69. I usually read the instructions for carrying out experimental work carefully.

70. I feel the time I spend in the laboratory doing experiments could be much better utilized.

71. In studying my science course, I am beginning to see how knowledge from one science area relates to another area.

72. I believe my vocabulary of technical and scientific terms has improved considerably this year.

APPENDIX B

DIRECTIONS FOR ADMINISTRATING TOUS

THE TOUS INSTRUMENT

DIRECTIONS FOR ADMINISTERING TOUS

In order to have confidence in the comparability of test results, it is important to follow precisely the procedure outlined below. This includes reading aloud the directions on the back cover of the test booklet. The reason for this is that these directions contain the definition of "scientist" used in the test, and we wish to be certain that all students taking TOUS have seen this definition. The definition is contained in the example which is explained in the directions. The directions also emphasize the importance of selecting the one BEST answer, out of several possible partly correct alternatives, in each item.

ASSEMBLING MATERIALS BEFORE TESTING

The following should be used as a check list by the examiner in determining that all necessary materials are available before any students are to be tested:

1. The same number of TOUS as the number of students to be tested - plus a few extra copies for emergencies.

2. The same number of answer sheets as number of students to be tested - plus a few extra for emergencies.

3. This direction sheet.

4. Pencils - students should not use ink, as it would be difficult to change an answer if desired. Some extra pencils should be kept on hand for emergencies.

5. A timer - any watch or clock for recording the time.

6. A notebook or paper on which the examiner can record the exact starting and stopping times and make any relevant notes during and after testing.

ARRANGEMENTS TO BE MADE BEFORE TESTING

As with materials, the examiner should consider the following a check list. The instructor should be sure that all details are taken care of before any students are tested.

1. Study of testing materials. It will pay the examiner in terms of smooth test administration to study carefully the test booklet to be given to the students, the answer sheet, and all of the directions given on these pages before testing.

2. Practice administration. The examiner can more nearly assure good testing if he gives the complete test for practice - to another teacher, a friend or a small group of students who will not be included in the actual testing.

3. Time scheduling. 40 minutes are to be allowed students for completing TOUS. Students in a single class can be tested in one testing session of approximately 45 - 50 minutes. Examiners dealing with large groups may need more time for distributing materials, having students fill in information on answer sheets, and for answering students' questions.

4. Room scheduling. If possible, testing should be conducted in a room that does not crowd examinees. Good lighting and ventilation and freedom from noise and interruption are other factors to be considered in selecting a testing place.

5. Seat and desk arrangement. Students should be provided with reasonably comfortable seats and smooth, hard writing surfaces. Writing surfaces should be large enough to accommodate a folded test booklet and an answer sheet.

6. Information on students. The answer sheet provides space for each student to write in name, age, sex, grade, science course, school and date tested. Ask the students to include the name of their science teacher. This information will be used only for cross reference and not as an evaluation device.

AT THE TIME OF, AND DURING, THE TESTING SESSION

1. Read directions carefully to students, word for word.
2. In answering questions raised by students, it is essential that the examiner stay within the meaning and, as far as possible, the exact wording of the directions. Directions concerning guessing are particularly troublesome. Questions on this point should invariably be answered by reading these sentences from the directions: "You will make your best score by answering every question. You should work carefully but not spend too much time on any one item. If a question seems too difficult, make the most careful guess you can. If you finish before time is called, go back and spend more time on the questions about which you are doubtful."

3. Timing must be carefully observed; under no circumstances is additional time to be allowed to any student.

Note: Instructions which are to be read aloud to students are underlined and double spaced. Instructions, printed in single space, without underlining, are intended only for the examiner.

TEST INSTRUCTIONS

When the students are assembled in the examination room and seated, SAY:

The testing period has begun. There should be no talking among you until you have been dismissed.

We shall now pass out test materials. Do not open your booklet or turn it over until you are told to do so.

Distribute booklets, answer sheets and pencils. Then SAY:

Do not open your test booklet until I tell you to. Take your answer sheet and turn it so that you can PRINT your name on it. Fill in today's date. (Examiner should give the correct date.) Fill in Age, Sex and Date of Birth.

On the next line, write in the name of your school, city or town, Grade and name of Instructor. Fill in the name of Test as TOUS. In section, marked PART 1 and 2 fill in the name of the textbook you are using. Do not write anything under Scores or Identification Number.

Pause to make sure there are no questions about the information to be filled in on the answer sheets. Then SAY:

> Please turn your test booklet to DIRECTIONS, on the back cover.
>
> Read these directions silently while I read them aloud.

Read the directions from a copy of the test booklet. After you finish reading the directions, SAY:

Are there any questions?

Be sure that every student understands the general Directions. Emphasize any points that need emphasis and answer any legitimate questions concerning procedures. If there are any questions on whether or not to guess, read verbatim the sentences that cover the point in the Directions. Then SAY:

There are 60 questions on this test, and you will be allowed 40 minutes to complete it. You will have to work rapidly, but do not rush. Are there any questions? I cannot answer questions after you begin working on the test.

After answering questions, SAY:

Open your test booklets to page 3 and begin working. Keep working until I tell you to stop. If you finish before time is called, go back over the test and check your answers. Be sure that you mark your answers in the proper spaces on the answer sheet. Make only one mark for each question.

Write on the board the exact time when students begin working on the test. Also write on the board the time when the students must stop work. After exactly 40 minutes, SAY:

Stop! Put down your pencils.

Even if you have not finished you must stop.

Collect the answer sheets, then the test booklets and pencils. Package the answer sheets separately and forward them to the following address:

K. H. Charlesworth
Curriculum Branch
Department of Education
Room 411, 1181 Portage Avenue

The test booklets are required for use with class in other schools. These should be packaged together and returned to the same address as the answer sheets.

612500

TOUS

TEST ON UNDERSTANDING SCIENCE

Form W

1. The chief purpose of the science of botany is to

   A. teach farmers how to produce more food.
   B. develop new drugs and medicines from plants.
   C. provide explanations on how plants grow and reproduce.
   D. tell us what plants will grow best in various kinds of soils.

2. Among the hundreds of scientific societies in various countries throughout the world, we find that

   A. scientists voluntarily join the societies related to their special field.
   B. national governments generally direct these societies.
   C. membership is generally restricted to scientists of one nation.
   D. national governments are seldom interested in these societies.

3. In the past, many important scientific discoveries were made by men who were clergymen, statesmen, or businessmen, and who worked on science as amateurs. This is no longer true today because

   A. men in other professions are less interested in science today than they used to be.
   B. scientific research today requires many years of preparation, usually study beyond college.
   C. important discoveries cannot be made today without expensive equipment which only scientists possess.
   D. only professional scientists have the abilities needed to make important discoveries.

4. The people and government of a country influence scientific activity

   A. very little, because scientists are quite isolated from the rest of society.
   B. a little, because people must be willing to become scientists and to pay for science.
   C. a great deal, because most scientists work for the government and must follow its instructions.
   D. a great deal, because the education and support given to scientists depend on how the people feel about science.

5. In the 17th century, Newton formulated his laws of motion and the theory of universal gravitation, which were eventually accepted by all physicists. In the 20th century, Einstein proposed a much broader theory of relativity, which physicists have generally accepted. Physicists today consider Newton's ideas as

   A. mistaken notions, because of Newton's limited experience.
   B. part of Einstein's theory, as a special case.
   C. applicable only to physical events in another world.
   D. superior to Einstein's, because they have a longer tradition.

6. An astronomer in Australia reports that he has seen evidence of plant growth on the planet Venus. American astronomers will accept this report as a fact if

   A. other independent observations confirm the report.
   B. the species of the plants have been identified.
   C. the Australian government certifies the observation.
   D. other astronomers agree that there is oxygen on Venus.

7. The microscope came into wide use in scientific work in the 17th century. This new instrument made it possible for scientists to see very small objects, and also to

   A. look more closely at the ultimate nature of matter.
   B. discover the real meaning of life.
   C. look more closely at cause and effect relationships.
   D. explore new problems unknown before this time.

8. The principal function of scientific societies is to

   A. promote the economic welfare of their members.
   B. publish and sell scientific books and periodicals.
   C. promote the exchange of ideas and maintain professional standards.
   D. inform non-scientists of important scientific discoveries.

9. If we compare successful scientists with successful people in most other professions, we find that these

   A. scientists tend to have higher incomes than other professionals.
   B. scientists require more specialized training than other professionals.
   C. scientists and other professionals have set rigid certification laws which keep out those who are not qualified.
   D. scientists and other professionals tend to devote most of their energies to their work.

10. If we ask an astronomer to explain why some stars vary in apparent brightness, he will most likely give his explanation in terms of

   A. the necessity of stars to vary in brightness.
   B. accepted scientific laws and principles.
   C. exact mathematical equations and formulas.
   D. verified astronomical observations and data.

11. Several recent reports have pointed out a tendency in the United States toward increased conformity, thus discouraging creativity. If these reports are correct, we can expect that in the United States

A. scientists will conform to higher standards of accuracy.
B. scientists will work together more productively.
C. creative arts, like music and painting will suffer, but not science.
D. both science and the arts will suffer in the future.

12. The principal aim of science is to

A. verify what has already been discovered about the physical world.
B. explain natural phenomena in terms of principles and theories.
C. discover, collect and classify facts about animate and inanimate nature.
D. provide the people of the world with the means for leading better lives.

13. It has often been said that published reports of scientific research are generally very accurate and honest.

A. This is true because scientists are very accurate and honest people.
B. This is true because only one answer can be correct in science.
C. This is true because reported results can be checked by other scientists.
D. There is little basis for this claim.

14. In 1935 a Japanese physicist, Hideki Yukawa, made an important contribution to the theory of nuclear physics. This occurrence was not considered unusual because

A. nuclear physics is taught in schools throughout the world.
B. almost anyone can contribute a scientific theory.
C. most Asian scientists know a great deal about nuclear physics.
D. people from many countries contribute to science.

15. Of the following, which is the best statement about scientific knowledge?

A. Scientific knowledge is a systematic collection of facts.
B. Data and ideas from the past contribute to today's scientific knowledge.
C. Each generation starts anew to build up its own scientific knowledge.
D. Statements are not accepted as scientific knowledge unless they are absolutely true.

16. Which one of the following statements best describes the most important contribution scientists make to our society?

   A. Scientists provide knowledge about natural events.
   B. Scientists make improved products for better living.
   C. Scientists provide skilled services or advice to others.
   D. Scientists show us what we should strive for.

17. Are biology, chemistry, and physics related or are they not? They are

   A. not related because they are built on different sets of fundamental principles.
   B. related, because the observation, principles, and ideas of each field have connections with the other two.
   C. related, because mathematics serves to unify the sciences.
   D. not related, because biologists, chemists, and physicists study very different natural phenomena.

18. John Smith is a very imaginative young person. He may never become a scientist because

   A. he would not want to give up his freedom of thought.
   B. imaginative people usually become artists and writers.
   C. he might like some other field better than science.
   D. science is too factual for John.

19. If a physicist and a livestock dealer were to walk into an experimental biology laboratory together for the first time, which man would probably understand what was going on there more quickly?

   A. Both men would understand at about the same time, because neither of them is a research biologist.
   B. The livestock dealer, because the training for his job most likely included the methods of experimental biology.
   C. The physicist, because biologists and physicists have similar points of view toward investigating natural phenomena.
   D. The physicist, because physicists do the same kind of laboratory work that biologists do.

20. At present, at least 90% of U. S. Government money for research and development pays for such things as ballistic missiles, nuclear reactors, insecticides, vaccines, computers, rocket fuels, and space suits. Many scientists are critical of this allotment of Government money because

   A. less than 10% is allotted to technological applications.
   B. less than 10% is allotted to research in science.
   C. only 90% is allotted to research in science.
   D. only 90% is allotted to technological applications.

21. Today, physicists of several countries are working on experiments to determine whether or not one of Einstein's theories correctly predicts the effect of gravity on light. This activity best illustrates the fact that

A. an important function of theories is to stimulate research.
B. it is important to have a precise value for the speed of light.
C. it takes a long time to prove that a theory is really true.
D. theories are still doubted long after they are proven true.

22. Scientists are often described as having certain "scientific attitudes." These may be best observed when scientists are

A. actually engaged in research.
B. asked to work outside their field.
C. doing most anything.
D. with their families and friends.

23. The design of a television receiver is a problem of

A. science, because it calls for ingenuity and originality.
B. science, because the design must be developed by experiment.
C. technology, because it leads to the production of a practical device.
D. technology, because the designer must have technical ability.

24. Today, the education of American scientists who teach and do research at universities generally

A. is completed after four years of college.
B. includes a period of practical training in industry.
C. is completed after five years of college.
D. includes study for advanced degrees after completing college.

In items 25 to 30 you are to choose the answer which is an EXCEPTION or is LEAST LIKELY to belong in the group and blacken the space under the corresponding letter on the answer sheet.

25. Scientific journals have all of the following functions EXCEPT to

A. serve as a forum for the discussion of new theories.
B. provide information on research which is in progress.
C. print papers which were read at scientific meetings.
D. explain policies of scientific societies for the conduct of research.

26. If a botanist wants to determine the factors that contribute to the growth of a certain plant, which of the following things will he be LEAST LIKELY to do?

A. Formulate an hypothesis based on what he thinks the factors are.
B. Write a mathematical equation of the growth curve.
C. Think about the factors that contribute to the growth of other plants.
D. Look the subject up in the library.

27. The American Chemical Society (ACS) is one of the largest scientific societies in the United States. Which of the following functions would the ACS be LEAST LIKELY to carry on?

A. Negotiate contracts with companies employing chemists.
B. Assist its members in finding new jobs.
C. Publish chemical journals and books.
D. Establish standards of terminology in chemistry.

28. Scientists cooperate on an international scale through all of the following activities EXCEPT

A. setting the values of physical constants.
B. publishing scientific journals.
C. prescribing courses for the preparation of scientists.
D. advising United Nations agencies.

29. Which one of the following factors will be the LEAST HELP to the growth of science in America?

A. Setting national goals for discoveries that must be made.
B. Improving the means of communication among scientists.
C. Improving the training of high school science teachers.
D. Reducing security restrictions on scientific knowledge.

30. An example of a scientific model is: "The atom is like a miniature solar system composed of electrons in orbits, and, in the center, a nucleus containing protons and neutrons." Which one of the following statements about scientific models is NOT correct?

A. They are man-made constructs and may not represent reality.
B. They consist of a relatively small number of assumptions.
C. They represent what scientists could see with very powerful instruments.
D. They are tentative and may be modified or discarded.

SPECIAL DIRECTIONS FOR ITEMS 31 TO 37

In each of the following items, there is a statement about scientists on the left and a reason for that statement on the right. On the appropriate numbered line of the answer sheet, blacken the space under

A. if both the statement and the reason are generally true;
B. if the statement is generally true but the reason is false;
C. if the statement is false but the reason is generally true;
D. if both the statement and the reason are false.

Summary of Directions

	STATEMENT	REASON
A.	generally true	generally true
B.	generally true	false
C.	false	generally true
D.	false	false

	STATEMENT		REASON
31.	Two kinds of scientists, experimentalists and theoreticians, are found in most branches of science	BECAUSE	good theoreticians are not trained in the skills needed in laboratory work.
32.	Scientists are less likely than people in other professions to have a normal happy family life	BECAUSE	scientists spend every possible minute in their laboratories.
33.	Work in the various branches of science requires the same abilities and skills	BECAUSE	scientific methods are used in all branches of science.
34.	Scientists are honest and self-critical in their work	BECAUSE	these scientific attitudes are personal characteristics of scientists.
35.	Scientists are generally geniuses	BECAUSE	creative ability is often called for in attacking scientific problems.
36.	Most scientists are dedicated to their work	BECAUSE	scientists have an abnormal desire to succeed in life.
37.	The training of a physicist is just about the same as the training of a chemist	BECAUSE	the different branches of science demand the same kinds of skills in their workers.

38. Betty is planning an experiment to learn something about the role of potassium in the growth of a certain plant. She decides to grow one group of these plants in soil containing nitrogen and phosphorus, but lacking potassium. A second group of these plants, serving as a "control," should be grown in soil containing

A. potassium only.
B. nitrogen, phosphorus, and potassium.
C. nitrogen and potassium, but no phosphorus.
D. nitrogen and phosphorus, but no potassium.

39. Most of the important scientific advances have come about as the result of

A. the development of new and more significant sets of ideas.
B. the interaction of ideas and experiments in the solution of problems.
C. the dedication of an extraordinary man to the investigation of a particular specialty.
D. an interaction between a chance observation of a new phenomenon with an alert mind.

40. A scientific society is

A. a society that is run according to scientific methods.
B. an organization that seeks to make society more scientific.
C. a society in which people believe in the importance of science.
D. an organization of scientists that promotes scientific work.

41. Which one of the following statements best describes the connection between science and technology today?

A. Technology involves the practical applications of scientific knowledge.
B. Science depends on technology for ideas and the organization of experimental work.
C. Workers in science use the laws and principles discovered by workers in technology.
D. Technology is the part of science that deals with mechanical problems.

42. In regard to intelligence, most scientists

A. have about average intelligence.
B. are born with a special scientific aptitude.
C. are smart because of their special training.
D. have more than average intelligence.

43. Which of the following is the best description of a scientific law?

A. It is an exact report of the observations of scientists.
B. It is a generalized statement of relationships among natural phenomena.
C. It is a theoretical explanation of a natural phenomenon.
D. It is enforced by nature and cannot be violated.

44. Which of the following is the principal need of science?

A. much expensive equipment
B. well-trained assistants
C. large sums of money
D. creative individuals

45. When some of the facts in a certain area of science are <u>not</u> explained by an existing theory, scientists

A. may revise the unexplained facts so that they will fit into the theory.
B. may modify the theory so that more of the facts will be explained.
C. should discard the theory and formulate a new one immediately.
D. should show the theory to be in error in all cases.

46. Gay-Lussac carried out many experiments with gases and observed that when heat is applied to gases their volumes always increase, providing the pressure remains the same. Gay-Lussac decided that "at constant pressure, the volume of a gas varied directly with the temperature." This is an example of

A. formulation of a scientific theory.
B. testing of a scientific hypothesis.
C. formulation of a scientific law.
D. reasoning from the abstract to the concrete.

47. Bill always makes good grades in school, but is a practical joker. Frank also makes good grades but has no sense of humor. Janet is a serious, intelligent, and popular girl. Who would most likely become a research scientist?

A. Frank
B. Janet
C. either of the boys
D. any one of the three

48. In deciding whether or not a proposed theory can be accepted, scientists will probably make their decision on the basis of

A. whether or not the theory is true.
B. whether or not the theory can be expressed in mathematical form.
C. the evidence supporting the theory and their personal ideas.
D. the experimental and observational evidence available.

49. Before an astronomer presents a new theory, he will generally get criticism of his ideas from

A. his co-workers in astronomy.
B. a panel of experts on astronomical theories.
C. a theoretical physicist.
D. a philosopher who has studied the development of theories.

50. Ralph said: "Scientists do experiments to ask questions of nature." The best interpretation of Ralph's statement is that experiments and tests are used in science to

A. prove the regularity of nature.
B. learn by trial and error.
C. check predictions made from scientists' observations and ideas.
D. inquire into the mystery of creation.

51. Standing on a hilltop at dawn, two men were observing the eastern horizon. One said, "In a few minutes, the sun will rise above the horizon and travel up into the sky." The other said, "In a few minutes the earth will be turning into a position that will allow us to see the sun above the horizon." What aspect of observations in science is illustrated by this story?

A. Special instruments are needed to make accurate observations.
B. Good observations are objective and free from bias.
C. Observations are relative to the position of the observer.
D. Many apparently objective observations are interpretations of what is seen.

52. If we were to check on the contributions to science that have been made in various countries since 1900, we would expect to find representation chiefly from

A. the United States and Russia.
B. England and France.
C. the four countries listed in A and B.
D. the countries listed and others.

53. Manufacturers of scientific instruments are continually adding new models to their lines because

A. the older instruments are no longer reliable.
B. the old instruments go out of style, like automobiles.
C. improved instruments are needed as science advances.
D. new science laboratories require the latest equipment.

54. In carrying out biochemical research, the methods used by the investigator generally include

A. any method that is approved by the Biochemical Society.
B. any method he can think of to help solve his problem.
C. the method of trial and error experimentation.
D. only biochemical methods which are known to yield results.

55. After Volta devised an electric battery in 1800, a period of rapid progress in the sciences of electricity and chemistry soon followed, because this new instrument

A. made it possible to have well-lighted laboratories.
B. made possible a new industry to manufacture batteries for general use.
C. contained the answer to several electrical and chemical problems.
D. made possible many new experiments and observations.

56. If a geologist is attempting to establish a theory about the origin of mountains, he would

A. rule out all previous attempts to explain mountain-building.
B. correlate all his evidence with geologic maps.
C. see if it explains the known data on mountain-building.
D. study the geological record of all mountains in the United States.

57. When a scientist has established a theory, we may say that he has

A. developed new ideas and understandings.
B. uncovered one of the laws of nature.
C. moved mankind closer to knowledge of absolute truth.
D. discovered new experimental evidence.

58. Mary is interested in science but does not like the way her chemistry teacher makes her write down all the details of her experiments. However, this training will help Mary if she goes into science, because she will have learned how to

A. look for cause and effect relationships.
B. be patient.
C. make more accurate reports.
D. deduce theories from experiments.

59. If you were browsing through the periodicals section of a physics research library, you would notice that almost all the scientific journals

A. are written in English, German, or Russian.
B. report current work in a highly technical style.
C. carry many advertisements of new products.
D. explain the latest physical discoveries for the layman.

60. In discussing our country's disarmament policy, a famous scientist declared that we must continue our experimenting with nuclear bombs. What is the best evaluation we can give to this scientist's statement?

A. His conclusion is probably right, since he approaches the problem with a scientific attitude.
B. His conclusion is probably wrong, because scientists seem to be trying to destroy the world.
C. His conclusion and reasons are probably correct, because scientific results are the most reliable kind.
D. His conclusion and reasons should be weighed according to his knowledge of international affairs.

DIRECTIONS

This is a test of your general knowledge about science, scientists, and the ways in which scientists do their work.

Each of the questions in this test is followed by four suggested answers. You are to decide which one of these you think is the BEST answer to the question. Then mark the proper space on the answer sheet with the special pencil you have been given. Make the mark as long as the pair of lines, and move the pencil point up and down firmly to make a heavy black line. If you change your mind about an answer, erase your first mark completely. Mark only one answer for each question.

Example:

XX. The main thing that a scientist does is to

A. collect scientific books.
B. build laboratory equipment.
C. give lectures about science.
D. carry on scientific research.

	A	B	C	D
XX.	||	||	||	■

Notice that in this example several of the choices are at least partly correct but choice D is clearly the BEST answer, because carrying on scientific research is the "main thing" that a scientist does. In many of the questions of this test you may find several choices which are partly correct, so that you will have to decide which one is the BEST answer. Be sure that you mark only one answer for each question on the separate answer sheet.

You will make your best score by answering every question. You should work carefully, but do not spend too much time on any one item. If a question seems too difficult, make the most careful guess you can. If you finish before time is called, go back and spend more time on the questions about which you were doubtful.

Please do not mark this test booklet in any way.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

APPENDIX C

TOPICAL OUTLINE OF THE

PROGRAM KNOWN AS

IPS -

INTRODUCTORY PHYSICAL SCIENCE

PROVINCE OF MANITOBA

DEPARTMENT OF EDUCATION

UNIVERSITY ENTRANCE COURSE

SCIENCE 100

Authorized by the Minister of Education
for use in approved classes

1967

1968

UNIVERSITY ENTRANCE COURSE

SCIENCE 100

TEXT: INTRODUCTORY PHYSICAL SCIENCE: The IPS Group of Educational Services Incorporated

TIME ALLOTMENT: 12% or 180 minutes per week

The purpose of this program is to give students a beginning knowledge of physical science and to offer some insight into the means by which scientific knowledge is acquired. The theme of the course is the development of evidence for an atomic model of matter. The method employed to achieve the stated goals is one of student experimentation and guided reasoning on the results of such experimentation. Thus the laboratory experiments are contained in the body of the text and must be carried out by the students for the proper understanding of the course. Many of the conclusions and generalizations arrived at as a result of doing the experiments become essential parts of the complete text.

In arriving at the suggested time allotment for each chapter, it was recognized that time would have to be allowed in which the teacher could familiarize the pupils with laboratory procedure and the intricacies of the slide rule. Consequently, an extra four weeks has been allotted to Chapters 1 and 2, beyond the time considered necessary to cover the content.

Also, experience has shown that in situations where class periods are of 40 minutes duration or less the use of double periods is much more effective than is the use of single periods. Although the teacher meets the pupil less frequently, work can be covered in a much more efficient manner.

COURSE OUTLINE

CHAPTER 1 INTRODUCTION

Experiment: Distillation of Wood

Suggested time 3 weeks

CHAPTER 2 QUANTITY OF MATTER: MASS

Volume...Experiment: Measuring Volume by Displacement of Water...Shortcomings of Volume As a Measure of Matter... Mass...Experiment: The Equal-arm Balance...Experiment: The Precision of the Balance...Experiment: Beads and Grams... Experiment: The Mass of Dissolved Salt...Experiment: The Mass of Ice and Water...Experiment: The Mass of Mixed Solutions... Experiment: The Mass of Copper and Sulfur...Experiment: The Mass of Gas...The Conservation of Mass...Laws of Nature

Suggested time 6 weeks

CHAPTER 3 CHARACTERISTIC PROPERTIES

Density...Experiment: The Density of Solids...Experiment: The Density of Liquids...Experiment: The Density of a Gas...The Range of Density...Experiment: Thermal Expansion of Solids...Thermal Expansion of Liquids...Thermal Expansion of Gases...Elasticity of Solids...Elasticity of Gases...Experiment: Freezing and Melting...Experiment: Micro-melting Point...Experiment: Boiling Point

Suggested time 4 weeks

CHAPTER 4 SOLUBILITY AND SOLVENTS

Experiment: Solubility...Experiment: The Effect of Temperature on Solubility...Wood Alcohol and Grain Alcohol...Experiment: Methanol As a Solvent...Experiment: Preparation of Oil of Vitriol...Experiment: Two Gases...Hydrogen...Carbon Dioxide... The Solubility of Gases...Experiment: The Solubility of Ammonia Gas...Other Solvents...A More Careful Look at the Distillation of Wood

Suggested time 4 weeks

CHAPTER 5 THE SEPARATION OF SUBSTANCES

Experiment: Fractional Distillation...Petroleum...The Direct Separation of Solids from Liquids...Experiment: Separation of a Mixture of Solids...Experiment: Fractional Crystallization ...Experiment: Substances in a Sample of Black Ink...Experiment: Paper Chromatography...Mixtures of Gases: Nitrogen and Oxygen... Low Temperatures...Mixtures and Pure Substances

Suggested time 6 weeks

CHAPTER 6 COMPOUNDS AND ELEMENTS

Experiment: Decomposition of Sodium Chlorate...Experiment: Decomposition of Water...The Synthesis of Water...Experiment: Synthesis of Zinc Chloride...The Law of Constant Proportions... Experiment: A Reaction with Copper...Experiment: Reduction of Copper Oxide...Elements...Two Special Cases: Lime and Oxymuriatic Acid...Experiment: Flame Tests of Some Elements...Experiment: Spectra of Some Elements...Spectral Analysis

Suggested time 4 weeks

CHAPTER 7 RADIOACTIVITY

Experiment: The Effect of Some Substances on a Photographic Plate and on a Geiger Counter...A Historical Survey of the Discovery of Radioactivity...Radioactive Elements...A Closer Look at Radioactivity

Suggested time 1 week

CHAPTER 8 THE ATOMIC MODEL OF MATTER

A Model...Experiment: A Black Box...The Atomic Model of Matter..."Experiment": Fasteners and Rings; Constant Composition..."Experiment": Some Other Compounds of Fs and R...A Prediction from the Atomic Model of Matter...Experiment: Two Compounds of Copper...The Law of Multiple Proportions...Molecules ...Radioactive Elements and the Atomic Model

Suggested time 2 weeks

CHAPTER 9 SIZES AND MASSES OF ATOMS AND MOLECULES

The Thickness of a Thin Layer...Experiment: The Thickness of a Thin Sheet of Metal...Experiment: THe Size and Mass of an Oleic Acid Molecule...The Mass of Helium Atoms...The Mass of Polonium Atoms...The Size of Polonium and Helium Atoms...Atomic Masses and Molecular Formulas

Suggested time 2 weeks

CHAPTER 10 MOLECULAR MOTION

Introduction...Molecular Motion and Diffusion...Density and Pressure of a Gas...Boyle's Law...Temperature and Molecular Speed...Molecular Motion in Liquids and Solids...Experiment: Growing Small Crystals...Behavior of Gases at High Pressures

Suggested time 2 weeks

CHAPTER 11 HEAT

Quantity of Heat: The Calorie...Experiment: Heating Different Substances...Specific Heat...Experiment: Heat Lost by a Substance in Cooling...Experiment: Specific Heat of a Solid... Experiment: Heat of Reaction...Experiment: Heat of Solution... Experiment: Heat of Fusion...Heat of Vaporization...A Description of Heat of Reaction in Terms of Atoms...What Next?

LABORATORY EQUIPMENT: See appended sheets.

FILMS

The following films could be used to supplement the textual materials at the places indicated. All films are available from the Department of Education, Visual Education Branch, 1181 Portage Avenue.

BEHAVIOR OF GASES 15 minutes B/W

The Brownian motion of smoke particles is shown by photo-micrography and compared with a mechanical analogue. This evidence for molecules in chaotic motion is contrasted with the orderly behavior of gases as shown by Boyle's Law experiment. Animation and mechanical analogues are then used to develop a model for gas pressure based on chaotic molecular motion.

Use with IPS Chapter III.

ELEMENTS, COMPOUNDS AND MIXTURES 33 minutes Color

A discussion of the difference between elements, compounds and mixtures, showing how a mixture can be separated by physical means. Demonstrates how a compound can be made and then be taken apart by chemical methods with identification of components by means of their physical properties such as melting point, boiling point, solubility, color, etc.

Use with IPS Chapter VI, Part 1.

DEFINITE AND MULTIPLE PROPORTIONS 30 minutes B/W

Here is the evidence on which Dalton based his conviction that matter came in natural units, atoms; the chemical laws of definite proportions demonstrated by electrolysis and recombination of water; and multiple proportions by the quantitive decomposition of N_2O, NO and NO_2.

Use with IPS Chapter VI, after "Elements".

THE MASS OF ATOMS (PARTS I AND II)
PART I - 20 minutes B/W
PART II - 27 minutes B/W

An experiment is performed in which the masses of a helium atom and a polonium atom are determined. A sample of helium is prepared by collecting the alpha particles decaying from a weighed sample of polonium. By counting the total number of particles collected and determining the mass of the sample, the mass of a helium atom is calculated. From the rate of the polonium decay and the mass of the polonium which produced the helium, the mass of a polonium atom is calculated. Throughout the film the various laboratory techniques and precautions necessary for these measurements are shown.

Use with IPS Chapter IX, Section 6.

CRYSTALS 25 minutes Color

Demonstrates the nature of crystals, how they are formed and why they are shaped as they are. Shows actual growth of crystals under a microscope; discusses how they may be grown. Relates these phenomena to the concept of atoms.

Use with IPS Chapter X, Experiment 7.

SPECIAL I.P.S. APPARATUS FOR A CLASS OF 32 STUDENTS

Quantity	Item	
16	Equal Arm Balance	1 per student pair
16	Peg Board Apparatus and Stand	1 per student pair
16	Conservation of Mass Kit	1 per student pair
16	Electrolysis Apparatus	1 per student pair
16	Fasteners and Rings	1 per student pair
16	Metal Cube and Slab Set	1 per student pair
16	Radioactive Materials Set	1 per student pair
1	Gas and Diffusion Tubes	1 per class
1	Cloud Chamber	1 per class
1	Elasticity of Gases Apparatus	1 per class
1	Elasticity of Wire Apparatus	1 per class
1 set	Immersion Heaters	1 per class
1	Mechanical Gas Model	1 per class
1	Molecular Layer Class Set	1 per class
1	Spectramatic Class Kit	1 per class
1	Thermal Expansion of Solids	1 per class
4	Weight Set, Gram Moss	1 per class
16 sheets	Polaroid Film (4 x 5) #57	1 per class
1	Film Roller	1 per class

The approximate cost of the above items is $400.00.

In addition the following chemicals and apparatus will be required, most of which are available in a standard chemistry laboratory.

Quantity	Item
2 gallons	Alcohol, Ethyl, Denatured
2 pints	Alcohol, Isopropyl
2 pkgs.	Alka Seltzer, pkg. 24
1 roll	Aluminum Foil 12"x25" roll
1 roll	Aluminum Foil, heavyweight
1 pkg.	Aluminum Strips, pkg. 30
$\frac{1}{4}$ lb.	Ammonium Chloride, Gran.
1 pint	Ammonia Solution
1 lb.	Boiling Chips
25 grams	Calcium Carbide
150 grams	Calcium Chloride, anhydrous
40 grams	Charcoal
$\frac{1}{4}$ lb.	Citric Acid, Gran.
$\frac{1}{4}$ lb.	Copper Dust (purified, elec.)
30 grams	Copper Granular
$\frac{1}{4}$ lb.	Copper Sulphate, Crystal
$\frac{1}{4}$ lb.	Cupric Chloride, powder
$\frac{1}{4}$ lb.	Cupric Oxide, powder
$\frac{1}{4}$ lb.	Cuprous Chloride
2 lbs.	Epsom Salts (magnesium sulphate)
2 pints	Ethylene glycol, industrial
$\frac{1}{4}$ lb.	Ferrous Sulphate, gran.
1 box	Filter Paper #1, 11 cm. diam.
1 roll	Filter Paper #3, 1" tape
$\frac{1}{4}$ pint	Glycerol (Glycerine)
1 pint	Hydrochloric Acid
$\frac{1}{2}$ pint	Ink, black, washable
25 grams	Lead Nitrate, crystals
2 pints	Limewater
2 oz.	Magnesium Carbonate, black
1/6 oz.	Magnesium Ribbon
1 lb.	Napthalene, Moth Balls
1 pint	Oil, cooking
1 lb.	Paradichlorobenzene Flakes
1 lb.	Potassium Nitrate, Gran.
$\frac{1}{4}$ lb.	Potassium Permanganate
60 grams	Salol (phenylsalicylate) crystals
2 lbs.	Sand, playground
1 lb.	Sodium Chlorate, crystal
2 lbs.	Sodium Chloride, Gran.
20 grams	Sodium Iodide, Gran.
$\frac{1}{4}$ lb.	Sodium Nitrate, Gran.
20 grams	Sodium Nitrite, Gran.
1/3 lb.	Sugar, Granular
15 grams	Sulfur, Flowers
$\frac{1}{2}$ pint	Sulfuric acid, conc.
1000	Wood Splints
1 pkg.	Wool, Glass, Aquarium
1 pkg.	Wool, Steel #1
100 pieces	Zinc, commercial

Quantity	Item
12	Battery 6 volt
12	Beaker Pyrex 100 ml.
12	Beaker Pyrex 250 ml.
12	Beaker Pyrex 600 ml.
1 pkg.	Blades, razor, single edge
12	Boiling Can, tall
2	Bottle, Plastic Squeeze 500 ml.
12	Brush, Test Tube
1 vl.	Capillary Tubes, vial of 100
1 pkg.	Corks #7, pkg. 24 slotted
16	Crucible #00
16	Dish, Evaporating #000
16	Funnel 65 mm., $2\frac{1}{2}$" stem
32	Goggles, safety
16	Graduated Cylinder 10 ml.
16	Graduated Cylinder 50 ml.
16	Magnifiers, hand
1 oz.	Rubber bands, assorted
16	Scoopula
16	Stirring rods 6"x3/16"
1 lb.	Stopper, Rubber #2 solid
32	Stopper, Rubber #2, 1 hole
32	Stopper, Rubber #2, 2 hole
2 lb.	Stopper, Rubber #4, solid
16	Stopper, Rubber #4, 1 hole
16	Stopper, Rubber #4, 2 hole
128	Text Tube, Pyrex 20x150 mm.
48	Test Tube, Pyrex 25x150 mm.
16	Test Tube Rack
32	Thermometer -20°C. to $+110^{\circ}$C.
16	Triangle, wire 2" pipe stem
15 ft.	Tubing, Amber Latex
32	Washers, brass
16	Watch glass 6.5 cm. diam.

APPENDIX D

TOPICAL OUTLINE OF THE PROGRAM

BASED ON THE TEXTBOOK

AN INTRODUCTION TO PHYSICAL SCIENCE

BY R.L. HEDLEY

PROVINCE OF MANITOBA

DEPARTMENT OF EDUCATION

GENERAL COURSE

SCIENCE 101

Authorized by the Minister of Education

STATEMENT OF PHILOSOPHY OF THE GENERAL COURSE SCIENCE COMMITTEE

> "That science has played a significant role in the development of our culture is an obvious fact; that it will play an increasingly important role in our future development is, in the light of present progress, taken for granted. What the exact nature of that role will be is a question with which all educators need be concerned." [1]

Science, both applied and theoretical, has become an increasingly important factor in everyday life. It affects the consumer and the producer of the necessities and the luxuries of life. Every aspect of routine living is, in some way, dependent upon or associated with the body of knowledge known as science. The period of time since World War II has been characterized by an explosion of knowledge in all fields, particularly in science. Major "break-throughs" to extend our knowledge in science are occurring more frequently. Hence, educators are especially concerned with the prospect of even further increases in knowledge at an ever increasing rate.

Science has a significance beyond that of a general cultural subject for the student of today, whether or not he is going to college. As an intelligent citizen he should be aware of the implications of scientific knowledge on local, national and international levels. He may at some future date be required to use the knowledge of science for responsible social action.

The General Course Science Committee takes the position that all students require a knowledge of science for effective citizenship. The course is designed for a student, who, in choosing a career other than through a university program, will require a body of scientific knowledge as a basis for future training in technical fields, and a knowledge of science, with the associated skills and abilities that would enable a student to assume some responsibility for his own learning. The program should also provide for the needs of the student who would not be engaged in a specific technical field but who, as an intelligent citizen, might be expected to have a degree of scientific literacy. The course will stress a basic knowledge of science with emphasis on the application and utilization of science. It is hoped that through this course the student will attain a favourable attitude to science with an appreciation of the nature and role of science for effective citizenship.

OBJECTIVES

The objectives of education in a democracy as stated in the Senior High School Program of Studies are:

1. The development of broad literacy.

2. The promotion of democratic citizenship.

---

[1] J. Darrell Barnard, "The Role of Science in our Culture", Re-thinking Science Education, 59th Yearbook of the National Society for the Study of Education, Part 1 (Chicago, Illinois, University of Chicago Press, 1960) page 1.

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 careful observation and through the use of reliable data to suggest possible conclusions.
5. An appreciation for the methods and procedures of science.
6. A disposition to use the knowledge and methods of science appropriately.
7. The development of skills and abilities normally associated with science.

It is suggested that the following means, among others, be used to develop scientific literacy:

1. The awakening of an interest in the basic science, particularly on the part of those who are "science shy" by:

    a. A high degree of pupil participation in the handling and manipulating of apparatus in the laboratory.
    b. Both teacher and pupil demonstration of scientific principles on an elementary level.
    c. An orderly development of topics within the scope of the pupil's abilities.

2. The utilization of laboratory investigations to develop:

    a. Skills in laboratory techniques.
    b. An understanding of the "scientific method".
    c. A spirit of inquiry within the capabilities of the pupil.
    d. Suitable elementary experiments for testing ideas.

TEXT: AN INTRODUCTION TO PHYSICAL SCIENCE: R. Hedley

REFERENCES: LIVING CHEMISTRY: Ahrens, Bush, Easley
CHEMISTRY: Garrett, Richardson, Kiefer
PHYSICS, A BASIC SCIENCE: Burns, Verwiebe, Hazel, Van Hooft
MODERN PHYSICS: Dull, Metcalfe, Williams

GENERAL SCIENCE - COURSE 101

Detailed Outline

Suggested Time Allocation: 25 periods laboratory work composed of:

1. 5 periods preliminary experiments
2. 10 periods Chemistry
3. 10 periods Physics

60 periods Chemistry Theory
50 periods Physics Theory

TOPIC - CHEMISTRY

Time Suggested

1 period A. 1. Chemistry Improves Man's Living

- understanding of life through chemistry
- more healthful living through chemistry
- more useful living through chemistry
- more abundant and happier living through chemistry
- reasons for studying chemistry

a. to form the habit of thinking scientifically in all life experiences
b. to gain additional knowledge of health and to assist you in forming proper habits of health
c. to understand, at least partially, the significant changes that have been brought about by science in the life of each individual and in society as a whole
d. to discover and develop new wholesome leisure-time activities
e. to provide basic understanding which will make it possible for you to select and use goods and services wisely
f. to develop the ability to study and investigate a particular problem which may be of interest to you
g. to develop an understanding of the relationship of industry to society
h. to provide an opportunity to explore vocations closely related to chemistry so that you may plan for the future more intelligently
i. to become acquainted with and learn some of the facts of chemistry

Time

1 period 2. Matter

What is matter and how do you recognize it

- definition of matter
- how do you recognize matter
- what are the physical and chemical properties of matter
- physical properties by which you may identify a substance
- chemical properties also aid in determination of the nature of substance

9 periods B. Atoms and Our Understanding of Chemistry

- John Dalton and the atomic theory
- the theory
- developing the modern atomic theory
- size of atoms
- weight of atoms
- some early work on the problem of atomic weight
- solution of the problem of atomic weights
- gram-atomic weights
- shape of atoms
- the nucleus
- protons
- neutrons
- electrons
- arrangement of electrons around the nucleus
- * subshells
- methods of determining the number of electrons in each main energy level of shell
- * orbitals
- atomic number
- diagrams of atoms
- isotopes
- * use of mass spectrometer
- summary of some of our ideas about the atom

10 periods C. Combination of Atoms

- electron configuration of the inert gases
- electron configuration of the active elements
- the stable forms of atoms
- ions
- ionic compounds
- ionic bonds

* Mentioned only. No special emphasis.

Time

* - ionic clusters
- combining capacity or valence
- determination of valence number of elements
- writing formulas of ionic compounds
- radicals
- valence number of radicals
- writing the formula of compounds
- covalence
- the hydrogen molecule
- molecules of other elements
- covalent compounds
- other covalent compounds

* - covalence number

* - the metallic bond
- considerable drill work on the writing of formula

4 periods D. Oxygen and Its Properties

1. How plants and animals depend upon oxygen

   - oxygen helps plants grow
   - animals require oxygen

2. How was oxygen discovered

   - Priestly

3. To what extent does oxygen occur

4. What are the physical and chemical properties of oxygen

   - physical properties
   - oxygen reacts with substances to form oxides
   - spontaneous combustion due to oxygen
   - the formation of oxygen in the free state
   - why does air smell fresh after a thundershower
   - oxygen forms many oxides
   - compounds that liberate oxygen

5. How may pure oxygen be prepared

   - laboratory methods

6. How has man made practical use of his knowledge of oxygen

   - oxygen is a useful element

* Mentioned only. No special emphasis.

Time		
4 periods	E.	Hydrogen and Its Properties

1. Where is hydrogen found
2. What are the physical and chemical properties of hydrogen
3. How may hydrogen be prepared
   - hydrogen and the activity series
   - laboratory preparation of hydrogen
   - commercial preparation
4. How has man used the scientific knowledge of hydrogen to make better the life he lives
   - uses
   - the most useful compound hydrogen, water

4 periods (combined with other) — F. Chemical Equations

1. Writing the symbols and formulas in the form of a chemical equation
   - review of deriving formulas from valence
2. Balancing the equations - equating the number of atoms
   - chemical equations represent a chemical reaction
   - classification of chemical reactions

4 periods — G. Solutions and Ionization

- solvent, solute and solutions
- separation of solids from liquids
- rate of solution
- dilute, concentrated, saturated and supersaturated solutions
- effect of solutes on freezing and boiling points
- ionization

4 periods — H. Acids, Bases and Salts

- what is an acid
- characteristics of acids
- binary acids
- ternary acids

Page 7 omitted in page numbering.

Time

- characteristics of bases
- neutralization
- some common acids and bases
- how salts are named and classified

10 periods each: Classes will do 2 of the following sections: J, K. L.

J. The Chemistry of Cosmetics

1. Face Creams

- kinds of face creams
- how to make face creams
- cost
- why use face creams
- can face creams replace soap and water
- special ingredients have little value
- lanolin, the ideal skin softener
- vanishing creams
- buying a face cream
- making a face cream at home

2. Face Powders

- the value of a face powder
- the composition of face powders
- how to select a face powder

3. Hand Lotions and Creams

- beautifying the hands
- making a glycerine hand lotion
- comparative values of hand preparations

4. Nail preparations

- composition and use of nail preparations

5. Make-up Preparations

- lipstick, rouge, mascara

6. Dentifrices

- tooth pastes, tooth powders, and liquid dentifrices
- what ingredients are used in dentifrices

7. Shaving Preparations

- shaving soaps
- brushless shaving creams
- lotions
- styptic pencil
- shaving by electricity

Time

8. Toilet Soaps

- soap necessary for cleanliness
- the making of soap
- factors to be considered in selecting toilet soap

9. Hair Preparations

- soap shampoos
- "soapless" shampoos
- rinsing the hair
- hair tonics
- hair bleaches and dyes
- hair oils

10. Deodorants and Depilatories

- deodorants and astringents
- depilatories or hair removers

K. The Chemistry of Home Decoration

1. Why should decorative materials be used in the home

- what are decorative materials
- protection and preservation
- appearance
- sanitation

2. What are paints, enamels, varnishes, etc., composed of and how are they made

- paint
- titanium dioxide
- vehicle and binder
- thinner
- drier
- color
- latex paints
- alkyd paints
- silicone paints
- water paint
- varnish
- enamels
- lacquers
- stains
- linoleum and oil cloth
- wallpaper

Time

3. How may home decorating be done successfully

   - decorating; a skilled trade
   - how should the surface be prepared for painting
   - applying the paint
   - suggestions and notes for the house painter
   - care of brushes
   - dangers
   - color selections

4. What factors should be taken into consideration in purchasing decorative material

   - good workmanship essential
   - buy quality materials
   - refinishing a decorated surface
   - selecting a decorator

L. The Chemistry of Gardening

1. What chemistry is involved in gardening

   - plant growth involves chemistry

2. How do plants grow

   - growth begins with seed
   - germination of seeds
   - plants are food factories
   - plants use manufactured foods
   - soil an important source of plant food

3. Why is it necessary to use fertilizers

   - growing plants exhaust the fertility of the soil
   - kinds of fertilizers
   - sources of nitrogen compounds
   - the Haber process
   - the Cyanamide process
   - sources of phosphorus compounds
   - soil often needs lime
   - plant hormones
   - soil conditioners
   - analyzing soils

Time

4. How can insects, diseases and weeds that threaten the growth of plants be controlled

- pests destroy the beauty of home gardens
- how to control insects
- what insecticides should be used
- DDT
- Lindane
- Chlordane
- Malathion
- Lead Arsenate and Paris Green
- insecticides from plant sources
- nicotine
- Rotenone
- Pyrethrum
- Sabadilla
- the control of plant disease
- seed fungicides
- organic fungicides
- the control of weeds
- new chemical herbicides
- ammonium sulfamate
- other uses of plant hormones

5. How are gardens grown without soil

- chemical gardens growing in importance
- what is chemical gardening
- what are the advantages of soilless culture
- how can one successfully engage in chemical gardening
- germination of seeds
- aeration
- caring for the growing plants

TOPIC - PHYSICS

Time

10 periods A. Static Electricity

1. Action of electric charges

- producing electric charges
- electric attraction and repulsion - laws of electrostatics
- conductors and insulators
- the electron theory
- what is an electric charge

Time

* - the eletroscope
* - methods of transferring an electric charge

2. Atmospheric electricity and electrostatic machines

- Franklin's experiment
- electric discharge from points
- lightning and lightning rods
- electric capacitor
- capacitance of a capacitor
- dielectric
* - the electrophorus
* - electrostatic machines

10 periods B. Magnetism

1. How magnets behave

* - magnetic and non-magnetic substances
- magentic poles
- magnetic attraction and repulsion
- the magnetic field and lines of force
* - magnetic permeability
- nature of magnetism
- theory of magnetism
- magentic shielding

2. The Earth as a magnet

- the magnetic compass
- the earth's magnetic field
- magnetic polarity of the earth
- declination
- inclination

Time		
2 periods	C.	Measurement
		1. The concept of matter
		2. The meaning of volume
		3. The meaning of weight
		4. The meaning of mass and inertia
		5. The meaning of density
		6. The meaning of energy
		7. The relation between mass and energy
2 periods	D.	Systems of Measurement
		1. Metric system prefixes
		2. Units of length in metric and English system
		3. Units of area and volume in both systems
		4. Units of mass in both systems
		5. Derived units
1 period 1 lab.	E.	Making Measurements
		1. Method of making measurements Laboratory work
25 periods	F.	Work, Power, Energy and Machines
		1. Work and Friction - work - friction - coefficient of friction - how friction is reduced - efficiency of machines
		2. Inclined Plane - inclined plane - advantages - work done on the inclined plane - mechanical advantage

Time

3. Lever

   - the lever
   - advantages
   - work and the lever

4. Equilibrium

   - forces on a lever
   - moments
   - types of levers

5. Pulleys

6. Wheel and Axle

7. Screw

8. Wedge

9. Energy and Power

   - what is energy
   - transformation of energy
   - conservation of energy
   - sources of energy
   - measurement of energy

10. Power

    - what is power
    - units of power
    - horsepower

Source: Burns et al

APPENDIX E

TOPICAL OUTLINE OF THE PROGRAM

BASED ON THE TEXTBOOK

EVERYDAY PROBLEMS IN SCIENCE

BY BEAUCHAMP, MAYFIELD AND WEST

PROVINCE OF MANITOBA

DEPARTMENT OF EDUCATION

UNIVERSITY ENTRANCE COURSE

GENERAL SCIENCE 100

Authorized by the Minister of Education
for use in approved classes

UNIVERSITY ENTRANCE COURSE

GENERAL SCIENCE 100

TEXT: EVERYDAY PROBLEMS IN SCIENCE: Beauchamp et al

TIME ALLOTMENT: 12% or 180 minutes per week

The course for the first year of the Senior High School is based on General Science. The approach will be that calculated to develop in the pupil a lively interest and an intelligent understanding of his natural environment. At a later stage more specialized work will be undertaken in the fields of Chemistry, Physics and Biology.

General Objectives

1. To lead the learner to search for truth by building well-organized patterns of knowledge.

2. To develop relevant skills and habits both mental and physical, so that they can be satisfactorily utilized by the learner.

3. To inculcate healthy moral and social attitudes for living in a democratic society.

Specified Objectives

1. The development of the technique of fact-finding.
   This involves:
   (a) The ability to perform satisfactorily certain simple laboratory experiments.
   (b) The ability to observe and measure accurately.
   (c) The ability to pursue suitable field activities.

2. The development of the power to base logical conclusions upon the facts that have been found.
   This involves:
   (a) The power to organize data.
   (b) The power to interpret data.
   (c) The ability to utilize facts and inferences logically in the solution of problems.

3. The development of the ability to use a balanced combination of inductive and deductive reasoning in the exploration of new fields of thought and action.

4. The development of the ability to understand our natural environment and to live effectively therein.

Course Outline

Unit 1 - "How Do Scientists Work?"
Unit 2 - "What Are Things Made of?"
Unit 3 - "How Can Materials be Changed?"
Unit 4 - "How Do We Use and Control Power?"
Unit 9 - "How Do We Control Heat?"
Unit 11 - "How Do We Provide Our Homes With A Good Water Supply?"
Unit 12 - "How Do Simple Machines Help Us Do Work?"
Unit 15 - "How Do We Harness the Energy of Nature to Do Our Work?"
Unit 16 - "How Do We Obtain and Use Electrical Currents?"
Unit 17 - "How Do We Use Energy for Communication?"
Unit 19 - "How Do We Provide Transportation?"
Unit 20 - "How Can Science Help Us From Wasting Nature's Wealth?"