

STUDENT ATTITUDE AND ACHIEVEMENT
IN SCIENCE COURSES IN MANITOBA
SECONDARY SCHOOLS

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This is to certify that the

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ABSTRACT

STUDENT ATTITUDE AND ACHIEVEMENT IN SCIENCE COURSES IN MANITOBA SECONDARY SCHOOLS

by Robert Lloyd Hedley

The purpose of the study was to develop evaluation techniques of existing and experimental science programs. It examined pupil achievement and pupil attitude in grade ten science programs in Manitoba schools.

An experimental group of 458 students taking the General Course science program was obtained from twenty selected secondary schools. A control sample of 414 students was selected by random numbers from the same schools. Of the control group 349 students were enrolled in a traditional science program and 65 students were in a PSSC-CHEMS program. General Course students used as a text, An Introduction to Physical Science by Hedley. Traditional Course students used Everyday Problems in Science by Beauchamp, Mayfield and West, while the PSSC-CHEMS group used text material from PSSC Physics and CHEMS programs. All students were enrolled in grade ten.

Prior knowledge of all students sampled was measured by an achievement test in science administered at the ninth

grade level. Mental ability was determined from scores on the OTIS Mental Ability Test, Form Am. A Test on Understanding Science, by Cooley and Klopfer, yielded scores on pupil understanding of the scientific enterprise, the aims and methods of science and the role of scientists. A Student Attitude Toward Science instrument was developed to measure student acceptance of text material, course content, laboratory work, interest in the course, involvement and satisfaction of perceived needs. Student scores on all instruments provided a total of thirteen variables.

A correlation matrix of the thirteen variables was examined for significant correlations. The mean scores and standard deviations of each of the three groups was calculated for the thirteen variables. The variables were then adjusted by the independent variables of prior knowledge and mental ability and examined for central dispersions and central tendencies. The adjusted mean scores of eight remaining dependent variables of the three groups of students were examined for differences. An order of discrimination of the dependent variables was calculated.

Students of the PSSC-CHEMS group scored the highest on all variables before covariance adjustment. They had the highest scores on: prior knowledge, mental ability, understanding about the scientific enterprises, about the role of scientists and about the aims and methods of science. They

had the most positive outlook and the suitability of text material, on the content of the course, on the usefulness of laboratory work, and in their involvement in the course. They showed the most interest in their science course.

After adjustment for prior knowledge and mental ability, the PSSC-CHEMS group still scored highest on all variables considered except understanding about the role of scientists. The traditional group scored highest on this variable.

The General Course group had the lowest scores on prior knowledge, mental ability, and each of the three TOUS sub-tests. After adjustment for prior knowledge and mental ability, the General Course group still scored the lowest on the sub-tests of TOUS. However, after adjustment, the General Course group had higher scores on the suitability of text material, on course content, on laboratory work and on need satisfaction than students of the Traditional Course but still below the scores of the PSSC-CHEMS group. Students of the General Course and the Traditional Course showed little interest in science programs prepared for them.

The study showed that it was possible to compare the effectiveness and the acceptance of science courses at the grade ten level. It is also possible to select the best discriminator between the General Course group and the Traditional Course group. This was SATS 1, Text Material. The study

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also showed the need for revision of the two last mentioned science courses offered to grade ten students in Manitoba schools.

STUDENT ATTITUDE AND ACHIEVEMENT IN SCIENCE
COURSES IN MANITOBA SECONDARY SCHOOLS

By

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CHAPTER I

INTRODUCTION

The climate of science education today may readily be characterized as one of change. The evidence for change is to be found in such recently developed high school science courses as those developed by the Physical Science Study Committee (PSSC Physics), the Chemical Education Materials Study (CHEM Study), the Biological Sciences Curriculum Study (BSCS Biology) and the Chemical Bond Approach (CBA Chemistry). In the elementary and junior high schools levels of science, such curricular studies as Introductory Physical Science (IPS), Elementary School Science (ESS) and the work of the American Association for the Advancement of Science entitled Science - A Process Approach, indicate the changes taking place in the public schools. Many science courses have been developed or are currently being developed. All of these courses have evolved since 1956 and reflect the concern of educators with the content, methodology and materials of science education programs. Writing teams composed of high school science teachers, university personnel and practicing scientists have worked together to produce textual materials and laboratory investigations at every school level.

The 1960 Yearbook of the National Society for the Study of Education, Rethinking Science Education,¹ reflects the concern of a national organization with the quality of science education for the youth of today. An examination of the secondary school science program suggests that many of the newer programs may well be suited to students whose abilities lie at the upper level. Little attention has been paid to the requirements of the mythical average student in the school. Since course content has changed markedly and since the aims of the newer courses are different from those of the older and more traditional courses, the evaluation of the newer courses has been largely subjective. To date, little has been done on the evaluation of recent curricular developments in the field of science.

The Problem

Statement of the Problem

It was the purpose of this study to develop and to test techniques in evaluating existing and experimental science curricula. An instrument measuring pupil attitude toward science programs in Manitoba secondary schools was developed and used in the study to determine the extent of

¹Nelson B. Henry (ed.), Rethinking Science Education, The Fifty-Ninth Yearbook of the National Society for the Study of Education (Chicago: The University of Chicago Press, 1960).

student acceptance of grade ten science courses. A test measuring an understanding of the nature of the scientific enterprise, an understanding of the aims and methods of science and an understanding of the role of the scientist in society was used to determine pupil achievement in science programs offered in grade ten in Manitoba schools. Thus two phases of evaluation of science courses were considered. How well do pupils achieve in different science courses? To what extent do pupils accept different science courses?

The major course of study under investigation was the non-matriculation course which has been designated as the General Course Science Program. Comparisons were made between groups of students taking the University Entrance Program and those taking the General Course on the basis of achievement and of attitude toward the science course they were studying. The details of the problem are considered under the heading of Experimental Design. The null hypotheses which were investigated are also stated under that heading.

Importance of the Study

Considerable evidence is to be found that present day curricula are changing at an ever increasing tempo.

Woodring notes:

Curricular reform is long overdue. In the natural sciences the vast expansion of knowledge of recent

years is not yet reflected in the conventional courses in physics, chemistry and biology . . . even if all the proposed reforms continue to expand at the present speed, it will take a decade or more for the school curriculum to catch up with the fast moving events in the frontiers of knowledge. Clearly the time has come for an educational revolution.²

Prior to 1959 the secondary school program for Manitoba schools was organized around three main areas: the General Course, the High School Leaving Course and the Vocational Course. The Royal Commission on Education, reporting to the Manitoba Legislative Assembly in 1959, noted:

. . . The General Course leads to entrance to the university, to the Manitoba Teachers College or professions such as Nursing or Chartered Accountancy. It is the traditional course which emphasizes the academic disciplines and demands the highest standards of the three courses . . . The High School Leaving Course is a modification of the General Course arranged locally by principals of those pupils who do not meet the standards required for the General Course . . . Unlike the General Course, the High School Leaving Course is, in practice at least, not subject to external examinations, and standing is awarded by the school on certification by the inspector. This course has little status either with pupils or with employers. The main alternatives to the General Course are to be found in the Vocational Course which includes the Commercial, Home Economics, Industrial and Agricultural programmes. In these programmes, half of the pupil's time is devoted to academic subjects and half to technical subjects. The Home Economics and Agricultural programmes have never found much favor with potential candidates because they do not lead directly either to gainful employment or to university entrance. The Commercial and Industrial programmes, however, have attracted a

²Paul Woodring, "Introduction," New Curricula, Robert W. Heath, editor (New York: Harper and Row, 1964), p. 2.

reasonable number of pupils probably because they do lead to gainful employment.³

A careful study of the representations made to the Commission revealed the demand for four specific courses. These are the Matriculation or university oriented course, the General or non-matriculation course, the Vocational course and the Terminal course. It is the General and Matriculation courses with which this study is concerned. An attempt is made to examine the achievement of pupils and the attitude of pupils towards the science course they are studying. Students registered in the grade ten General Course science program, in the traditional University Entrance program and in a newer program--a combination of PSSC Physics and CHEM Study--are the subjects of this investigation.

Approximately 80 per cent of the Manitoba secondary school students were enrolled in the Matriculation or university oriented program prior to 1959. Less than 15 per cent of the secondary school students in this province subsequently enrolled in the University of Manitoba or affiliated colleges. It was thus reasoned that a vast number of students were enrolled in courses which were not suited to their needs. The aims and goals, the aspirations and desires, the skills and interests of high school students who

³Manitoba Commission on Education, Report of the Manitoba Royal Commission on Education (Winnipeg: Queen's Printer, 1959), pp. 141-142.

are university bound would seem to be different from those students, who for varied reasons, have decided not to attend University. A General Course was developed on an experimental basis for those students who would follow programs other than those required for entrance to the University of Manitoba. The proposed General Course was described as:

A second course, substantially academic in type, with suitable non-academic options, partly identical with the first course (Matriculation) in content, yet partly different also in aims and emphasis.⁴

The necessity for the evaluation of a course of study with an indication of the procedures which may be considered is illustrated by Cronbach by:

. . . We can define 'evaluation' broadly as the collection and use of information to make decisions about an educational program . . . Many types of decisions are to be made and many varieties of information are useful. It becomes apparent that evaluation is a diversified activity and no one set of principles will suffice for all situations . . . We may separate three types of decisions for which evaluation is used: (1) course improvement; deciding what instruction materials and methods are satisfactory and where changes are needed, (2) decisions about individuals; identifying the needs of the pupil for the sake of planning his instruction, judging pupil merit for the purpose of selection and grouping, acquainting the pupil with his own progress and deficiencies, (3) administrative regulation; judging how good the school system is, how good individual teachers are. It was for the sake of course improvement that systematic evaluation was first introduced.⁵

⁴Ibid., p. 142.

⁵Lee J. Cronbach, "Evaluation for Course Improvement," New Curricula, op. cit., pp. 231-232.

Those who are associated with the education of Manitoba youth--administrators, teachers, parents and pupils--need some indication of the effectiveness of experimental programs in science in secondary schools. Questions pertaining to the degree of achievement of the students in relation to course objectives, the views and acceptance of the course by students, and indeed how reasonable and clear the objectives of the course seem to be, need to be answered. With computer facilities now available to researchers in education, it seems no longer necessary to inquire of the superintendent of schools how well he "thinks" his principals "think" the teachers "think" the students are accepting the course, and how useful the students are finding the course of study. While trained subjective judgment of teachers and administrators is indeed valuable and frequently accurate, too many vitiating variables are introduced for the evaluation to be anything more than such a subjective opinion. The ultimate test for a program of study must be in terms of how clear the objectives are and how well the students are achieving these objectives. Cronbach notes: "The greatest service evaluation can perform is to identify aspects of the course where revision is desirable."⁶

A review of the literature on research studies in science education revealed the paucity of research on the

⁶Ibid., p. 236.

evaluation of experimental programs. While nearly every text on curriculum construction contains some material on the necessity for evaluation, the scarcity of research studies on the newer science courses suggests that seldom have these courses of study been subjected to a detailed analysis. It is the purpose of this study of student achievement in a specific set of science courses to develop techniques in the evaluation of new courses. The result of the development of such techniques should shorten the period of time between the introduction of an experimental program and the decision to implement the program on a broad basis.

Science courses will continue to change and, indeed, need to change as new knowledge is added. So should, then, the techniques of evaluation change and improve so that feedback on new courses has some statistical validity. Thus an investigation into the grade ten Science Course in Manitoba secondary schools was deemed to be a worthwhile study.

Definition of Terms

General Course

This term is used to describe the non-university oriented course of study of high school students. Students electing the General Course of study will not necessarily meet the entrance requirements set forth by the University of Manitoba. The course of study has been organized for

three years of secondary schooling; that is, for grades ten, eleven and twelve.

Matriculation Course

The term "Matriculation Course" is used to describe a university oriented course of study for secondary school students. Successful completion of this course as measured by examination of five subject areas at the grade twelve level will permit a student to enroll in the University of Manitoba.

Curriculum

The total academic and non-academic experiences within the formal organization of the school are said to be the curriculum of the school.

Program of Study

The outline of the topics to be studied, the detailed structure of the discipline, is taken to be the program of study. Thus each of the courses included in the total curriculum of the school may be expected to have a program of study as its base.

External Examination

This term refers to a written examination set by examiners appointed by the Department of Education of the

Province of Manitoba. It is administered to all students who are enrolled in courses for which the examination is set. The student answer papers are normally marked and graded by a committee of teachers during the month of July. The reader of the examination paper does not know the name nor the school of the student.

Internal Examination

Teacher constructed tests in each school are considered to be the evaluation of student achievement undertaken locally in a subject area. The term "internal examinations" refers to teacher-made examinations conducted separately in each school and with each class.

Pretest

The test given to the group of students in this study prior to their selection for experimental and control groups was considered to be the pretest. It was an externally set, externally marked examination administered to all ninth grade students in June, 1964. It was conducted in the subject area of science.

Criterion Test

The criterion test used in the investigation was entitled Test on Understanding Science (TOUS), developed at the Harvard University Graduate School of Education.

Achievement

The score obtained on the TOUS instrument and/or on the pretest in science is defined for this study as the achievement of the pupil.

Attitudinal Scale

The instrument developed to obtain a reaction of the student's attitude towards his science course was considered to be in the realm of attitudinal scales. The instrument, developed for this study, was the Student Attitude Toward Science (SATS) scale.

Design of the Study

All students in Manitoba schools write external examinations at the end of the ninth grade in five academic subject areas. These areas are English literature, English language, social studies, mathematics and science. A mental abilities test, the Otis Gamma test, form Am, was administered as part of the examination proceedings. Students then elect, with guidance and counselling, to take a program of studies in grade ten which may be classed as the Matriculation Course, the General Course or the Vocational Course. The last course includes such options as shops, home economics and commercial subjects.

Students enrolled in the grade ten science program in September 1964 were chosen as the subjects of the study.

From a list of secondary schools in Manitoba twenty schools were selected that offered the General Course program and offered science as an elective. The basis for selection was the geographical area and the size of the school, so that the study would represent course achievement of students in secondary schools in Manitoba. The sampling, on a representative geographical basis, included schools from Metropolitan Winnipeg, the largest city in the province; from Brandon, the second largest city, and from rural Manitoba. Chapter IV presents a more detailed explanation of the study.

The schools were contacted and asked for their cooperation in the study. The writer had an opportunity to contact personally many of the teachers and students, and to explain the importance of the study. Only two schools of the 20 selected failed to assist in the testing associated with the study. Unfortunately the writer was not notified by the principals of these schools in time to substitute other schools in the evaluation program.

Science teachers in each school provided the writer with a list of students taking the General Course science program in their school. The scores of these students on an external achievement examination in science at the ninth grade level were obtained from the files of the Department of Education, Office of the Registrar. The Intelligence Quotient for each student of the experimental group (General

Course) was also obtained and recorded. It was noted that the Otis Gamma Test, Form Am, for senior high schools and colleges, had been used as the test of mental ability with students enrolled in the ninth grade in the academic year 1963-64. It then became necessary to eliminate from the study all those students who were repeating the tenth grade as a result of failures in subjects during the school year 1963-64. The reason for eliminating these students from the study was that their Intelligence Quotients were calculated from the Henmon-Nelson Test, Form A. It was thought that the results of two different mental ability tests could not be readily equated. Thus it was decided to limit the study to students who had been in the ninth grade in 1963-64 and were enrolled in the tenth grade in 1964-65.

The names of all the students who were enrolled in grade ten in each selected school were obtained from Department of Education records and assigned a number. By means of a table of random numbers a sample of students was drawn from each school. The sample was approximately numerically equal to the experimental group in that school. An examination of this procedure revealed that there might be a shrinkage of data due to students transferring from one district to another, from one province to another, absences from school on the selected day for testing and other such normal occurrences as cause data to shrink. The ninth grade

science achievement scores and the Intelligence Quotient for the control group were tabulated also.

The above procedures resulted in records of two groups of students from eighteen schools: one group taking the General Course science program and designated as the experimental group; the second group not taking the General Course science program but who were taking a science course. The control group was enrolled in two different science courses. Some, the traditional group and the largest section of the control group, followed a course of study from the text, Everyday Problems in Science by Beauchamp, Mayfield and West. Others, a very small group, were following a course of study instituted on a trial basis, which used as textual material the first six chapters of the CHEM study program and the first six chapters of PSSC Physics program.

A criterion test was selected for administration to all students during the last week of May, 1965. By this time, all students had completed 90 per cent or more of the course work. The test selected was the Test On Understanding Science (TOUS), Form W, developed by W. W. Cooley and L. K. Klopfer of the Graduate School of Education, Harvard University. The test was selected as it seemed to be consistent with modern objectives in science teaching. It purported to measure understanding of the scientific enterprise, understanding about scientists and understanding about the

methods and aims of science. A more detailed argument for the selection of this criterion test is developed in Chapter IV. The test was kept secure until the week of the test period. It was then mailed to all schools participating in the experiment, with accompanying detailed instructions for administering the test. Thus the results of the TOUS instrument gave one set of information which could be evaluated statistically. The test results were scored by the writer and recorded on tabulation sheets for keypunch coding.

A second instrument was developed to determine student attitude to the course of study being undertaken in science. The instrument, entitled Student Attitude Toward Science (SATS), was designed to obtain a reaction from students that would indicate what they thought about the science course in which they were enrolled. The items of the instrument covered such areas as interest, student needs, content of the course, text materials, laboratory work and student involvement. The statements associated with the SATS instrument are in Appendix A.

The newly developed instrument underwent pilot trials with students in a metropolitan secondary school. The sample included twenty-five students taking the grade ten General Course science program and twenty-six students studying selected sections of the PSSC and CHEMS programs. The preliminary edition of the instrument was revised on the basis of information obtained from this group of

students. The writer was able to determine which items needed rewording, which items were not clear, which items could be dropped entirely from the instrument and which instructions needed clarification. On the basis of this preliminary investigation, a revised edition of SATS was developed containing seventy-two generalized statements. Students were to react to each statement on a five point, non-linear, unitized scale in which an "A" response would indicate a strong agreement with the statement and an "E" response would indicate strong disagreement. Other intermediate positions could be obtained. While it cannot be assumed that a "strongly agree" answer may be equivalent in all respects to a "strongly disagree" answer on another generalized statement, it is possible to obtain a numerical value for each of the sub-test items and thus make statistical comparisons.

The instrument was then administered to students at or about the same time as was the achievement test (the last week of May, 1965). The test results were scored, and the data were recorded and prepared for entry on punched cards for analysis on the computer. By the time the returns were completed and recorded, the original data had shrunk from 1416 returns to 872. The shrinkage resulted from (1) students being absent from school on the day tests were administered, (2) students being transferred to another school, (3) the testing period being too long for one class period,

(4) spoiled answer sheets being incorrectly marked by students and (5) instructions not being strictly adhered to.

Assumptions and Limitations of the Study

Assumptions

It was assumed that the tests administered as part of the investigation were secure and that students had no opportunity to practice questions similar to those used on the TOUS instrument. It was further assumed that the tests were administered at or about the same time to all students in the testing program and that the instructions were followed in all cases with regard to time and scoring directions. It was also assumed that students had approximately equal experience in handling multiple-choice response items. It was assumed that the teachers would be experienced in handling test directions, and that adequate test conditions were maintained.

Delimitations

It was not the purpose of this study to develop a science program for grade ten students but to examine pupil achievement in and pupil attitude toward existing science programs, some of which have been used in Manitoba schools for fifteen years and some of which have been introduced within the last four years. The study was restricted to

those students who were in grade nine in 1963-64, who graduated to grade ten for the school year 1964-65, and does not include an evaluation of those grade ten students who failed or repeated course work.

Limitations

The study was limited by sample size to a relatively small sample of students taking the combined PSSC and CHEMS program (N = 65). A further limitation is to be found in the fact that only the science achievement score was used as pre-test information. It might well be that other achievement scores would have been as revealing or even more revealing as were the science scores.

It is recognized that the qualifications, experience and service of the teacher may have as much bearing on this investigation as the course of study. By taking the sample from many schools an attempt was made to minimize the teacher effect by selecting from a variety of school types so that other variables would not be unduly affected.

Hypotheses Tested

The following null hypotheses were tested in this study:

1. There is no significant difference in how students of the experimental group responded to items on each of the three sub-tests of the Test on Understanding Science and

how students of the control groups responded to the same items.

2. There are no significant correlations to be found between the following thirteen variables by members of the total sample population, the general course science group, the traditional science group and the PSSC-CHEMS group:

- a. prior knowledge test
- b. mental ability test
- c. TOUS 1--Test on Understanding About the Scientific Enterprise
- d. TOUS 2--Test on Understanding About Scientists
- e. TOUS 3--Test on Understanding About the Methods and Aims of Science
- f. TOUS total score of the three sub-tests
- g. SATS 1--Student Attitude Toward Science - Text Materials
- h. SATS 2--Student attitude Toward Science - Content
- i. SATS 3--Student Attitude Toward Science - Interest
- j. SATS 4--Student Attitude Toward Science - Needs
- k. SATS 5--Student Attitude Toward Science - Laboratory
- l. SATS 6--Student Attitude Toward Science - Involvement
- m. SATS - total score of the six sub-tests

3. There is no equality of dispersions of the three groups on eight variables indicated above. The total scores on TOUS and SATS as well as the SATS 6 sub-tests are removed. This null hypothesis is termed the H_1 test.

4. There is no equality of population centroids of the three groups on the unadjusted means of the eight variables termed the H_2 test, measured by Wilks' lambda test.

5. There is no equality of population centroids, an H_2 -Wilks' lambda test, after covariance adjustment on eleven criterion variables and two control variables, the prior knowledge scores and mental ability scores.

6. There is no order of discrimination between the control group and the experimental group of the dependent variables on TOUS 1, 2, 3 and SATS 1, 2, 3, 4, 5 and 6.

CHAPTER II

REVIEW OF THE LITERATURE

In carrying out an investigation of pupil achievement and attitude toward science courses in Manitoba secondary schools, the writer reviewed the literature on evaluation of secondary science programs. The literature was also examined for statistical techniques useful in scrutinizing the null hypotheses stated in this study.

Investigations into Evaluation of Programs

In the field of curriculum construction, Smith, Stanley, and Shores¹ refer to six major curriculum studies which were concerned with investigations of curriculum organization. The first of these was the New York City experiment as reported by Jersild, Thorndike, Coleman and Loftus² in 1939. It was concerned with a comparison of an activity program with a traditional textbook program. The experiment involved 75,000 children and 2,500 teachers. The

¹S. Othanel Smith, William O. Stanley and J. Harlan Shores, Fundamentals of Curriculum Development (New York: Harcourt, Brace and World, Inc., 1957), p. 396.

²A. T. Jersild, H. L. Thorndike, S. Coleman, and J. J. Loftus, "An Evaluation of Aspects of the Activity Program in the New York Public Elementary Schools," Journal of Experimental Education, 8:166-307 (December, 1939).

experimental and control groups were paired on the basis of national or social background, socio-economic status, location in the city, and intelligence. The significance of this study in relation to experimental designs is that it was almost impossible to hold experimental and control conditions constant from school to school and from classroom to classroom. Some other technique is needed to examine the performance of groups of students statistically.

The second major experiment in the field of curriculum noted by Smith and others is the work of Pistor³ in the experimental school at Ball State Teachers College where attention was paid to the elementary school grades five and six. This experiment was conducted around a pre-test, post-test design. The importance of Pistor's study is to be found in the controlled observation of thirty-eight "trait-actions" selected by a panel of experts. The study had little bearing on the study being reported in this thesis as it dealt with elementary school grades.

The third and fourth major contributions to experimental work in curriculum studies as noted by Smith and others are to be found in the work of Wrightstone⁴ in

³F. A. Pistor, "Evaluating Newer Practices by the Observational Method," Sixteenth Yearbook of the Department of Elementary School Principals (Washington, D.C.: National Education Association, 1937), pp. 377-389.

⁴J. W. Wrightstone, Appraisal of Newer Elementary School Practices (Columbia: Teachers' College Publications, 1939), pp. 40-41.

connection with pupil achievement, attitude, honesty, and judgment scales between pupils in school organized on a traditional pattern and pupils in schools organized around the experiences and interests of the child. Wrightstone had conducted a previous study with secondary school children on the same basis. While the results of his experiment seem to favor the newer or experimental type of school in which the program was organized around an activity or integrated approach, the study had little bearing on the problem of evaluating courses in which the content, pupils and teaching techniques differed.

The fifth study referred to by Smith and others is the Knight and Mickelson⁵ experiment carried out in Los Angeles with 1,415 pupils in ninety-six classes of eleven different elementary schools. The general purpose of their study was to compare a problem-centered approach to teaching with a subject-centered approach. Their findings supported the problem-centered approach, but once again, the investigation was with elementary schools and the techniques were not clearly outlined.

The sixth study of importance to those working in the field of curriculum studies was the Eight-Year Study. This study reported the progress in college of students involved in the eight year study. The evidence presented by

⁵S. S. Knight and J. M. Mickelson, "Problems vs Subjects," The Clearing House, 24:7 (September, 1949).

Chamberlin, Chamberlin, Drought and Scott⁶ was that the products of the thirty schools that had been freed from the college entrance board examinations as a group, had done better in all subjects in college as judged by the three-fold criteria of college standards, students' peers or by the individual student. The study dealt with overall performance. The present study was concerned with performance in one subject area at one grade level.

The studies reported above were very general. There are very few studies in the field of science education relating to curriculum development and to evaluation of newer curricula. In a review of research on science teaching, Watson noted:

The relative scarcity of research on science teaching in relation to pupil behavior arises from at least two factors: the persistent focus upon knowledge in the sense of ability to recall, and the orientation of those few individuals who might be expected to carry out most of the research. Most of the research involving pupil behavior has utilized pupil gain on achievement tests as the sole or primary description of changed behavior. Such tests have been concerned mainly with recall and recognition behaviors and with application of principles . . . to academic problems similar to those used in class instruction.⁷

It would seem that behavioral change is not readily detected or it may be that the scarcity of research noted

⁶Dean Chamberlin, Enid Chamberlin, N. E. Drought, and W. E. Scott, Did They Succeed in College? (New York: Harper and Brothers, 1942), pp. 207-209.

⁷Fletcher G. Watson, "Research on Teaching Science," Handbook of Research on Teaching, N. L. Gage, editor (Chicago: Rand McNally, 1963), p. 1031.

by Watson stems from a lack of clear definition of the objectives of science education. However, the work of Bloom⁸ and others in the development of the cognitive and affective domains of knowledge, and in the objectives and testing techniques associated with these domains, should eventually give rise to studies on changes in pupil behavior. Even many of the achievement tests used in studies examined in this review of pertinent literature are concerned with only a small portion of the cognitive domain of knowledge. The other domains indicated by Bloom--comprehension, application, analysis, synthesis and evaluation--are seldom found in science achievement tests.

A survey of recent research in secondary science education by Cohen⁹ covering the areas of higher education, curriculum and teaching methods, student reaction, student achievement, extra-curricular studies, the philosophy and objectives of science, examination and evaluation, provides an interesting summary of current research between the years 1953-62. He reports that during this period in the field of curricula the following studies were undertaken:

Mendenhall, Laughlin and Harmer reviewed recent research on science curricula, and found that probably the most important trend was from Newtonian to an

⁸Benjamin S. Bloom (ed.), Taxonomy of Educational Objectives Handbook I: Cognitive Domain (New York: David McKay Company, 1964), p. 62 ff.

⁹David Cohen, "The Significance of Recent Research in Secondary School Science Education," Science Education, 48:157 (March, 1964).

atomic picture of the universe . . . A corollary trend was from consideration of the various physical sciences as separate disciplines to recognition of their unity. These trends brought increased awareness of the importance of science as a method and the transient value of certain science subject matter . . . Little research has been done on the content of general science courses.¹⁰

Cohen reports that more than half the schools in research studies reviewed were engaged in science curriculum review and revision before the first Russian space craft was launched. While there seems to have been much activity in the development of curricula such as PSSC, CHEMS, BSCS and CBA, reports on accompanying research on the evaluation of these programs have been minimal.

In general, the study of research during the 1953-62 period by Cohen suggests the topics of study were grade placement of science principles relating to the study of heat, areas of interest for grade seven to nine by a student questionnaire, demonstrations suitable for a general science course, conservation--the topic of six studies reviewed, interests of students as the basis for units of study, and changes arising because of dissatisfaction with a general course approach in science. A comprehensive study of trends in science education conducted by Raskin and Metzner and summarized by Cohen:

. . . they identified these changes as embodying a dissatisfaction with general science curricula because of the repetition and duplication they contain, a firming up of elementary science, provision of

¹⁰Ibid., p. 159.

ninth year programs (especially for the gifted) in earth science, biology, physical science (with emphasis on atomic and molecular structure, basic chemical reactions, and physical phenomena), more class time, usually with two laboratory periods each week, 'increased emphasis on laboratory work with such attention being paid to open-ended experiments', increased stress on academic content, provision of electives, expanding offerings of college courses with advanced study, national planning of science courses with the collaboration of outstanding 'scientists', more emphasis on mathematics, physics, chemistry and less on biology, experimentation with curricula, summer institutes for gifted students and improved equipment and modernization of laboratories largely through application of NDEA funds.¹¹

An examination of a review of research studies in science education for the period 1961-63 as carried out by Taylor¹² and others in the area of science curriculum research reports the work of Davitt in the use of televised instruction, of Jackson in the use of filmed courses in physics and chemistry, and of Reed and Cooley with factors of warmth, demand and intrinsic motivation as related to the development of interest in science of ninth grade students. While many of the research topics reviewed would suggest other investigations, the problems outlined had little bearing upon the proposed study for this thesis. There were no studies in the literature reviewed by this group that related to the investigation of achievement and of student attitude to science courses.

¹¹Ibid., p. 165.

¹²Wayne Taylor, J. R. Brandou, F. B. Dutton, J. M. Mason, C. H. Nelson, and W. W. Walsh, Review of Research Studies in Science Education. (Mimeographed), undated.

Hubrig and Summers¹³ reviewed the doctoral dissertations in science education for 1963. An examination of the topics listed in this report indicates only one dissertation which is similar to the investigation at hand. This is the work of Slesnick, who investigated the effectiveness of a unified science program in the high school curriculum. In his study, a course sequence in unified science was begun with the ninth grade classes, and thereafter the next course was added, replacing the traditional courses of chemistry, physics and biology.

When the facts, concepts and methods of science are taught as a unity of relationships, the relationships are learned better than when the same facts, concepts and methods are presented in the context of isolated disciplines. Students who have studied unified science have demonstrated a superior understanding of the unity and orderliness of nature . . . At the ninth grade level, the control individuals outscored their counterparts, significantly so, at the physical science level. These results imply that the sequence in unified science was directed primarily to higher ability students or that the criterion instrument became increasingly less effective in measuring a rational universe image as grade, ability and achievement levels are descended or that physical science as taught in the control school was as effective as unified science in teaching for a rational image of the universe.¹⁴

There are major differences between the above study and this thesis. The content of the course, a unified

¹³Billie Hubrig and Edward G. Summers, "Doctoral Dissertation Research Reported for 1963," School Science and Mathematics, 65:628-645 (October, 1965).

¹⁴Irwin L. Slesnick, "The Effectiveness of a Unified Science in the High School Curriculum," Journal of Research in Science Teaching, 1:312 (December, 1963).
312.

science, differed from the content of the courses under consideration in this study. As well, the instrument for evaluating the achievement of pupils was not applicable to the investigation conducted in Manitoba schools.

Among earlier studies in science is that of Boeck,¹⁵ who investigated a method of instruction in the chemistry laboratory that involved pupil planning of controlled experimental laboratory procedures. While the study was of general interest, it had little bearing upon this investigation. Another study, reported by Boer,¹⁶ dealt with children in the primary grades who were encouraged to find answers to questions and problems by experimenting. Studies conducted by Weisman,¹⁷ Teichmann¹⁸ and Alpern¹⁹ examined elements of the scientific method. This study, the investigation of pupil achievement in science in Manitoba secondary

¹⁵C. H. Boeck, "The Inductive Compared to the Deductive Approach to Teaching Secondary School Chemistry" (Ph.D. dissertation, University of Minnesota, 1950).

¹⁶H. E. Boer, "Using Visual Sensory Aids in Teaching Science in the Primary Grades," Science Education, 32:272-78 (October, 1948).

¹⁷L. L. Weisemann, "Some Factors Related to the Ability to Interpret Data in Biological Science" (Doctoral dissertation, University of Chicago, 1946).

¹⁸L. Teichmann, "Ability of Science Students to Make Conclusions" (Doctoral dissertation, New York University, 1944).

¹⁹M. L. Alpern, "The Ability to Test Hypotheses" (Doctoral dissertation, New York University, 1946).

schools, is concerned with the overall behavior of the student, and with the selection of a criterion instrument which would be suitable to compare the achievement of students following different courses in science.

Investigations of Achievement Instruments

The literature was reviewed to obtain leads on achievement tests that might be useful in determining the achievement in science of the control and experimental groups in the study concerned with Manitoba students. Smith notes:

Recent reviews of educational research concerned with elementary science have commented that 'within the span covered by this review, no published studies dealt with evaluation of pupil achievement'. This statement underscores one of the major problems of the elementary science program at the present time. Since the programs in elementary science have been so amorphous, it has been difficult, if not impossible, to construct satisfactory standardized measuring instruments . . . Research workers have often been in despair because of the lack of objective measures and have had to fall back on expert opinion, observation, rating scales, or other subjective approaches. Most serious research efforts are confronted with the task of devising suitable evaluating devices.²⁰

In searching for reports on suitable testing instruments for evaluating secondary sciences, the work of Raftor²¹

²⁰Herbert A. Smith, "Educational Research Related to Science Instruction for the Elementary and Junior High School: A Review and Commentary," Journal of Research in Science Teaching, I:219 (September, 1963).

²¹Christopher D. Raftor, "A Comparison of the Relative Effectiveness of Two Methods of Teaching a Course in Physical Science to Sophomore College Students," Science Education, Vol. XLV, No. 2 (March, 1961), pp. 164-68.

is noted. To compare a problem-solving method of teaching to a lecture-demonstration method with sophomore college students Raftor used a Test of Application of Principles of Physical Science, and an Interpretation of Data Test, both developed by the Cooperative Test Bureau, the Watson-Glaser Critical Thinking Appraisal published by the Word Book Company; and a Test of General Proficiency in the Natural Sciences. These tests, however, are at a higher level than is expected of a tenth grade student following a course in general physical science. Consequently, the above tests were not used in this study of Manitoba students.

An investigation of the CBA course for secondary school students was conducted by Montean, Cope and Williams²² by means of a questionnaire composed of twenty-three statements. The questionnaire was sent to three different groups of professors for their reaction. This procedure seemed momentarily to have some value for this study, but was discarded due to the uncertainty in Manitoba of obtaining sufficient professors of science who would be willing to examine such courses in detail for evaluation.

Smith investigated the degree to which students of a summer institute could think critically, and were able to manifest the intangibles of science. The study involved

²²John J. Montean, Ruth C. Cope and Royce Williams, "An Evaluation of CBA Chemistry for High School Students," Science Education, Vol. XLVII (February, 1963), pp. 35-43.

thirty-six boys and twenty-four girls of ages fifteen to eighteen years. One of the instruments used in this study was entitled Test on Understanding Science. Smith reports:

Apparently the attitudes and mood of science and scientists are not getting through by teaching students indirectly. Even surmising that these intangibles may not have been measured adequately in an eight week period, it does seem as if the carry-over of such an experience from the mathematics and science courses taken in high school plus the institute experience would have placed these students in a much more favorable position among the twelfth graders of the norm group especially in view of their relatively high ability to think critically, this suggests that these intangibles should be taught directly by designing a course or by constructing a unit of experiences to be placed in an existing course for such purposes. Certainly if these so-called intangibles have been identified as measurable factors, they are tangible assets which can be organized to further student development.²³

In another review Finger, Dillon and Corbin, dealing with literature on evaluation of PSSC programs, produced evidence that subjective evaluation is still dominant.

Subjective evaluation continues to remain important in judging educational programs. These techniques range from judgments of students, of experienced teachers, and of specialists in the field. Not infrequently, subjective evaluation which deals with the intrinsic worth if a program is of overriding importance. Such procedures allow for judgments along broad criteria which cannot be accommodated to any kind of experimental control.²⁴

²³Paul M. Smith, Jr., "Critical Thinking and the Science Intangibles," Science Education, Vol. XLVII, No. 4 (October, 1963), pp. 405-408.

²⁴John A. Finger, Jr., John A. Dillon, Jr., and Frederic Corbin, "Performance in Introductory College Physics and Previous Instruction in Physics," Journal of Research in Science Teaching, 3:61 (March, 1965).

Cooley and Bassett, in an evaluation of a summer institute program, used as a pre-test the STEP tests in science and a Facts About Science test developed by the Educational Testing Service. These investigators note:

Two related research efforts have already emerged from this investigation. The results of the summer testing indicated the promise of the Facts About Science test, but an improved instrument seems necessary. We are therefore developing here at the Harvard Graduate School of Education, a new instrument, the Test on Understanding Science, which will attempt to measure student perceptions of science and scientists.²⁵

Thus, the Test on Understanding Science would seem to be a more promising instrument for the purpose of investigating science courses in Manitoba secondary schools than would the Facts About Science instrument. It becomes obvious that three courses designed to meet different requirements would not contain the same content and hence the Facts About Science test would be inoperable.

It might be noted that many of the newer courses such as PSSC Physics or CHEM Study, to mention but two, seem to favor the better-than-average student. Is there no way that great numbers of students in school today can have an opportunity to experience the work of a scientist? The work of Cooley and Klopfer in the development of the Test On Understanding Science (TOUS) appears to have merit in

²⁵William W. Cooley and Robert D. Bassett, "Evaluation and Follow-Up Study of Summer Science and Mathematics Program for Talented Secondary School Students," Science Education, Vol. XLV (April, 1961), pp. 209-241.

measuring scientific attitudes. Cooley and Klopfer note:

The selection of appropriate evaluation instruments is probably the most crucial aspect of research and development in the areas of curriculum and methods. In spite of this, tests are usually chosen for educational experiments in far too cavalier a fashion. General achievement tests, being familiar and readily available, have been used almost exclusively in the past. However, such tests yield only general overall scores, which allow very few specific generalizations to be drawn from the experimental findings. Consequently, most educational experiments yield few theoretically or practically significant results, even though statistically significant differences may have been found.²⁶

When the conditions for educational experimentation are examined, the more common means has been to try to obtain matched groups of students and make comparisons on the basis of these groups. The work of Cooley and Lohnes in the statistics of multivariate analysis gives an indication of how large groups may be handled, with the variables being examined but not necessarily controlled. As they note:

Multivariate analysis is generally considered to include those statistical procedures concerned with analyzing multiple measurements that have been made on a number of N individuals. The important distinction is that the multiple variates are considered in combination, as systems . . . Attention is directed to a procedure for multivariate analysis with covariance controls which has not been encountered by the authors in published reports of educational or psychological research, but which seems to have great promise for these fields. For example, in curriculum

²⁶William W. Cooley and Leopold E. Klopfer, "The Evaluation of Specific Educational Innovations," Journal of Research in Science Teaching, Vol. I (March, 1963), pp. 73-80.

research it would be possible to test the separation of a number of treatment groups on a set of 'm' achievement variables with covariance adjustment for differences on a set of 'o' aptitude variables.²⁷

The implication of these statements by Cooley and Lohnes is that educational curricula research need not be as concerned with the matching of students on the basis of a number of discernable variables, as with the possibility of adjusting the controls and examining the achievement. For example, the aptitude to learn as determined by a mental abilities test and the initial knowledge of a subject as determined by a pre-test may be controlled with respect to student achievement. The procedure makes it statistically possible to equate results of mental abilities and initial knowledge on a regression line, and then to examine the results in the light of these adjusted factors.

The Development of Science Programs

In evaluating newer science programs, Brakken investigated the various intellectual factors in the PSSC course and found that, according to his treatment of the data, that differences with respect to effects of the intellectual characteristics of adolescents do exist between PSSC Physics and the so-called conventional approaches. As he noted:

²⁷William W. Cooley and Paul R. Lohnes, Multivariate Procedures for the Behavioral Science (New York: John Wiley & Sons, 1962), p. 7.

. . . related to greater development of critical thinking ability as measured by the evaluative instruments. However, more gain in reasoning ability was found for students enrolled in conventional courses. Since previous research indicates that these two abilities are closely related, this result is surprising . . . The PSSC approach resulted in significantly more gain in numerical ability . . . Critical thinking was somewhat more important for PSSC physics achievement than it was for the conventional approach. The relative importance of this factor appeared to diminish for both as the courses progressed.²⁸

It would seem from these statements that there is a need for a thorough evaluation of the newer programs in science, so that the entire school population may be exposed to a science program of value, indeed of survival value. Hurd emphasizes this thought as follows:

To escape the threat of obsolescence, education in the sciences must be based upon the kind of information that has survival value and upon strategies of enquiry that facilitate the adaptation of knowledge to new demands. This education must go beyond the immediate and include the future. What is more, it should provide young people with the background and intellectual talents for shaping the future in a manner that assures the welfare of human beings and sustains progress.²⁹

There is a strong conviction that in today's society one is a scientist or a non-scientist. If society is to survive, both the scientist and the non-scientist require

²⁸Earl Brakken, "Intellectual Factors in PSSC and Conventional High School Physics," Journal of Research in Science Teaching, 3:19 (March, 1965).

²⁹Paul DeHart Hurd, "Toward a Theory of Science Education Consistent with Modern Science," Theory Into Action in Science Curriculum Development (Washington, D.C.: National Science Teachers Association, 1964), p. 7.

course work in science, or some form of science, at the secondary school level. As noted by Rogers:

Only a fraction of those who learn science in high school continue with science in college, and of these, only a small fraction become professional scientists. On those specialists the colleges lavish special training and care; all the more reason why high schools need not do so, since later training can make good any existing deficiencies. The future scientist can look after himself, if only you will find and encourage him . . . The same thing, then, is wanted for all: an understanding of science: but the speed of teaching need not be the same for all.³⁰

If science education, as suggested by Rogers, is to be for all students, what is the nature of the courses that students may profitably elect? In reviewing the literature to find what courses are currently available for students today, the roll-call of new courses sounds very much like the roll-call of universities. It seems that these become the centers for the distribution of new ideas, new curricula and new approaches to the teaching of science, whether at the elementary or the secondary level. Since most of the so-called new courses in science are no longer new, the foregoing review of the literature merely attempted to analyze critically some of the sources of science curricula in an attempt to see whether any programs corresponded to the programs under investigation in this study.

³⁰Eric M. Rogers, "The Research Scientist Looks at the Purpose of Science-Teaching," Rethinking Science Education, The Fifty-Ninth Yearbook of the National Society for the Study of Education (Chicago: The University of Chicago Press, 1960), p. 20.

There has been much progress in recent years in the teaching of physics, chemistry and biology in the secondary schools. The stage of development is such that the work of the Physical Science Study Committee is readily recognized as PSSC, while the Chemical Bond Approach becomes CBA and the Chemical Educational Materials Study is CHEMS. In the biological sciences the work of the Biological Sciences Curriculum Study is now known as the Yellow, Blue or Green version of the BSCS.

In elementary school, a variety of science programs is being developed. The American Association for the Advancement of Science, in its Science Education News, lists many projects at the junior high and elementary levels of science. The more frequently mentioned or advertised courses are the AAAS Science--A Process Approach for elementary schools, with materials from kindergarten to grade six completed and in experimental form; the Princeton project entitled Time Space and Matter: Investigating the Physical World; the School Science Curriculum Project known as SSCP which envisages the development of eighteen units in diverse areas of anthropology, physical science, biological science and the earth science. Reports are to be found on the Earth Science Curriculum Project, ESCP from Boulder, on the Elementary Science Curriculum Improvement project and on the Elementary School Science, ESS, dealing with units or experimental blocks in science.

At the secondary level, the Harvard Project Physics purports to halt, and possibly reverse, the continuing decline in the percentage of students taking physics. The plan of this project is to appeal to all levels of students, those who may not go on to college, or those who in going on to college may concentrate on the humanities or social sciences.

One of the newer projects, entitled "Introductory Physical Science," is directed by Haber-Schaim and is being developed by the Physical Sciences Study Committee as an outgrowth of Educational Services Incorporated. Now known as IPS, the course is designed to replace the amorphous "general science" commonly offered as the course of study for the junior high school student. The philosophy of the course seems to be investigatory, experimental and oriented toward the average student in school. This is noted by:

Whether there is such a thing as an 'average' student is open to question. One cannot teach any group of students very long before it becomes evident that each student is, in some respect at least, atypical. Nevertheless, the students in the test classes are probably much like those what would be found in any school having classes from which highly competent and slow learners had been drawn.

What then are the 'average' students like? Many of them are lacking in skills that make language and mathematics the tools of science. All too often before this, science has been one thing, English another and arithmetic still a third; and they find grave difficulty in fusing these fields into a single instrument for learning. They are often troubled by the mechanics of expression and computation, so that they cannot see the woods for the trees. They have difficulty in translating directions into purposeful activity. They have

trouble in relating measurement to ideas. They do not grasp the significance of quantities and have little concept of the magnitudes of things. The nature of numbers, related to measurement escapes them. In short, all the deficiencies that will hinder progress in future science courses are here highlighted.³¹

The review of the literature in the area of new science programs shows that many new courses are being developed to try to provide for the current science needs of today's children. Replacing the traditional programs are new courses, new content, and new materials, all seemingly aimed at developing the process, the strategies and the concepts of science. Emphasis has swung to the experimental approach and it is argued by many that the way to develop a "feel" for science is by "sciencing." Brandwein notes this with:

. . . If these curriculums (particularly PSSC, CHEMS, CBA) do have a fault, it is this: a curriculum should be responsible to the historic period in which people live and work. Ours is a time of great technological advance. The new curriculums have generally removed technology from their scope, but technology remains in the lives of people. In school, youngsters must come to understand the nature of technological advances--as it stems from science and from social and personal demand. . . .

It is necessary to develop courses in chemistry, biology, physics and geology (the major high school courses) for all educable students who are in high school, no matter what their intellectual gifts or destination. We need science programs which meet the requirements of four levels of intellectual

³¹John H. Dodge, "Introductory Physical Science and the Average Student," Introductory Physical Science--A Brief Description of a New Course (Watertown, Mass.: Educational Services, Inc., publication, undated).

capacity: slow, moderate and fast groups--and gifted students as well. The object is to emphasize comprehension of the world of science. The science endeavor is supported by the entire populace, its processes must be understood as well as its products--as must its limitations.³²

In summary, from the literature reviewed, there would seem to be two broad areas of development in science programs through the last part of the 1950's and the early 1960's. In the first place, there is evidence of an attempt to develop courses in science for those students whose abilities, gifts and opportunities have destined them for college. The second discernable trend toward the newer experimentally oriented science courses is the degree of rigor in the concepts and generalizations. These two trends may be excellent preparation for students who will continue the study of science in college or universities and will become the scientists of the future. On the other hand, there is not the same attention being paid to the needs of those who are not to be the experts in science or who may not enter college. Science is having an increasing impact on personal life, and on the forms and functions of society. Education, especially science education, is needed to help all citizens understand the processes of science, to understand the aims and goals of science in our society, and to understand the nature of the scientist in society.

³² Paul F. Brandwein, The Strategy of the New Developments in Science Teaching, Mimeographed address given to Canadian Education Association, Quebec City, September, 1963.

In addition to these two broad trends, the literature has been reviewed for tests and statistical techniques which might be useful in this study. In this respect, the Test On Understanding Science would seem to be an effective instrument in measuring the goals of science courses in Manitoba schools. A detailed rationale for the selection of this test as a criterion instrument is given in subsequent sections of the thesis. While many research studies have been indicated in reviewing the literature, little has been done in Manitoba on the evaluation of the traditional science programs, on the evaluation of the newly introduced science programs, or on programs that, while they may be only three years old, may not be fulfilling adequately the aims and goals of modern science teaching.

CHAPTER III

SCIENCE PROGRAMS IN MANITOBA SECONDARY SCHOOLS

The development of a literate citizen in science does not result from the teaching associated with a single teacher, a single grade, or a single course. Such a person is not a product of a single solitary factor in school but is a result of many composite experience factors. Such development can only be achieved through a carefully planned program starting with kindergarten and ending, as far as the public school system is concerned, with the twelfth grade.

In the Manitoba school system, as explained in Chapter I, there are three science programs readily identified in the tenth grade. These are the General Course program, the University Entrance Course and the Matriculation Course. The three science programs in these courses are not comparable in terms of pupil achievement nor are they comparable in terms of course objectives. The content of science information to be found in each of the courses, the way that the teacher transmits the content, and the relative amount of student involvement in the science courses are variable.

The Traditional Matriculation Course

The objectives of the oldest of the three courses, the Traditional or Matriculation Course, as stated in the Program of Studies for Schools of Manitoba 1963-64, are as follows:

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.¹

If the preceding statement refers to the outcomes of interest and understanding of the environment, what then are the specific objectives which are developed through the daily round of science instruction? The objectives listed in the Program of Studies are:

- (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 incorporate healthy moral and social attitudes for living in a democratic society.²

An examination of these objectives for the traditional program indicates the three areas that are normally found in the development of any science program. These three areas are knowledge, skills and habits, and attitudes. No

¹Programme of Studies of Schools of Manitoba, Senior High Schools, 1963-64 (Winnipeg: Queen's Printer, 1963), p. 50.

²Ibid., p. 50.

one would argue that the development of knowledge, that is, the increase in amount of information on a specific discipline, the development of skills and habits, and the development of worthwhile attitude, are not worthy objectives.

Whether one course at the tenth grade level can develop all of these to the full remains to be seen. An examination of the achievement of the pupils in the traditional science program at the tenth grade level would seem to indicate that the goal has not been achieved in the past.

Further specific objectives that are given for the teaching of the grade ten science program are:

1. The development of the technique of fact finding. This involves a) the ability to perform satisfactorily simple laboratory experiments, b) the ability to observe and measure accurately, c) the ability to pursue field activities.
2. The development of the power to reach logical conclusions upon 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 a problem.
3. The development of the ability to use vast combinations of inductive and deductive reasoning in the exploration of new fields of thought and action.
4. The development of the ability to understand the natural environment and to live effectively therein.³

Once again, it could not be argued that these are not worthwhile objectives. Whether indeed all can be developed within the space of one year is a point of contention. In spite of these written objectives, it is a matter of concern that students taking the traditional science course at the tenth grade level have had little if

³Ibid., p. 50.

any opportunity to carry out simple laboratory experiments in the classroom. The students, therefore, have not developed the ability to observe and measure accurately but simply have watched the teacher demonstrate how to measure accurately. In very few cases have the pupils been able to carry out suitable field activities. The power to organize data and the power to interpret data are worthwhile objectives. But can the students develop this power if they are not given data or are not required to find data to organize? The objectives are not achieved by lecturers telling students "how-to-do-it," nor are they achieved by using outmoded and outdated material. It would seem logical that the way to develop the power to organize data is to carry out experimental work and ensure that students have an opportunity to collect data and to organize it systematically, and then to draw interpretations from the data. The ability to use deductive reasoning in the exploration of new fields of thought and action, which again might be a worthwhile objective, has not been realized by this program. It does not follow that a person can be told to reason deductively and then become proficient with logical tautologies.

In formulating a course of study, the textbook that is used in the tenth grade program in most of the secondary schools in Manitoba is entitled, Everyday Problems in Science, by Beauchamp, Mayfield and West, published in Canada in 1948 by W. Gage and Company. The course title in

the program of studies is General Science 100. A student following this course of study would encounter the following topics: 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 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?" and Unit 20 - "How Can Science Help Us From Wasting Nature's Wealth?"

An examination of these unit titles reveals that the topics might be reasonable for a general course in science at the tenth grade level. A more detailed examination of the content and the method by which the content is transmitted to children would indicate that the course of study is one of technology. The British Association of Teachers of Science is critical of this point of view.

They note:

The effects of science on human life and thought have become so great and are potentially so much greater, that those who have no understanding of them and of the science that has produced them, cannot be considered to be properly educated and truly cultured, and therefore unable to participate fully in the life of their times. Present 'scientific illiteracy' is, in part, due to the lack of factual knowledge, but

is much more the result of a lack of understanding of the basic nature and aims of science.⁴

One of the major criticisms by teachers of the traditional science program as exemplified by the Everyday Problems in Science text has been that the textual materials emphasized technology and, because it emphasizes technology, much of the material is dated. While it might be a worthwhile endeavor to obtain and present to students some of the impact of science and technology on our society, it would hardly seem to be the true purpose of the program to teach technology. Such an objective as the teaching of technology is neither given nor implied in the statement of objectives of the traditional course. Even if it were implied in the Program of Studies (the handbook of the novice teacher) that the students should gain a mastery of the impact of technology on society, then the text materials prepared today for such a course would soon be outmoded because of the speed at which present technical changes are taking place. Hurd emphasizes this point in the following:

A rapid change in society stimulated by advances in science demands an educational program designed to meet the challenge of change. Schools exist to help young people know about and participate in the life of their time. In the past when the climate for change and progress in science were slow instruction in science could lag fifty years or more with little ill consequence in the individual or the nation . . . Adjustments made in science curricula reflect new

⁴The Science Masters' Association and the Association of Women Science Teachers, "Science and Education," Secondary Modern Science Teaching, Part I (London: John Murray, 1962), p. 5.

technology and technological developments but generally fail to reflect the extent of modern science. The impact of science on man's thinking on social conditions, on economic development and on political action escaped wide spread attention even among highly educated non-scientists. In many ways the influence of science in shaping modern America is the unwritten history of the twentieth century.⁵

The traditional program of science in the tenth grade in Manitoba Schools has been characterized, at the best, by teacher demonstration with little pupil participation in experimentation.

The following experiments will constitute the minimum requirements for formal experimental work. The experiments marked with an asterisk are to be done by the students wherever possible, otherwise they are to be carried out as demonstrations by the teacher.⁶

Following the above statement from the Programme of Studies is a list of fifty-six experiments, twelve of these marked by an asterisk. Thus the traditional program emphasizes teacher demonstration with little pupil participation. This procedure is quite different from the experimental approach suggested for elementary and junior high schools by the Elementary School Science program cited earlier.

The purpose of an experiment is to explore ideas, to test theories, to raise questions, to gather data through

⁵ Paul deHart Hurd, "Toward a Theory of Science Education Consistent with Modern Science," Theory Into Action in Science Curriculum Development, National Science Teachers Association (Washington, D.C.: NSTA, 1964), p. 7.

⁶ Programme of Studies, op. cit., p. 50.

the process of observing, and to base thinking upon facts obtained from rational conclusions. Experiments purely for the purpose of data gathering are not sufficient. They must go further than the data gathering stage. Experimental work should show the variety, characteristics and limitations of experimental design, the relationships between experimental observations and the nature of the data obtained. If a course of study prescribes certain experiments for a student to follow, the greater the probability is that these experiments are not experiments at all but simply demonstrations and verification of already known facts. Brandwein notes:

Built into school curriculums is the incredibly naive notion that scientists have a successful method, and that this method could be itemized, in steps collectively called problem solving. Concomitant with this was the singular notion that science was a way of life (not that it was a part of life).⁷

As well as the false concept that one successful method is held by all scientists for problem solving is the erroneous belief that the content of science is composed of a verified and certain body of facts. If this were the case, and all the facts in science were uncovered, then there would be little reason to go into the laboratory to confirm what is already known. As Brandwein points out:

The content of science has been confused with a verified and certain body of facts. The truth of the matter is that in all probability most of the

⁷ Paul F. Brandwein, The Strategy Of the New Developments in Science Teaching, mimeographed copy of an address presented to the Canadian Education Association, Quebec City, September, 1963.

facts known in 1850 are not facts now. What was taught in all schools was the history of science, but only a superficial history. In essence the teacher confronted students with the past; he reviewed the work of great scientists and repeated their experiments. The uncertainties and intelligent failures of science were not mentioned. If science was to be taught as a history rather than a discovery, if facts were to be covered rather than uncovered, if the laboratory was the place for the problem-doing rather than problem-solving, if the product of science was the important aspect rather than its process, then why go into the laboratory to confirm what was already known. The lecture-demonstration was found to be effective in transmitting facts for receptive memories.⁸

A close examination of the traditional science program in Manitoba schools reveals that much of science teaching is or has been organized along the very lines criticized by Brandwein. First, built into the program is the notion that there is such a thing as one successful scientific method. This is found in Unit 1: "How Do Scientists Work?" Second, teachers and texts are emphasizing technology, the product of science, rather than the fundamental concepts in science. Such units as "How Do We Use Energy for Communications," and "How Do We Obtain and Use Electrical Currents" are examples of such technologies. Third, there is an attempt to teach within the grade ten traditional science program the concept that science is a closed body of verified and certain facts. The following statement indicates such a point of view:

⁸Ibid., p. 3.

Your experiment showed that a current is produced in the coil connected with the galvanometer when the circuit is closed.⁹

Fourth, within the classroom itself, science has become acquainted with telling rather than with learning. Fifth, what seems to be happening in science teaching is that the history of science is being presented to students rather than the development of the scientific enterprise. Thus students learn the names of scientists and the contributions made by the scientists rather than examining problems faced by scientists in making their contribution to a world community. Sixth, the objective of developing literacy in science is not being attained. For if science is being taught as a technology and a history, as an anthology of topics to be covered in a given scope and sequence, then it becomes the fate of children to enter school in one era of technology and leave school twelve years later unprepared for a new era. Children who entered school in the horse and buggy age came out into an age of combustion engines, followed by the air age, by the atomic age and by the space age. This in turn might be followed by an age that does not, as yet, have a name. It may be the age of automation or the age of computers. It would seem to follow that science courses which do not provide a foundation in the major schemes of science but remain stable over a generation are doomed to

⁹Wilbur L. Beauchamp, John C. Mayfield and Joe Young West, Everyday Problems in Science (Toronto: W. J. Gage and Company, 1948), p. 571.

failure. With regard to the course under consideration, references can be found to telephones now found only in museums, to radios which are also museum pieces, along with such statements as, "Only a few large cities have television broadcasts and these can be received only a few miles."¹⁰

While an astute teacher can correct the statements and possibly even use the statements to illustrate how times have changed, the confidence of a student in such a program as outlined is destroyed. This, then, is the traditional university entrance program still found in schools today. In but two more years, the revised edition of the text will be twenty years old.

Newer Science Programs

In 1963 a science curriculum committee, meeting about the University Entrance program, recommended that sections of PSSC and CHEMS be combined to form the science course for those students in the tenth grade who were enrolled in the University Entrance program.

It will be recalled that the Physical Science Study Committee was formed in 1956 by a group of university and secondary school physics teachers who had worked together to develop an improved introductory physics course. The areas of study were shortened from what was considered in past

¹⁰Ibid., p. 66.

years to be the introductory areas of physics. Instead of the traditional areas of light, of sound, of heat, of machines, of Archimedes principle and so on, four major areas of physics were developed. Part One, the part used in the combined PSSC-CHEMS course, was outlined by Finley as follows:

The course begins with a consideration of the dimensions of time and space and how they are sensed. Through laboratory work the student sees how his sense can be extended by instrumentation and begins to develop a perception of the role, nature, and limitations of measurement. This perception is extended through films that go beyond the usual facilities for measurement available in school laboratories. Familiarity with techniques of defining intervals of space and time leads to a study of motion through space in the course of time. The student learns the relation between distance, velocity and acceleration and how to move from one to another through graphical differentiation and integration. The use of vectors to represent these quantities completes this introductory view of the descriptive tools of physics. The course then turns to an introduction to matter, the substance of the universe. Here, the ideas of mass and conservation of mass are considered. The student examines experimental evidence for the existence and size of atoms. In the laboratory he establishes an upper limit for the size of a molecule and sees how extensions of this experiment can lead to determining the size of an atom. The combination of atoms in molecules is studied, and the ideas of atomicity are extended through a consideration of the arrangement of atoms in solids (crystals) and in gases. A beginning on the molecular interpretation of a gas makes it possible to deal specifically with the idea of a physical model.¹¹

The section of physics used in the grade ten science course in Manitoba schools was the first six chapters of the

¹¹Gilbert C. Finley, "The Physical Science Study Committee," Modern Viewpoints in the Curriculum (New York: McGraw-Hill Book Company, 1964), p. 42.

text produced by PSSC which deals with the introduction to physics, matter, and its relationship in space and time. In the course the student works mainly with the relationships between distance, velocity and acceleration. In general he finds the answers to these problems in laboratory situations. The text is up-to-date, the problems are challenging and the laboratory exercises, in the opinion of teachers, are stimulating.

The Chemical Education Materials Study (CHEMS) is an approach to high school chemistry oriented around laboratory or experimental work. The program was developed during the summer of 1960 through the co-operative work of high school and college teachers under a grant from the National Science Foundation. The total program is composed of five major parts: Part One, observation and interpretation; Part Two, an overview of chemistry dealing with scientific models; Part Three, chemical reactions and principles; Part Four, atomic structure and chemical bonds; and Part Five, descriptive chemistry.

The general organization of the text is, then, into three portions--introductory portion where . . . with laboratory experiments the student discovers the basic ideas which will be used throughout the course. These include ideas of atomic-molecular theory, chemical reactions, the gas phase and kinetic theory, condensed phases and atomic structure in the periodic table. The second section of the text then extensively discussed the major ideas under the general heading of energy, rates, equilibrium (with examples from chemical reactions, solubility, acids and bases, oxidation-reduction) chemical calculations, atomic

theory and structure, molecular structure and bonding. The third section of the text consists of a set of seven chapters which deal extensively with the principles discussed in the first portion of the course, using many applications to the chemistry of typical elements and their compounds.¹²

The major purpose of the CHEMS approach was to obtain from a group of experienced chemists an outline of a first course in chemistry which was based on the best information currently available. Campbell notes:

A course which would present an honest and encompassable view of the subject for either the terminal student or for the student who is going on for further study in science or, indeed, in chemistry . . . A first course in chemistry should be based on an excellent set of laboratory experiments and a first course in chemistry should emphasize the importance and limitations of concepts in correlating chemical facts and comprehending with minimal effort the wide scope of the subject.¹³

The aims of the PSSC program were similar to those of the CHEMS program. While the committee on the University Entrance program did not make a statement as to all the reasons for the selection of these two programs for the grade ten course, a statement of the aims of the PSSC committee would seem to indicate that the two programs were compatible.

The aim was to present a view of physics that would bring a student close to the nature of modern physics and to the nature of physical enquiry. Finally the committee sought to transmit the human

¹²J. A. Campbell, "CHEM Study: An Approach to Chemistry Based on Experiments," New Curricula, op. cit., p. 87.

¹³Ibid., p. 82.

character of the story of physics, not simply an up-to-date codification of the findings. The student should see physics as an unfinished and continuing activity. He should experience something of the satisfaction and challenge felt by the scientist when he reaches vantage points from which he can contemplate both charted and uncharted vistas.¹⁴

Many of the criticisms made by Brandwein about secondary science courses have been removed by the suggested program. First, because the student experiments in the laboratory, because more than one model of the structure of the hydrogen atom is suggested, because more than one model of the nature of light is suggested by the textual materials, science is not taught as one infallible method. Second, technology is used sparingly both in CHEMS and PSSC programs. The text material contains few references to technological developments. Third, because the student makes his enquiries in the laboratory, because chapters of text materials are devoted to the development of a model only to discard the model, science is not being taught as a closed body of facts. Fourth, the history of science as such is not the principal emphasis. Rather the process of enquiry, the right to discover, and the right to make errors in laboratory work and in experimental design is given to students of this course. Fifth, while it is hoped that teachers do not revert to the older forms of teaching or to the poorer forms of teaching--that of telling students--the course is so designed

¹⁴Finlay, op. cit., p. 39.

that at least this procedure should be minimized. Whether the development of the sixth point of contention, that of scientific literacy, is being attained is too soon to tell. Only a study at some future date of the products of this curriculum can give an answer to this charge.

The new course of study then, for the university oriented student, was a combination of the first five to six chapters of PSSC Physics, combined with the first five to six chapters of CHEMS. Reference is made to five or six chapters as at the end of the tenth grade a student would undertake internal examinations. It was recommended by the science committee on the University Entrance program that the teacher take the science student as far as he could go. In the first pilot course of the study, it was found that the student would be able to cover only a portion of the work as outlined. While there is no concrete evidence for the statement, it would seem that the course is more suited for students of above average mental ability. The claim of Campbell¹⁵ that this be a terminal course for some students may have its justification in the number of students who are unable to handle the scope of the concepts in the course, and who refrain from taking future science courses.

One outcome which is not measured in this course is raised by Rosenbloom. This is the necessity of continued

¹⁵Campbell, op. cit., p. 82.

learning to keep pace with the knowledge explosion. He notes:

A fundamental problem is that we are the first generation in history which must educate children for an unforeseeable changing society. Many of the things they will need to know have not been discovered yet. They will have to face problems for which we cannot specifically prepare them. Learning must be for them a life-long process. We cannot foresee what use a child will have for any particular thing he learns. Any jobs he takes will change, perhaps even disappear within a few years. Our main efforts, therefore, must be directed toward teaching the child how to learn new things and toward giving him the desire to keep on learning all his life. We must teach him elementary concepts in skills and methods which he can apply in further study.¹⁶

While one may argue with Rosenbloom that no society can determine the needs twenty years from a given moment, and that all generations have to educate their children for a changing future, it must be stated that the pace of change has changed so markedly that retraining and re-education will be a life long process if a citizen is to make a significant contribution to society.

The General Course Science Program

The third science program currently offered at the tenth grade level in Manitoba schools is referred to as the General Course science program. Since this course is the major concern of this study, a detailed outline of the

¹⁶Paul C. Rosenbloom, editor, Modern Viewpoints in the Curriculum, op. cit., p. vii.

topics to be found in the Appendix. Of all the courses that have been discussed, this is the one course that has a statement of the philosophy of the committee.

The General Course Science Committee takes the position that all students require knowledge of science for effective citizenship. The course is designed for the 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, a knowledge of science with the associated skills and abilities to 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 a student will obtain a favorable attitude towards science and an appreciation for the nature and role of science for effective citizenship.¹⁷

The objectives of the science program for the General Course as outlined by the committee deal with several areas, one of which is the development of scientific literacy.

Scientific literacy is considered to be dependent, among other things, on 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 enquiry through careful observation and through the use of reliable data.

¹⁷ Statement of Philosophy of the General Course Sciences Committee, p. 1. (Mimeographed.)

5. an appreciation of 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 that are normally associated with science.¹⁸

An examination of these objectives clearly indicates that few of the objectives are operationally defined. The list does not specify the extent of the background of knowledge in science, nor does it specify what behavioral attributes indicate a disposition to use the knowledge and methods of science appropriately. What skills and abilities are normally associated with science? Some indication of what is meant by scientific literacy is to be found in an additional statement of philosophy of this committee:

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 pupil and teacher demonstration of scientific principles on an elementary level,
 - c) an orderly development of topics within the scope of the pupil's activities.
2. the utilization of laboratory investigations to develop:
 - a) skills in laboratory techniques,
 - b) an understanding of the "scientific method,"
 - c) a spirit of enquiry within the capabilities of the pupil,
 - d) suitable elementary experiments for testing ideas.¹⁹

¹⁸ Ibid., p. 1.

¹⁹ Ibid., p. 2.

The topics that are covered in the General Course Science program are the following: "How Chemistry Effects Man's Living"; "Atoms and Understanding of Chemistry"; "A Combination of Atoms"; "Oxygen and Its Properties"; "Hydrogen and Its Properties"; "Chemical Equations"; "Solutions and Ionization"; "Acids, Bases and Salts"; "Cosmetics"; "Home Decoration"; "Gardening."

In the area of physics, the topics considered are: "Static Electricity"; "Magnetism"; "Systems of Measurement"; "Work, Energy, Power and Machines." As part of the program of study there is a laboratory manual which is designed to help students make a beginning in the investigations associated with laboratory exercises. Students are given directions to follow, are required to carry out observations, or are given practice in developing their abilities to prepare material for tabular representation and are asked to draw conclusions from the tables that have been prepared. Unlike some of the newer courses of study in science, there are as yet no open-ended experiments in the General Course program.

The text used in conjunction with the course is, An Introduction to Physical Science, by R. L. Hedley, and a laboratory manual, An Introduction to Physical Science Experiments, Book I by Bridge, Browning, Connell, Hedley, Mutchmor and Watkins.

The content of the General Course science program was organized to overcome one of the major criticisms of

survey science courses, that of attempting to cover a little bit of all the fields of science from Astronomy to Zoology. It was developed to meet the needs of the mythical average student in the school--mythical because no individual is average; he is an individual.

But what then are these average students like? Many of the average students are lacking in skills that make language and mathematics the tools of science. They are often troubled with the mechanics of expression and computation. They often have difficulty in translating direction into any purposeful activity. They have difficulty relating measurement to ideas. Frequently they do not grasp the significance of quantities, and have little concept of magnitude. In short, all the deficiencies that will hinder progress in future science courses are normally to be found in many of our average students. Has it been possible within the period of one year and within the framework of one course in science to overcome many of the weaknesses of these students? Much of the progress and attitude of these students depends upon the science teacher--how he is able to capture the spirit of the course of instruction and provide the degree of enthusiasm that the course and content needs. He must understand the content of the course, have a conviction that the content as outlined needs to be taught to students, and possess the force and character of understanding that can lead students through the areas of difficulty.

To determine if these goals are achievable through a general course science program as outlined in the appendix is the purpose of this study.

The philosophy of the General Course Science Committee is found in the preamble to the program of studies and is stated as:

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 breakthroughs to extend our knowledge in science are occurring more frequently. Hence, educators are especially concerned with the prospect of an even further increase 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 a local, national and international level. He may at some future date be required to use the knowledge of science for responsible social action.²⁰

Implied in the preamble to the General Course science program are many of the so-called intangible aspects of science. These include the understanding of the nature of scientific enquiry, of the function of science in our lives, of the nature of scientists as people. It includes the development of citizens who at some future date will make use of their knowledge of science for responsible

²⁰General Course Science Committee, op. cit., p. 2.

social action. Such understandings today are important as our nation and our world are increasingly affected by the results of scientific activity, and as we tend to attract young people into scientific careers.

The committee which developed the General Course expressed the point of view that it was not the purpose of the General Course science program to attract young people into scientific careers. It was thought that these young people, by completing the science program of the General Course, would be able to enter the technological fields that are so closely associated with and dependent upon the developments of science. The committee, expressing its views at in-service meetings, took the position that topics relating to cosmetics, home decoration and gardening were areas with which high school students might be expected to have some contact. It was reasoned that students would use most of the products developed in these areas in their adult life and would be subjected to the usual sales promotion related to articles from these three fields. The position taken by the committee seems to be the introduction of consumer education as related to cosmetics, paints and garden products.

As subsequent analysis shows, the level of student interest in these topics is not high. The inclusion of broader and more fundamental problems in science, for example a consideration of problems associated with a high population growth, of food supplies, of genetic defects in

populations, of energy utilization, and of water and power consumption might be more useful and meaningful to the students enrolled in the General Course.

The rationale for the General Course Science program might be found in the statement of the National Science Teachers Association on curriculum development. It states:

While science is an intellectual quest for understanding of natural phenomena, technology is a practical effort to use and control these phenomena. Technology yields the tangible products of science. All three aspects of the scientific enterprise must be a part of the science curriculum:

- a) Descriptive science or natural history, because it provides the basis for scientific enquiry and plays so prominent a role in a child's environmental experience;
- b) Science proper, because of its intellectual challenge, which should be a primary goal of scientific education;
- c) Technology, because it serves so well to illustrate the practical applications of scientific principles and because of its impact on modern society.²¹

How does this course fare when analyzed under the criteria set forth by Brandwein? First, the course, particularly the text, tends to be authoritarian. There are no alternative models in atomic structure, although the development of atomic models is shown. Secondly, the content of the course is organized to emphasize technology. While the course is not one of technology, nearly every scientific principle is followed by an illustration of where the

²¹National Science Teachers Curriculum Committee, Theory into Action in Science Curriculum Development (Washington, D.C.: National Science Teachers' Association, 1964), p. 42.

principle is used in the environment of the student. Thirdly, because of the format of the text, with the inclusion of laboratory exercises in a separate manual, it might seem that the laboratory work is divorced from the content or text material. A closer examination of suggested time allocations shows that a serious attempt is made to tie in laboratory experiences with the content. However, the laboratory work is pre-determined so that the pupil's questions and the course problem are not necessarily the same. The course then tends to be one of problem-doing instead of problem-solving. Fourthly, from watching student teachers instructing students enrolled in the general course, the writer is convinced that there is still too much telling and insufficient pupil involvement in the course. Fifthly, the course does not become one of the history of science solely but uses the events of science to broaden a pupil's outlook on the role of science. An analysis of the program as reported in Chapter V suggests several areas of deficiencies in the program.

Summary

An examination of the science courses taught at the tenth grade in Manitoba secondary schools reveals three science courses. The first of these courses is characterized by an emphasis on technology in which the technology used is

dated. The second of the programs uses an investigatory approach based on pure science (chemical and physical laws) that, by the emphasis on pure science, might be better suited to the above average ability student in the school either by selection or by election. The third of these courses is a general course in physical science which attempts to blend the investigatory aspects with a directed slant, and with attention to the technological aspects of science. A comparative assessment of these programs is the purpose of this study.

CHAPTER IV

THE PROCEDURE OF EVALUATION

The General Course science program for grade ten students was developed and authorized for use in Manitoba schools in the 1962-63 school year. At that time, twenty-nine classes in twenty-five secondary schools began the General Course. The total number of students involved in the new General Course was 767. The total grade ten population in Manitoba schools was then approximately 15,000. In the following school year, 1963-64, forty-six classes in thirty-seven schools were enrolled in the General Course and were taking the science program of that course. In 1964-65, the school year which is the concern of this study, eighty-three classes in sixty-nine schools were taking the General Course program.

The enrollment of students in the General Course is shown in Table 1.

An examination of Table 1 shows that there has been a steady increase in the number of students enrolled in the General Course over a three year period. However, it is evident that there has been a low retaining power in the program, for there are only 396 students in grade twelve of the

767 students who began the course in grade ten. This is an attrition rate of nearly fifty percent. The attrition might have resulted from students dropping the course as it was too difficult, or from students leaving school directly for employment. It might even have been the result of principals and counsellors enrolling students in the General Course whose academic record indicated that they were terminal students rather than average pupils capable of taking the General Course.

Table 1. Student enrollment in the General Course.

Grade	Number of Students Enrolled		
	1962-63	1963-64	1964-65
Ten	767	1205	2271
Eleven		620	946
Twelve			396

Two school inspectors, Mr. Lee and Mr. Mackay, were assigned by the Department of Education to visit those schools offering the General Course, to give assistance, to make suggestions with regard to instructional techniques in the various subjects, and in general to assess subjectively the progress of students in the course. They reported, in general terms, upon the acceptance of the new programs developed in all subject areas, including science, for secondary schools of Manitoba.

On the Manitoba scene several points should be noted. In a province with approximately one million population, half the population is to be found in Metropolitan Winnipeg. Even more noticeable is the fact that sixty per cent of the school population is to be found in this area. Of the 211 secondary schools in Manitoba, enrolling students in grades nine to twelve in some cases and in grades ten to twelve in others, 129 schools were six rooms or smaller. Only eighty-two schools in the province had seven or more rooms. It was estimated that a school of eleven rooms was needed to be able to offer both the General Course program and the University Entrance program. There are only fifty-one such schools in the Province of Manitoba.

In selecting the schools for this study, the original inspectors and their subsequent replacements suggested schools which were typical of those they visited, and which presented a cross section of the larger secondary schools of Manitoba. The smallest school in the sample enrolled 135 students while the largest school enrolled 1363 students in the 1964-65 school year. Four schools in the sample selected were from Metropolitan Winnipeg, two schools were from Brandon, the second largest city and the remainder were selected from rural Manitoba. All schools in the study had nine rooms or more.

The principals of the twenty schools selected for testing were contacted by letter asking for their cooperation

in conducting the study by assisting in carrying out the testing necessary for the evaluation of the General Course science program. Without exception, all principals agreed to cooperate. Subsequently two schools withdrew from the testing.

Teachers of the General Course science provided the writer with the names of the students enrolled in the General Course science classes. In many cases the teachers were able to provide additional information about students, such as indicating the students were repeating the course or repeating a grade. Once a list of students taking the program under investigation had been compiled, the writer obtained from the Registrar's Office of the Department of Education the results of a mental ability test written by the selected students in grade nine in June, 1964. The results of the grade nine science achievement test was also recorded. This test was an externally set, externally marked examination written by all ninth grade students in the province.

Once tabulation was completed on General Course students, all students enrolled in other science courses in the selected schools were assigned a number. By means of random numbers a sample was selected from each school to form the control group. The only criterion for selection in this group was that a student be currently enrolled in the tenth grade and not be a repeater due to failure in grade ten the previous year. This precaution was necessary to insure that



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students had written the same form of the mental abilities test and thus make it possible to compare the test results. When a student had been selected by this procedure, the results of his grade nine science achievement test were recorded as was his score on the mental ability test, the Otis Gamma Test, form Am.

Thus, in setting the experimental design for the study, the writer had access to pre-test scores of mental ability and of science achievement for groups of students. Since all students in the study had written, at the end of grade nine, the same achievement test administered under Department of Education regulations, set by a committee of examiners appointed by the Department of Education and scored in committee by teachers who had taught the course, it would seem that uniformity of grading student responses to the science test prevailed.

The present study measured student achievement (among other things) after an experimental and a control group of students had followed different courses of instruction in science at the tenth grade level of secondary schooling during the school year 1964-65. It was the original plan of the study to determine how well the General Course science program functioned in comparison with the traditional science program. As the study proceeded, however, it was noted that three different courses were being followed in Manitoba secondary schools: the experimental or

General Course program; the traditional program using Every-day Problems in Science by Beauchamp, Mayfield and West; and the combined PSSC-CHEMS program described in the previous chapter.

How does one equate pupil achievement in a discipline where three different sets of aims, objectives and content are to be found? Ferris¹ notes, in this connection, that the ACS Chemistry Test, however well constructed it might be, is inadequate for evaluating such new courses as CBA of CHEMS because the items of the test do not cover the objectives of the newer courses.

The same point of view is stated by Cronbach as:

Too often test questions on standard tests are course-specific, stated in such a way that only the person who has been specifically taught to understand what is being asked for can answer the question . . . To appraise understanding of processes and relations, the fair question is one comprehensible to the pupil who has not taken the course. This is not to say that he should know the answer but that he should understand what is being asked. Such course-independent questions can be used as standard instruments to investigate any instructional program.²

Reference has been made in the three science programs to objectives for students taking science courses. One of the goals is the attainment of realistic understanding

¹Frederick J. Ferris, Jr., "Testing in the New Curriculum: Numerology, Tyranny or Common Sense?" School Review, 70:114 (1962).

²Lee J. Cronbach, "Evaluation for Course Improvement," New Curricula (New York: Harper and Row, 1964), pp. 245-46.

about the function of scientists and the role of science in a society. This is illustrated by:

Such understandings have frequently been referred to as "appreciations" or "intangibles" and include understanding by students of science as an institution, of scientists as people, of the aims of science and of the processes of science. In the present stage of our technological civilization where science, through its applications and orientation, is making an even more profound impact on our national and world society, there can be little doubt that the possession of realistic understanding of science and scientists by students and citizens is essential.³

The criterion test used by Klopfer and Cooley in their investigation on the HOSC Instruction Project was entitled Test On Understanding Science. Their report showed that the Otis Quick Scoring Mental Ability Test, Gamma form Am, had been used to measure student scholastic aptitude. It turned out that the Otis test was also used as a measure of mental ability in June 1964 at the ninth grade level with all students in Manitoba schools. The criterion test, abbreviated TOUS, was investigated further and the following 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,

³Leopold R. Klopfer and William W. Cooley, "The History of Science Cases for High Schools in the Development of Student Understanding of Science and Scientists," Journal of Research in Science Teaching, 1:33 (1963).

the selection or design of testing instruments which will evaluate those specific objectives.⁴

The manual of the TOUS instrument contained the following comment which was both appropriate and applicable to the evaluation needed for the study in Manitoba schools:

For many years, science educators have acknowledged the importance of teaching and learning 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 as we seek to attract young people into scientific career fields. However, while a large variety of tests have been prepared to measure student achievement in the facts and principles of science, no adequate instrument has yet been constructed to assess the extent which the important instructional outcomes of understanding science and scientists has been achieved. Numerous studies of science curriculum methods assert that a particular technique or procedure has contributed to these understandings in the students, but, in the absence of a valid instrument, such judgements cannot be made objectively to any extent.⁵

A factor supporting the selection this test is reinforced by the following statement made by the authors:

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

⁴William W. Cooley and Leopold M. Klopfer, "The Evaluation of Specific Educational Innovations," Journal of Research in Science Teaching, 1:73 (1963).

⁵William W. Cooley and Leo E. Klopfer, Manual for Administering, Scoring and Interpreting Scores on Test On Understanding Science, Form W (Princeton: Educational Testing Service, 1961), p. 1.

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.⁶

The TOUS instrument was developed around three major themes: understanding about the scientific enterprise; understanding about scientists; and understanding about the methods and aims of science. Table 2 shows the areas and topics covered by the test items.

An examination of the table indicates that some of the intangible objectives in teaching science have been set forth and might be considered as measurable items. It was felt that this instrument would be suitable for evaluating different curricula in science to determine whether these objectives of science teaching were being met. Moreover, a detailed item analysis of the responses to the above items might give some indication of areas of science teaching requiring attention or new emphasis.

The overall effect of evaluation is described by Woodring:

Before it is fully accepted and becomes the standard or most prevalent pattern any new curriculum should be carefully evaluated against the ultimate criterion--its long range effect upon the children who study it. Such an evaluation takes time because it is not enough to know how the curriculum affects the immediate test scores, we need to know how it influences the child's later

⁶Ibid., p. 9.

success in college and in his career and also his adult outlook on life.⁷

Table 2. Major themes measured by TOUS^a

AREA I

Understanding About the Scientific Enterprise

1. Human element in science
2. Communication among scientists
3. Scientific societies
4. Instruments
5. Money
6. International character of science
7. Interaction of society and science

AREA II

Understanding About Scientists

1. Generalizations about scientists as people
2. Institutional pressures on scientists
3. Abilities needed by scientists

AREA III

Understanding About the Methods and Aims of Science

1. Generalizations about scientific methods
 2. Tactics and strategy of sciencing
 3. Theories and models
 4. Aims of science
 5. Accumulation and falsification
 6. Controversies in science
 7. Science and technology
 8. Unity and interdependence of the sciences
-

^aCooley and Klopfer, op. cit., p. 74.

It is noted that the student taking the General Course science program will not necessarily be taking

⁷Paul Woodring, "Introduction," New Curricula, Robert W. Heath, editor (New York: Harper and Row, 1964), p. 7.

advanced studies in science through university courses. Thus it is not possible to follow the student's success in meeting the demands of industry by using currently available tests. It is not the purpose of this study to examine the attainment and success of students over a long period of time. Students beginning the General Course in 1962-63, the first year of the course, graduated from grade twelve in 1964-65, the year of the investigation. Thus, it becomes necessary to examine the scores on such test instruments as the TOUS instrument to determine the level of achievement in some of the tangible areas of science.

Woodring notes that the examination of test scores alone is insufficient in the evaluation of new curricula. Ultimately, value judgments must be made upon the success of courses as determined by the objectives of the courses. This is noted by:

The collection of test scores and other statistics is not evaluation, but only the first step toward evaluation. Evaluation is not complete until someone has made value judgments which are based upon the empirical data but which interpret the evidence and draw conclusions from it in relation to a clearly stated philosophy of the proper goals of education. Such an evaluation will be made the more difficult by the fact that the older curricula now being replaced have rarely been adequately evaluated on a national basis in terms of such goals and, hence, comparison will be made difficult.⁸

The TOUS instrument was thought to be a suitable device which would serve to measure some of the stated but

⁸Ibid., p. 7.

intangible objectives of science instruction for three different science courses. Norms were available for the tenth grade level, the area of interest of this study. The authors of the test indicated that the mean score of the tenth grade students on the TOUS instrument was 28.58 with a standard deviation of 7.66 based on a sample of 1064 students. As well, the test correlated well with mental ability scores with reported product moment correlation of 0.69 between mean scores on TOUS and the Otis mental ability test.

Development of the SATS Scale

In attempting to determine how a student feels about a course of study, one is brought into the frame of reference of those instruments which attempt to measure attitudes or belief about a situation. How an individual feels or what he believes may be considered as his attitude. As Best points out:

. . . it is difficult, if not impossible, to describe and measure attitude. The researcher must depend upon what the individual says as to his beliefs and feelings. This is the area of opinion. Through the use of questions, or by getting an individual's expressed reaction to statements, a sample of his opinion is obtained. From this statement of opinion may be inferred or estimated his attitude--what he really believes.⁹

⁹ John W. Best, Research in Education (Englewood Cliffs: Prentice-Hall, Inc., 1959), p. 155.

It is obvious that there are limitations to the type of instrument which purports to measure attitude or belief about a situation. Best notes these limitations by:

An individual may conceal his real attitude and express socially acceptable opinions. An individual may not really know how he feels about a social issue. He may never have given the idea serious consideration. An individual may be unable to know his attitude about a situation in the abstract. Until confronted with a real situation, he may be unable to predict his reaction or behavior.¹⁰

While it is noted that there is no sure method of describing and measuring, the description and measurement of opinion in many instances may be closely related to the real feeling or attitude of an individual. Of the several methods of gathering data by means of eliciting the expression of opinion, the writer fixed upon the technique of asking the individual to check a statement indicating a degree of agreement, or disagreement, with the statement. This became a measure of opinion. It is possible to ask an individual directly how he feels about a topic and obtain a free response to such a question. However, the analysis of a number of cases under such a situation is beyond the scope or resources of this study. The system used in this study is referred to by Best¹¹ as the Likert method of summated ratings. In the Likert method of investigating attitudes toward a subject, the investigation can, unlike the

¹⁰Ibid., p. 156.

¹¹Ibid., p. 157.

Thurstone technique, be carried on without a panel of judges.

As Best notes:

The first step in constructing a Likert type scale consists of collecting a number of statements about a subject. The correctness of the statement is not important. If they express opinions held by a substantial number of people, they may be used. It is important that they define favorableness or unfavorableness to a particular point of view.

After the statements have been gathered, a trial test should be administered to a number of subjects. Only those items that correlate with the total test should be retained. This helps to eliminate statements that are ambiguous or that are not of the same type as the rest of the scale.¹²

The technique used in the development of the Student Attitude Toward Science instrument was that recommended by Best. A number of statements that had bearing upon the course of study in science were made. These were edited, revised and categorized into six somewhat distinct, but sometimes overlapping, categories. In general, one set of statements purported to obtain a reaction from students on how they viewed the text used in the course they were studying. An examination of the instrument, included as Appendix A shows that thirteen of seventy-two statements were made concerning the text material of the science courses at the tenth grade level. These statements were made concerning the reading level of the text, the inclusion of practice questions, and the adequacy and pertinancy of explanations. Some statements were included which were contradictory to statements in the same section. For example statement fifty-one--"The

¹²Ibid., p. 157.

problems at the end of the chapter are useful and beneficial to me. They help me understand the course," is contradictory to statement fifty-seven--"I think the exercises in the text serve no useful purpose and are merely busy work." In scoring these statements, a pupil who scored both statements in a strongly agree category would end with a neutral response as one value would tend to cancel the other. This technique served to determine if students were consistent in responding to statements in the instrument and to bring to a neutral position the value assigned to the differing responses.

In a similar manner, twelve statements were made about the content of the course of study. Attempts were made to include statements on the recency or newness of the content, the importance of including a topic in the course, the use of open-ended versus directed experiments, the difficulty of the course, the usefulness of the course in requiring a student to think as he imagines a scientist works, and the length of the course. The statements made in the area of content are reproduced in the Appendix.

The third section of the SATS instrument dealt with students' interest in the course they were taking. In all, fourteen statements were made to determine student interest in the science course. Statements included were concerned with student reaction to teacher demonstration of scientific concepts, to the inclusion of display material in the

classroom, to the use of apparatus and materials which had appeal to the student, to his interest in pursuing a similar course of study the following year, to the amount of time he devoted to science as a measure of interest, to his reading of science oriented and related articles, to the carrying out of extra investigations or extra projects, to a general statement of his interest in school studies, and to the extent to which he thought he noticed the application of scientific principles around him.

The fourth area of investigation with the SATS instrument was termed "student needs." The seventeen statements in this category were concerned with how useful the student felt the course was to his goal in life or to his aspirations. The instrument provided for reaction to statements about the importance of the study of science, the usefulness of the course in developing an understanding of other courses, the extent to which the course satisfied the felt needs of the student, the involvement of the student in the selection of course content, the extent to which the course helped in the development of the ability to read popular science articles, the involvement of the student in experimental or laboratory work and the perceived usefulness of the science course, now and in the future. These statements became part of the SATS device and were recorded under the heading Student Needs.

The fifth area of investigation pertained to laboratory work. The more recent secondary science programs such as PSSC, CHEMS and BSCS were designed to be laboratory oriented. It would seem that an investigation into student belief about the function of laboratory work would be revealing. Just what is student opinion with regard to the experiments they have performed during the past year of study in science? It was realized that many students had no experience with laboratory exercises. In order to obtain consistent response, students were advised in the manual of instructions developed for the SATS instrument to score column three or section C of their answer sheet if they wished to indicate a neutral position or "cannot say" position. Thus eleven statements were made in the general topic of laboratory work. These statements asked students to express an opinion about the length of the laboratory experiment, the availability of laboratory equipment, the investigative nature of the experiment, for example, "I know the result of an experiment before I performed it in the laboratory," the method of reporting laboratory work, the timing or coincidence of experimental and theoretical work, the importance of understanding laboratory techniques, the involvement of the individual in laboratory investigations, the usefulness of open-ended experiments as perceived by the student, the adequacy of directions in laboratory manuals, and the usefulness of such instructions.

The sixth and final area of investigation as carried out with the **SATS** instrument was termed "student involvement." In observing student-teachers developing science concepts with secondary school students, it has been the writer's observation that there seems to be a greater degree of permanency in learning if high school students are involved and participate in class discussion as contrasted to a teaching situation in which the students are passive recipients of a lecture. Hence five statements were developed to obtain a student opinion of the amount of involvement as afforded by laboratory investigations, the presentation of demonstrations of scientific principles, and the development of simple apparatus to carry out investigations.

Best¹³ notes that the Likert method of summated ratings scale may be analyzed in several ways:

A simple way to describe but not to measure opinion is to indicate the percentage of responses on each item. Three of four teachers agree; 80 per cent of male teachers agree with the statement.

The actual Likert scaling techniques assigns each position a scale value. Starting with a point of view all statements favoring this position would be scored:

Statements	Scale Value
a. Agree	5
b. Tend to agree	4
c. Cannot say	3
d. Tend to disagree	2
e. Disagree	1

¹³Ibid., pp. 158-159.

The writer made seventy-five statements in a form similar to the one shown in Appendix A and asked students to respond on the basis of the following scale values.

Statements	Scale Value
a. Strongly agree	5
b. Agree	4
c. Neutral	3
d. Disagree	2
e. Strongly disagree	1

The responses were recorded on IBM form ITS 1100 A167.

It should be noted that certain statements were made in the negative form. This was done so that the students would not automatically check all items on one side of the scale or on the other. Thus the scoring of the instrument was done on the basis of a five point scale which gave three a neutral value, five indicated a strongly positive reaction to the statement while the value one indicated a strongly negative reaction to the statement.

The directions written for the SATS instrument indicate that the student was encouraged to respond as he believed he viewed the statement. It was thought that sufficient description had been given for the student to react to the statement.

A trial run of this investigation was scored on a percentage response for each of the five sections of each statement. The trial edition of the experimental SATS instrument was administered to twenty-five students taking a course of study in science described earlier in this study

as the General Course science program. In the same school there were twenty-six students who were taking the PSSC-CHEMS program. These students also responded to the items on the experimental instrument. The writer personally conducted this investigation with the students and had an opportunity to discuss with the students, upon completion of the test, their reaction to statements in the instrument. It was possible then to determine which statements in the original edition were ambiguous, which statements contained more than one position, and on which statements the students required clarification. On the basis of the trial edition a revised form, the one used in this study, was developed.

The original instrument was scored on an electronic scoring machine and an item analysis completed on the basis of the sample student response. From an examination of the preliminary edition, and from suggestions made by the teachers and students, the revised form was developed on the basis of seventy-two items. One of the reasons for the selection of seventy-two items is that that was the limit of items that could be machine scored with four passes per answer sheet.

It was found in the revised edition that the items could be scored manually with a key, a value from one to five assigned to each item in each of the six sub-sections and a total value for all items obtained at a reasonable rate. Table 3 indicates the maximum positive scores, the minimum

negative scores and total neutral scores for each of the six categories.

Table 3. Total score values of the SATS instrument.

Category	Strongly Positive	Neutral	Strongly Negative
1. Text	65	39	13
2. Course Content	60	36	12
3. Interest	70	42	14
4. Student Needs	85	51	17
5. Laboratory Work	55	33	11
6. Involvement	25	15	5
Totals	360	216	72

The most favorable response possible would have a total score of 360, while a score of 216 would indicate a total neutral position. A most unfavorable attitude would show a total score of seventy-two. The scores of each of the sub-tests of the SATS instrument are also shown in Table 3. It would seem that the instrument could be used to ascertain a student's opinion about certain aspects of the course of study in science that he was following.

Treatment of Results

In May, 1965, the Test On Understanding Science, Form W and the Student Attitude Toward Science instruments were mailed to all participating schools. The science teachers in the schools administered the tests and returned

the student papers for scoring. The student scores were tabulated, and recorded were information on the science program they were following, age, sex, science teacher, and each of the sub-test scores. Thus on each of 872 students in the study, information was available on: the age of the student, the course taken in grade ten science, the grade nine science score, the mental ability of the student as an Intelligence Quotient, the sex of the student, scores on each of the three sub-tests of the TOUS instrument as well as the total test score, the test scores on each of six sub-tests on the SATS instrument as well as the total SATS scores and an identification of the science teacher.

The information was recorded on tabulation sheets and transferred to punch cards for processing by a computer. The original plan was to subject each of the null hypotheses stated to a Chi-Square test or to a t-test to determine which of the hypotheses were significant at the five per cent level and the one per cent level. A consultation with a statistician on the computer staff indicated that the suggested procedure might not be a valid one. With over seventy null hypotheses generated to be handled by the computer, it follows that three or four of the hypotheses could be accepted when they should be rejected if one used the five per cent level of significance. If one hundred null hypotheses had been used, the five per cent level of significance would be interpreted to mean that five per cent of the time the

statement would be accepted by chance. Thus an analysis of covariance as suggested by Cooley and Lohnes¹⁴ was followed. Computer programs suggested by these writers were modified to suit the program for this study. A correlation matrix was computed for the total group, and for each of the three subgroups comprising this study on the basis of thirteen variables. The variables finally selected for examination were: grade nine science achievement scores, intelligence quotient, TOUS 1--the scientific enterprise scores, TOUS 2--the scientists, TOUS 3--the aims and methods of science, total score on the TOUS test, SATS 1--text materials, SATS 2--course content, SATS 3--interest, SATS 4--student needs, SATS 5--laboratory work, SATS 6--involvement, and total score on the SATS instrument.

The investigation of the test results of these three groups, those students taking the general course science program, those taking the PSSC-CHEMS science program and those taking the traditional science program, suggested that further analysis be conducted concerning a covariance. In this case, the two variables, grade nine science achievement scores and intelligence quotient, were statistically equated and analysis of the remaining eleven variables were computed for the three groups.

¹⁴William W. Cooley and Paul R. Lohnes, Multivariate Procedures for the Behavioral Sciences (New York: John Wiley and Sons, Inc., 1962).

In addition, a detailed item analysis was conducted on the TOUS instrument to examine student response to the individual items. The analysis was conducted on the basis of percentage correct response on each item making up the total test between two groups, the group taking the General Course science program and those taking the other courses, the control group. The results of these analyses are considered in Chapter V.

CHAPTER V

ANALYSIS OF DATA

It is the purpose of this chapter to examine (1) the results of student response on the three sub-scales of the Test On Understanding Science; (2) the means and standard deviations of the thirteen criteria variables used in the study; (3) the correlation coefficients for levels of significance between the same thirteen variables; (4) the results of the Wilks' lambda test of equality of population centroids; (5) the results of covariance adjustment of initial knowledge and mental ability on the remaining dependent variables; and finally (6) the order of best discrimination among the remaining variables to show the differences between the groups of students participating in the study.

Cooley and Lohnes note:

The first task in multivariate analysis is to accumulate the sums and sums of squares and cross products of scores for the sample group. This preliminary reduction of the data is always necessary, regardless of the type of multivariate analysis to follow. From these summations, the deviations sums-of-squares and cross-products matrix, the variance-covariance matrix, and the correlation matrix can be computed. One of these three matrices is then used in subsequent computation.¹

¹Cooley and Lohnes, op. cit., p. 17.

These calculations are not shown in this chapter as they are basic to the study and not the final consideration in the analysis. The correlation matrix is the matrix examined in this study.

Analysis of the TOUS Scale

The accompanying figures show the percentage correct responses of the pupils of the experimental group who were enrolled in the General Course science program and of the pupils of the control group, 349 of whom were taking the traditional science course and 65 of whom were taking the combined PSSC-CHEMS program. The percentage of correct responses of the groups is shown in the vertical axis, while the test item numbers on which the correct response was made is shown on the horizontal axis. The experimental group results are indicated by the broken line; the results of the control group are indicated by the solid line.

Figure 1 shows the percentage correct response made by all students on the eighteen items used to measure pupil achievement in the sub-test on Understanding About the Scientific Enterprise. The main feature of this figures is the consistent way in which both groups respond correctly to each of the test items. Only three items fall below a twenty per cent correct response level while eight of the items lie above a fifty per cent correct response level. Both groups seem to respond in a similar manner. While

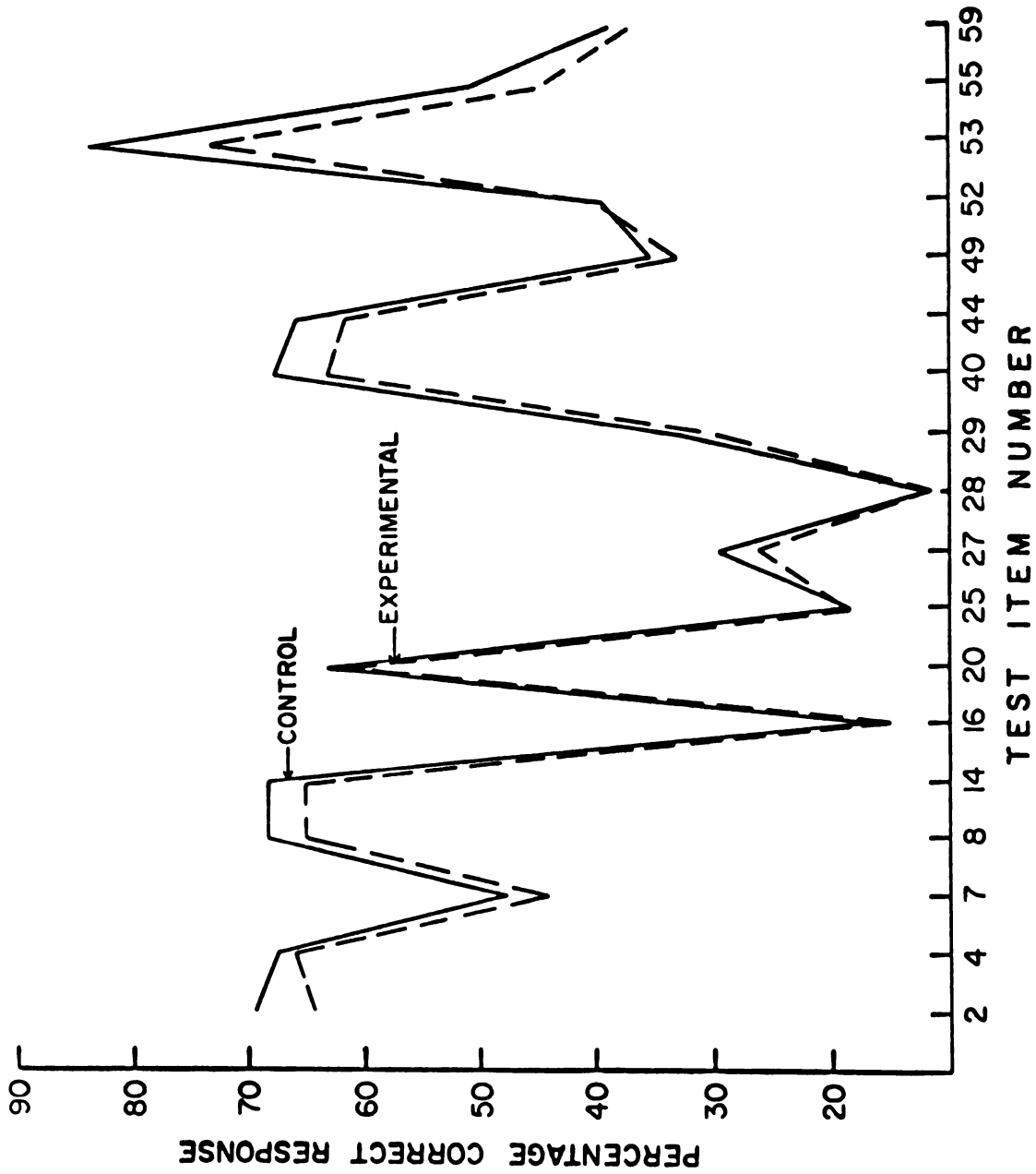


Figure 1. Percentage correct response on TOUS Scale I Understanding About the Scientific Enterprise by experimental and control groups.

there is a difference in the percentage correct response between the two groups on most items, there is a consistent pattern observed. The responses of the control group are above the responses of the experimental group, but both lines follow a similar response pattern. For example, all students respond well to the twentieth item on the test which was:

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 research²

On the other hand, all students had difficulty with item 28 which was:

Scientists co-operate on an international scale through all of the following activities EXCEPT

- A. setting the value of physical constants
- B. publishing scientific journals
- C. prescribing courses for the preparation of scientists
- D. advising United Nations agencies.³

It may be in the first example of the test item noted here that the answer is built into the question while

²W. W. Cooley and L. M. Klopfer, TOUS: Test on Understanding Science, Form W (Princeton: Educational Testing Service), unpagged.

³Ibid.

this is not the case in item 28. Neither item relies upon course work in any of the current courses in Manitoba schools, hence the differences in test response may arise from outside information, that is, information students gain through radio, television or films but not necessarily from school. To explain the difference between the two groups, one can speculate that the more intelligent the group, the more the members of the group are to be involved in additional reading and hence possess more information. It should be noted that there is a difference in the aptitude of these two groups of students as measured by mental ability scales. The mean I.Q. of the experimental group is reported as 101.3 with a standard deviation of 8.3, while the mean I.Q. of the control group is 108.9 with a standard deviation of 9.5. The mean I.Q. of the pooled group was 104.6 with a standard deviation of 9.5. One wonders whether the differences in correct response on test items arise from differences in mental ability or from other factors. The analysis of variance conducted later in this chapter indicates that with initial knowledge and mental ability variables adjusted, there is still a difference in the percentage correct total response on each of the sub-scales of TOUS.

Figure 2 shows the percentage correct response of students of the control and experimental groups on the second sub-scale of TOUS. The items of this sub-test pertain to a measurement of the Understanding About Scientists.

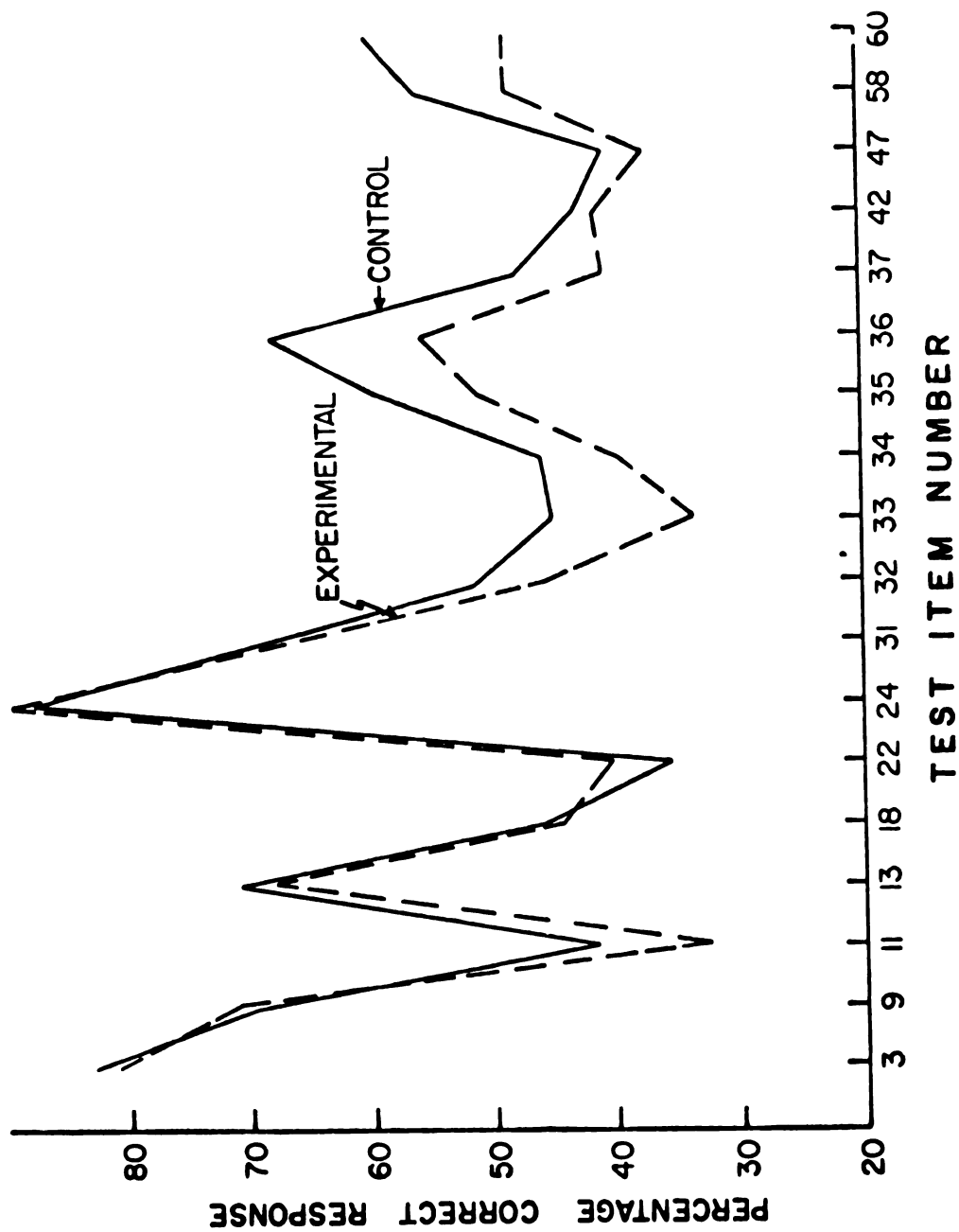


Figure 2. Percentage correct response on TOUS Scale II Understanding About Scientists by experimental and control groups.

There is little difference in the percentage correct response of the various items between the two groups until thirty-one to thirty-seven are considered. A separation occurs at this point. An examination of the items on the accompanying sheet indicates that these are a different form of multiple choice responses from what students in Manitoba schools have been accustomed to. It might be noted that the items take the form of a logical puzzle with four possibilities of answer.

At a later point in this study consideration is given to the determination of the best discriminator between the experimental and the control group. It turns out that TOUS 2, Understanding About Scientists is the best discriminator. The reason for this selection may lie in the difference in correct response which may in turn be related to mental ability. The selection occurs in spite of the statistical maneuvers to adjust the test results so as to remove or to minimize the effect of mental ability. It may be that the mental processes are so directly related to the correct response on these items that the influence cannot be removed.

Figure 3, on the following page, shows the percentage correct response of the experimental and control groups on those items designed to measure Understanding About the Methods and Aims of Science. Once again, graphical differences between these groups are represented by a broken line

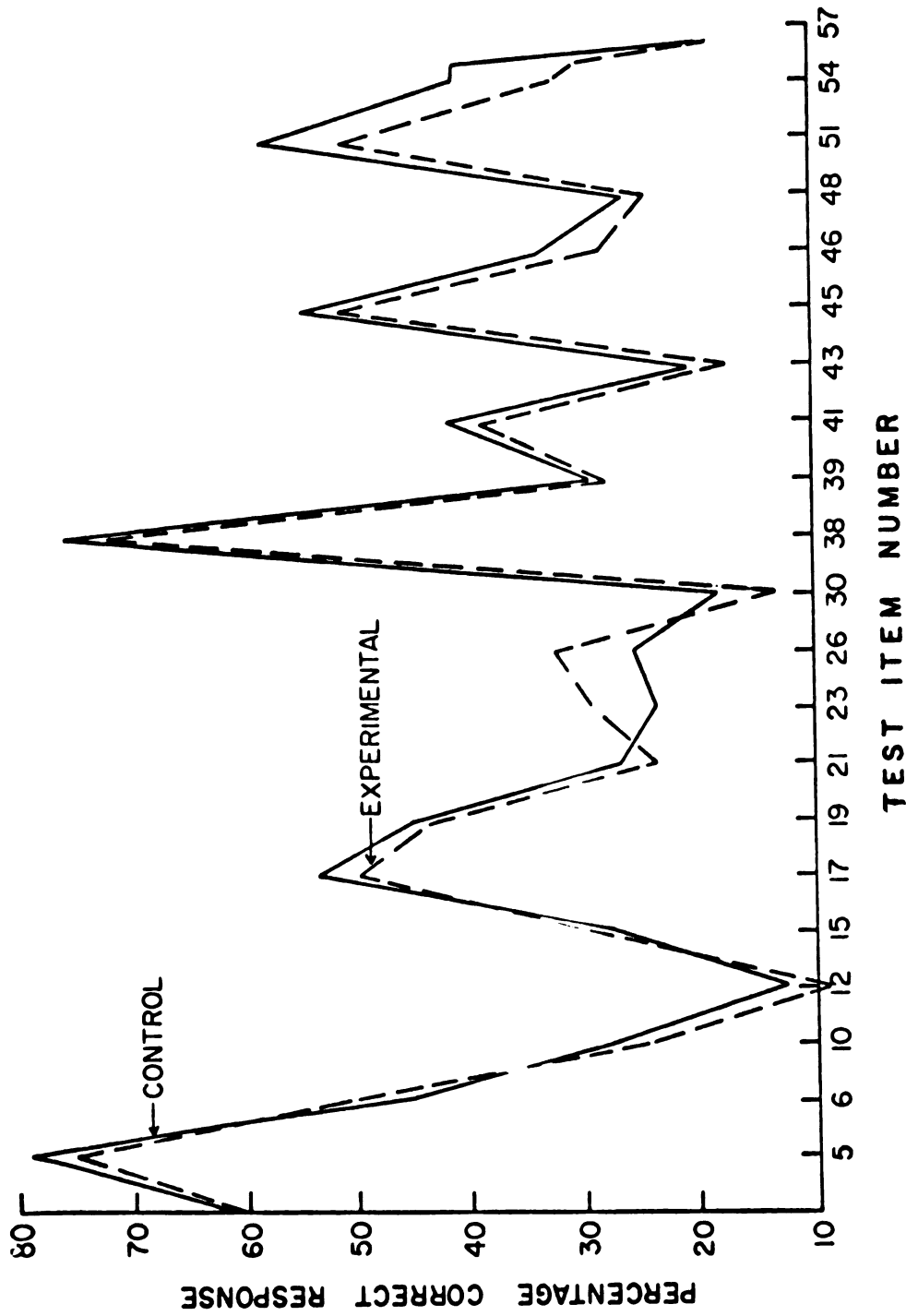


Figure 3. Percentage correct response on TOUS Scale III Understanding About the Methods and Aims of Science by experimental and control groups.

for the experimental group results and by a solid line for the control group results. In most cases, the control group scores higher than does the experimental group on the various items comprising this test. Once again one speculates that this difference may be due to a higher score on a mental ability test and a higher prior knowledge score by the control group. Covariance adjustment should minimize this difference if the correct response differential is due to either the ability of the student or to his prior knowledge.

Students of the experimental group scored higher on items twenty-three and twenty-six of this test than did the students of the control group. Item twenty-three was:

- 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 the technical ability.

While item twenty-six was:

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 up the subject in the library.⁴

⁴Ibid.

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.

There seems to be no reason for the difference in correct response to these two items. In general, both groups respond to the test items so similarly one wonders whether the course that the students are taking, the ability of the students or the fact that these are Manitoba students, has bearing on the response. The writer can offer no reasonable explanation of the difference in response to these items. This scale is the second best discriminator between the two groups after adjustment has been made for mental ability and prior knowledge.

Analysis of the Criteria Variables

Table 4 shows the mean scores and the standard deviation on thirteen variables of the student taking the General Course science program, the traditional science program and those taking the PSSC-CHEMS program in Manitoba schools. The variable listed in this table as I.Q. and interpreted to mean mental ability, shows a mean I.Q. of 105.4 with a standard deviation of 9.9 for the sample being considered in this study. The mean I.Q. of all grade nine students in Manitoba, based on 16,314 cases on the same test was 104.5 with a standard deviation of 10.85. While these values are less than one unit apart, there is a statistically significant difference on a t-test between the sample and the entire population now in the tenth grade in Manitoba schools. The discrepancy does not mean that there is a major difference

Table 4. Means and standard deviations of criteria variables in Grade X science courses.

VARIABLE	Total Group			General Course			PSSC-CHEMS			TRADITIONAL		
	Mean	Standard Deviation		Mean	Standard Deviation		Mean	Standard Deviation		Mean	Standard Deviation	
Pretest	65.1	14.1		59.0	11.8		76.4	10.8		71.1	13.5	
I.Q.	105.4	9.9		101.3	8.3		116.3	7.8		108.9	9.5	
TOUS 1	8.5	2.3		8.0	2.2		10.2	2.2		8.9	2.3	
TOUS 2	9.8	2.4		9.1	2.3		10.9	2.6		10.4	2.3	
TOUS 3	9.0	2.9		8.2	2.6		10.8	3.3		9.7	2.8	
TOUS	27.3	5.8		25.3	5.2		31.9	6.4		29.0	5.5	
SATS 1	44.2	9.5		45.3	9.9		46.9	8.9		42.3	8.6	
SATS 2	38.5	6.7		37.9	7.1		40.7	6.0		38.7	6.4	
SATS 3	41.0	6.2		40.8	6.2		43.6	5.6		40.7	6.2	
SATS 4	54.4	12.2		54.0	12.6		59.4	10.8		54.1	11.7	
SATS 5	38.6	4.9		39.0	4.7		41.2	4.4		37.5	4.8	
SATS 6	16.0	3.3		16.1	3.5		18.2	2.6		15.5	3.0	
SATS T	232.8	32.2		233.1	33.8		250.1	29.0		229.0	29.5	

between the sample population used in this study and the entire student population. The reader will recall that the study was limited to those students who were currently in grade ten and eliminated students who had failed their ninth grade. It might be assumed that students of lower mental ability would comprise a major portion of the failing group, and it would be expected that the mental ability of the group currently under investigation would have a slightly higher I.Q. than the entire group. Thus, it is thought that the sample of students composing this study were representative of the entire Manitoba student population as far as mental ability is concerned.

The pretest score used in Table 4 refers to the ninth grade science achievement scores. There are differences between the groups taking three different science courses. Those students taking the General Course science program have a much lower pretest or prior knowledge score than do either of the other two groups. In fact there is a marked difference, a mean value of 59.0 with a standard deviation of 11.8 in the score on prior knowledge of the general course group and values of 76.4 and 71.1 reported for the PSSC-CHEMS and the traditional groups respectively. The students taking the General Course program obviously enter the science course with much less knowledge and possibly less interest in science than students in the other two groups.

TOUS 1, TOUS 2 and TOUS 3 headings in Table 4 refer respectively to Understanding About the Scientific Enterprise, Understanding About Scientists and Understanding About the Methods and Aims of Science. The heading, TOUS, refers to the total score on the instrument. An examination of the four items in this table indicates that the order of achievement with the three different groups of students in PSSC-CHEMS, Traditional and General Course. This order turns out to be the same as that of the pretest scores or scores of prior knowledge. The tentative norms 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 1064 students. An examination of Table 4 shows a mean value of 27.3 with a standard deviation of 5.8 based on 872 students. While the mean score is slightly lower than the norms for this group, it is revealing to note that the general course students apparently contribute most to the lower values. Their mean score of 25.3 with a standard deviation of 5.2 is considerably lower than the value of 28.58. On the other hand, the mean score 31.9 with a standard deviation of 6.4 achieved by the PSSC-CHEMS group leads one to believe that the PSSC-CHEMS group are above average in their performance on the TOUS instrument.

The student in Manitoba schools taking the General Course science program achieves below the American norms for this grade level, while the student taking the traditional

course or taking the PSSC-CHEMS science course achieves above the American norms. This difference was not evident from a detailed analysis of the items of TOUS. Allowing for adjustment of prior knowledge and mental ability through the use of covariance techniques there is little change in the achievement of these students on the TOUS instrument.

The remaining variables considered in Table 4 refer to the scores obtained on the Student Attitude Toward Science instrument, referred to here as SATS. The first of the six sub-tests of this instrument is designed to obtain 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. There is an overall positive attitude shown to the texts by the three groups, although the scores are not strongly positive. The order of acceptance of text material by the groups in the study is PSSC-CHEMS, the General Course and the Traditional Course. This hierarchy may occur because the traditional course uses a text which is dated, in which the content relates to technological developments of the early 1940's rather than to present day, uses more technology than science and, in general, is held in low repute by Manitoba science teachers.

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. The order of content acceptance by the three groups of students is PSSC-CHEMS, Traditional and General Course. It should be noted that all three groups report a positive position on this scale. The relatively low position of the General Course student, indicated by a value of 37.9, might mean that the students taking the General Course are closer to employment than their counterparts, and therefore think that they require more practical science than is to be currently found in their course. The content of the combined PSSC-CHEMS course is laboratory oriented but it is also abstract, a pure science rather than a technology. It apparently satisfies some students, for a score of 40.7 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 reaction to statements about science courses. A neutral position would have a value of forty-two. An examination of this item in the table indicates an overall negative interest in science by the entire group. This value seems to be contributed about equally by the traditional group and by the General Course group. The value of 43.6 held by the PSSC-CHEMS group, while not highly positive, tends to offset the low values of the other two groups. It may be that the lack of interest in the science course is due to two different factors. The Traditional Course students may lack challenge

and hence lose interest. The General Course students may find that the material of the course is too difficult and that the subject matter is not appropriate and lose interest. On the other hand, the General Course student may not be sufficiently involved in the course, taught along traditional lecture techniques, to become interested. Any number of reasons might be sought as to why students are not interested in the science course. It seems evident that they are not, in their own opinion, interested in the science course they are following. This fact is of considerable importance to curriculum workers and to science educators for it points out a need for further examination of these science programs.

SATS 4 refers to those statements pertaining to students' needs in science. A value of fifty-one indicates a neutral position on this scale. The students taking the Traditional Course and those taking the General Course score about equally on this scale with a positive value about the course satisfying their needs. It may be that they are not fully aware of their needs in science as these data do not coincide with their lack of interest in the course. It might be possible for a course to satisfy their needs and still not be of interest to them, but it would seem improbable. It may be that students in answering these questions do not wish to stray far from conforming answers. It is interesting to note that the students taking PSSC-CHEMS

are positive in the viewpoint that the course material satisfies their needs.

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. There is a slight reversal in order on this scale. The PSSC-CHEMS group still score the highest but now the traditional group, in spite of their higher prior knowledge and greater mental ability score below the General Course group. The reversal may arise because there is more laboratory work, requiring more student participation, in the General Course than there is in the Traditional Course. The combined PSSC-CHEMS course, on the other hand, is laboratory oriented. A student would find it impossible to complete the PSSC-CHEMS course without becoming involved in laboratory work. The laboratory work is at times referred to as non-directive or with a minimum of directions. The General Course, on the other hand, still uses an investigation carried out by a student as an intern or an apprentice, with a great deal of direction and much suggestion. It is not open-ended; it may not even be experimental as considered by a purist. It should, however, involve the student.

The final item under the variable column in Table 4 is termed **SATS 6**. This scale was developed to determine the extent of involvement of students in their science

courses. A value of fifteen would indicate a neutral position. A value of 18.2 for the PSSC-CHEMS group indicates that, for many reasons, the group is involved in their science program. The extent of their involvement may be related to their interest in the course. On the other hand, the students following the Traditional Course indicate by their scores that they are little involved in the program. Their mean scores of 15.5 indicate only a very slightly positive position. The General Course student indicates a positive position with a mean score of sixteen on this section of the measuring instrument. Thus the order of student involvement as shown by the three groups is PSSC-CHEMS, the General Course group, and the Traditional course group.

The SATS instrument indicates that the PSSC-CHEMS programs are more acceptable to the students than are the general or the traditional. The General Course seems to have more laboratory work than does the traditional course, and seems to provide a more satisfying experience with textbook or text materials than does the traditional course.

The lack of interest exhibited by both groups, the Traditional and the General Course, suggests strongly that modifications should be made in both courses to arouse student interest and to satisfy student needs. One wonders from the evidence whether the brighter students, those taking the PSSC-CHEMS course, are satisfied because of the challenge of the course or whether their relative success

with science in the previous grade has helped to keep their attitudes positive as shown by the scores on the SATS instrument.

The study subsequently led to an adjustment of SATS and TOUS scores on the basis of prior knowledge and on mental ability to see whether there were still differences between the groups. The findings are reported later in this chapter in Tables 10 and 11.

Analysis of the Correlation Coefficients

Table 5 gives the intercorrelations of the thirteen variables used in the study for the total sample population. Only the upper triangle of the matrix is shown, as the matrix is symmetrical. The correlation coefficients, the "r's," for one variable relating to the others can be found by reading down the column of that variable until the last element in that column is reached, then reading from there across to the row just below the element. In this table, the results of the total sample population are considered. For those correlation coefficients greater than .09 the correlations are considered significant at the five per cent level of significance, while for coefficients greater than .12, the correlations are considered significant at the one per cent level.

The product-moment correlations reported in the manual of TOUS indicate a value of 0.69 between I.Q. and

Table 5. Correlation coefficients for thirteen variables in the total sample.

	I. Q.	TOUS 1	TOUS 2	TOUS 3	TOUS Total	SATS 1 (text)	SATS 2 (content)	SATS 3 (interest)	SATS 4 (needs)	SATS 5 (lab.)	SATS 6 (invol.)	SATS Total
Pretest	.498*	.291*	.323*	.370*	.429*	.008	.196*	.106*	.164*	-.001	.038	.128*
I. Q.		.368*	.387*	.381*	.495*	-.113*	.100*	-.058	-.011	-.098	.004	-.040
TOUS 1			.432*	.383*	.766*	-.010	.063	.046	.053	.026	.033	.048
TOUS 2				.338*	.747*	-.044	.100	-.003	.032	-.025	.053	.023
TOUS 3					.780*	.032	.153	.043	.117*	-.019	.004	.092*
TOUS Total						-.005	.144*	.037	.092*	-.005	.038	.075
SATS 1							.560*	.447*	.673*	.383*	.411*	.853*
SATS 2								.277*	.478*	.250*	.178*	.666*
SATS 3									.622*	.219*	.490*	.704*
SATS 4										.241*	.491*	.883*
SATS 5											.227*	.474*
SATS 6												.574*

N = 872

** indicates $r > .12$, $p < .01$ * indicates $r > .09$, $p < .05$

TOUS total score. This study shows a value of 0.495 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 one per cent 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 sub-tests of the SATS instrument. A correlation coefficient of .100, significant at the five per cent level is reported between TOUS 2, Understanding About Scientists and SATS 2, the Content of the Course. An "r" of .117, significant at the five per cent level, is found between SATS 4, How Students Feel the Course Meets Their Needs, and TOUS 3, Understanding About the Methods and Aims of Science.

An analysis of the Table 5 shows further that both instruments have a high correlation between the sub-tests and the total test. Values in excess of 0.7 are shown for the TOUS instrument, which indicates a highly significant relationship while values from .47 to .85 indicate a high correlation between the sub-tests of the SATS instrument. The lower correlation coefficient of SATS 5 Laboratory Work, with the total SATS test, a value of .474, might be due to a low response by one group, the traditional group, to this test. It is interesting to note that the SATS 5, statements pertaining to laboratory work, while having a significant

correlation with other **SATS** tests, has the lowest correlation values. It is not clear to the writer whether the low correlation is due to a lack of laboratory work in the schools, or to a lack of student perception of the value of laboratory work. From the nature of the statements used in **SATS 5**, it is thought that the lower scores are contributed by students who have done no laboratory work. It is known that the **PSSC-CHEMS** course is laboratory oriented, and it is recommended that the General Course science program follow a series of laboratory investigations. On the other hand, the writer is aware that there are many grade ten science classes in Manitoba schools following the traditional science program in which students have had no opportunity to carry out experiments.

Table 6 shows the correlation coefficients for the variables used in the study of students taking the General Course science program. Some changes are noted between this table and the Table 5 which showed the same relationships for the total sample. The test of prior knowledge has a positive correlation with all the variables examined. It will be recalled that these students had a low pretest score. One interpretation of the positive correlation of the test of prior knowledge to the other variables is that the better students perform on the prior knowledge test, the better they respond to the remaining variables.

Table 6. Correlation coefficients for thirteen variables in the General Course.

	I.Q.	TOUS 1	TOUS 2	TOUS 3	TOUS Total	SATS 1 (text)	SATS 2 (content)	SATS 3 (interest)	SATS 4 (needs)	SATS 5 (lab.)	SATS 6 (invol.)	SATS Total
Pretest	.236*	.133*	.173*	.185*	.225*	.183*	.218*	.154*	.251*	.100*	.093	.241*
I.Q.		.237*	.260*	.194*	.312*	-.046	.076	-.075	.007	-.064	.035	-.017
TOUS 1			.358*	.308*	.734*	-.003	.024	-.016	-.008	.008	.020	-.002
TOUS 2				.263*	.723*	.023	.123*	0.000	.047	.008	.089	.059
TOUS 3					.740*	.125*	.180*	.033	.155*	.039	.044	.148*
TOUS Total						.073	.156*	.005	.098	.026	.072	.101*
SATS 1							.609*	.517*	.736*	.327*	.411*	.880*
SATS 2								.313*	.530*	.201*	.188*	.690*
SATS 3									.659*	.172*	.495*	.725*
SATS 4										.246*	.519*	.911*
SATS 5											.197*	.422*
SATS 6												.579*

$N = 458$
 $\begin{bmatrix} ** & r > .10 & p < .05 \\ * & r > .13 & p < .01 \end{bmatrix}$

Once again, little significant relationship is found between the TOUS sub-tests and the SATS sub-tests. An examination of Table 6 does show a higher correlation for the General Course group between the sub-tests of the two instruments than for the total sample. A correlation significant at the one per cent level is found between TOUS 3, the Methods and Aims of Science, and each of SATS 2, Course Content, and SATS 4, Student Needs. Correlations significant at the five per cent level are noted in this group between TOUS 3, the Methods and Aims of Science and SATS 1, Text. Significant correlations at the five per cent level are also noted between TOUS 2, Understanding About Scientists and SATS 2, Course Content. One interpretation of these correlations is that the content of the course, the needs of the students and the text material are oriented toward the objectives being measured by TOUS instrument.

It should be noted that there is a very high correlation of .911 between SATS 4 Satisfying Student Needs and the total score. This fact may be interpreted as an indication that students realize that their needs are being met, as they see them, but that they still are not particularly involved in the course, hence are not particularly interested in the course. A further interpretation may be that the course is being taught in an authoritarian manner in which the students are required to complete the course even if they are not interested in the work.

It should also be noted that there is a negative correlation, although not a significant one, between I.Q. and all the sub-tests of SATS with the exception of the statements associated with course content. One possible interpretation of the negative relationship is that the brighter students are not satisfied with the course. They have a negative attitude toward the text, are low in interest in the course and find the laboratory work unrewarding. However, such an interpretation must be treated with caution as the negative correlations show only a trend and cannot be considered statistically significant.

The relationships noted between the pretest or prior knowledge instrument and each of the sub-tests on TOUS and SATS would seem to indicate that some attitudes are being laid in the previous grades as well as some understanding of the role of the scientist, the nature of the scientific enterprise and the methods and aims of science. Not all the development of an understanding of the role of science in society is developed at any one grade level.

Table 7 shows the correlation coefficients for the same thirteen variables for the students taking the traditional course in science. The sample size is 349 for this group so that a correlation coefficient of .11 or greater is required for a significant correlation at the five per cent level and a correlation coefficient of .15 or greater is required for a significant correlation at the one per cent level.

Table 7. Correlation coefficients for thirteen variables in the Traditional Course.

	I. Q.	TOUS 1	TOUS 2	TOUS 3	TOUS Total	SATS 1 (text)	SATS 2 (content)	SATS 3 (interest)	SATS 4 (needs)	SATS 5 (lab.)	SATS 6 (involv.)	SATS Total
Pretest	.478*	.243*	.269*	.325*	.371*	-.121*	.124*	-.019	.021	-.050	-.060	-.022
I.Q.		.335*	.360*	.402*	.493*	-.203*	.046	-.178*	-.156*	-.163*	-.130*	-.164*
TOUS 1			.418*	.347*	.766*	-.020	.029	.040	.040	0.000	-.002	.032
TOUS 2				.271*	.712*	-.128*	-.013	-.114*	-.090	-.072	-.024	-.111*
TOUS 3					.757*	-.063	.058	-.034	.015	-.109	-.088	-.035
TOUS Total						-.094	.038	-.047	-.018	-.076	-.061	-.051
SATS 1							.483*	.349*	.600*	.429*	.356*	.914*
SATS 2								.182*	.364*	.324*	.123*	.608*
SATS 3									.551*	.276*	.464*	.663*
SATS 4										.240*	.431*	.843*
SATS 5											.206*	.537*
SATS 6												.523*

N = 349

**

r

>

.11,

p

<

.05

*

r

>

.15,

p

<

.01

There seems to be a higher correlation between I.Q. and pretest scores for the traditional group than for the General Course group. One interpretation of the higher correlation is that the scores on the pretest for the traditional group were higher and that their I.Q.'s were higher. Hence the higher correlation.

Another feature of Table 7 is an increased number of negative correlation coefficients over those found for the General Course group. The higher the I.Q. and the higher the pretest score, the less the student in the traditional course seems to think of the text he is using. The negative correlation coefficients associated with this test item indicate a weakness in the textbook. Another interpretation might be that the text is not satisfying the requirements of a modern science course. Evidence is found in the negative correlation between the attitude toward text materials in the traditional course and the score on TOUS 2, Understanding of the Role of a Scientist in Society.

Negative correlation coefficients are also to be found between the mental ability of students in the traditional course group and each of the attitudinal scales measured by SATS. For example, there are negative values between mental ability and a student's interests in the course, between mental ability and how the course satisfies his needs, between mental ability and his laboratory work, between mental ability and his involvement in the course

work. It becomes evident that the traditional course is not satisfying the better students in the school, if better is equated with mental ability. In all, the negative correlation coefficients between the SATS sub-tests and each of the student measures of prior knowledge, mental ability, understanding of the scientific enterprise, understanding of the role of scientists in society and of understanding of the methods and aims of science, would indicate that the course has little value as perceived by students. The negative relationships might be interpreted as a negative attitude of students toward the course they are following. In comparison with students following either the General Course or the combined PSSC-CHEMS course, these students tend to show more negative correlations than any other group.

Earlier in this study mention was made of a small group of students, sixty-five in number, who were following a course composed of the first five or six chapters of PSSC material and the first five or six chapters of the CHEMS material. Table 8 shows the correlation coefficients between the variables examined for this group. Since the sample size is small a correlation coefficient of .25 or greater is required for the five per cent level of significance, while a value of .33 or greater is required for a one per cent level of significance.

The group must be characterized as positive in their reaction to the SATS instrument, for no negative

Table 8. Correlation coefficients for thirteen variables in the PSSC-CHEMS Course.

	I. Q.	TOUS 1	TOUS 2	TOUS 3	TOUS Total	SATS 1 (text)	SATS 2 (content)	SATS 3 (interest)	SATS 4 (needs)	SATS 5 (lab.)	SATS 6 (invol.)	SATS Total
Pretest	.381*	.382*	.289*	.534*	.525*	.240*	.196	.398*	.331*	.152	.246	.358*
I.Q.		.228*	.269*	.188	.289*	.156	.028	.136	.139	.034	.190	.153
TOUS 1			.490*	.405*	.756*	.140	.180	.235	.302*	.327*	.044	.291
TOUS 2				.386*	.779*	.233	.227	.366*	.375*	.250*	.228	.338*
TOUS 3					.881*	.195	.190	.230	.206	.198	.046	.253
TOUS Total						.246*	.257*	.357*	.368*	.316*	.139	.394*
SATS 1							.729*	.455*	.610*	.232	.528*	.857*
SATS 2								.462*	.614*	.235	.285*	.810*
SATS 3									.669*	.107	.498*	.739*
SATS 4										.058	.443*	.866*
SATS 5											.106	.323
SATS 6												.590*

$N = 65$
 $** r > .25, p < .05$
 $* r > .33, p < .01$

correlations are noted. The SATS instrument gains in reliability with this group with correlation coefficients from .59 to .857 being noted. There is one exception to this relationship. There is a low but significant correlation between the statements associated with laboratory work and with the total score. There are also low correlations between each of the TOUS sub-tests and the response on the SATS scale pertaining to laboratory work, SATS 5. The low correlations do not lead to an easy or obvious interpretation. While care must be exercised against causal relationship in examining a correlation matrix, one might think that the students did not have too positive an outlook on the work they are performing. On the other hand, a possible interpretation might be that other factors are contributing more to the student reaction to the course than the laboratory work.

Further examination of Table 8 shows a significant relationship between mental ability and interest in the course. This relationship would seem to confirm the opinion that the course has a great deal of appeal for the upper level of student ability. It would also seem disappointing in spite of the emphasis on student participation and involvement in the course, that no significant relationships were shown between any of the TOUS sub-test scores and student involvement in the course. One interpretation of the lack

of significant relationship between TOUS sub-scores and student involvement is that the PSSC-CHEMS course is still being taught by traditional lecture-recitation techniques, with little student involvement.

TOUS 2 sub-test was designed to measure student understanding about the work of a scientist. It is interesting to note a significant relationship between the scores on TOUS 2 and student attitude toward laboratory work, SATS 5. The relationship is significant at the five per cent level and thus tends to support the contention that either the PSSC or CHEMS programs will enable a student to understand the nature of the work of a scientist. The opinion that the laboratory work is making a contribution in the area of understanding science is supported by the significant relationship between the total score on the TOUS scale and SATS 5 sub-test, Laboratory Work.

While the correlation between the sub-test of TOUS and the total score on TOUS is higher than for the other groups, the reason is not evident. It may simply arise from a smaller sample size in this group. This study does not examine whether one group is significantly higher than the other groups with each of the correlation coefficients.

Analysis of Test of H_1 , H_2 , Wilks' Lambda

In analyzing the results of the scores obtained on the thirteen variables used in this study by the three groups of students--the PSSC-CHEMS group, the General Course group and the Traditional Course group--two questions arise. Are the distribution of scores on these variables more homogeneous for one of the three groups than for another? Are the means of the scores on these three groups, the population centroids, equal?

The first of these questions is answered statistically by an H_1 test which asserts that the group populations have equal dispersions, a test of homogeneity of dispersion. If H_1 is rejected, the variance-covariance matrices and their determinants are compared. The determination of H_1 involves the calculation of D , the determinant of the dispersion matrix and is calculated by means of a program set for a computer. The second of the questions is answered statistically by a test termed H_2 . It is the test of equality of central tendencies or centroids of a group. Normally one rejects H_1 and accepts H_2 if the results are to be meaningful. The usual test of equality of centroids is termed Wilks' Lambda Λ and is defined by Cooley and Lohnes as:

$$\Lambda = \frac{|W|}{|T|}$$

Where W is the pooled within-groups deviation score cross products matrix and T is the total sample deviation score cross-products matrix. The test of the null hypothesis of the equality of mean vectors (H_2) assumes that the "g" group dispersion matrices are based on samples of "g" normal population with a common dispersion (H_1).⁵

Thus Table 9 reports the means and standard deviations of four groups, the General Course, the Traditional Course, the PSSC-CHEMS course, and the pooled group, on eight variables. The variables of previous knowledge and mental ability were removed as these were to be used as covariance adjusters. The total of TOUS scores and the total of SATS scores were removed as these scores were simply a compilation of certain sub-elements measured by the various subtests. The variable, SATS 6, which dealt with student involvement was also discarded as there were only five statements associated with this subtest.

Table 9 shows the absolute value of the dispersion determinants D for each of the groups, the values T and W as defined by Cooley and Lohnes, and shows the lambda values for H_2 , and the M values for H_1 . The results of this table would indicate from the F value for H_1 that the scores of the tests for each of the three groups have a common dispersion. The value is barely significant and so H_2 may be examined. The test here shows that Wilks' Lambda test is highly significant. While normally one does not accept

⁵Cooley and Lohnes, op. cit., p. 61.

Table 9. Unadjusted means and standard deviations of eight variables for four groups.

Variable	General Course		Traditional		PSSC-CHEMS		Pooled	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
TOUS 1	8.00	2.17	8.89	2.35	10.23	2.19	8.53	2.25
TOUS 2	9.12	2.27	10.43	2.27	10.86	2.63	9.78	2.30
TOUS 3	8.21	2.37	9.69	2.83	10.78	3.34	9.99	2.73
SATS 1	45.35	9.95	42.33	8.66	46.93	8.97	44.26	9.38
SATS 2	37.98	7.05	38.71	6.38	40.67	5.97	38.47	6.71
SATS 3	40.79	6.21	40.77	6.21	43.61	5.61	40.99	6.17
SATS 4	54.03	12.61	54.06	11.74	59.40	10.76	54.44	12.14
SATS 5	39.09	4.75	37.47	4.80	41.24	4.38	38.61	4.74

$$\left| \begin{smallmatrix} D_1 \\ D_2 \end{smallmatrix} \right| = 1.13 \times 10^{10}$$
$$\left| \begin{smallmatrix} D_2 \\ D_3 \end{smallmatrix} \right| = 1.47 \times 10^{10}$$
$$\left| \begin{smallmatrix} D_1 \\ D_3 \end{smallmatrix} \right| = 4.09 \times 10^9$$

$$\text{for } H_1, \mathbf{M} = 123.71;$$
$$\text{for } H_2, \mathbf{A} = .776;$$

$$T = 5.63 \times 10^{33}$$
$$W = 4.37 \times 10^{23}$$
$$F_{99134}^{72} = 1.67$$
$$F_{1724}^{16} = 14.53$$
$$F \leq .05$$
$$F > .05$$

H_2 unless he rejects H_1 , in this case where H_1 is barely significant and H_2 is highly significant, it was thought that the study warranted further analysis by removing the effects of prior knowledge and mental ability. In effect, then, the H_1 assumption of equality of dispersions is rejected because of the highly significant results of H_2 , the test of equality of population centroids.

Analysis of Covariance Adjustments

Thirteen variables have been used in the analysis of the groups of students taking the PSSC-CHEMS course, the General Course and the Traditional Course. Two of these variables were prior knowledge and mental ability. They were taken to be the independent variables and were determined by scores obtained on an achievement test and a mental abilities test administered at the grade nine level. If the effect of prior knowledge and mental ability were removed by covariance adjustment an examination of the results should reveal whether the differences reported between the three groups on the dependent variables were due to differences in mental ability and prior knowledge, or to both or to neither.

The same eight dependent variables used in the calculation of Wilks' Lambda test were used in the covariance adjustment. Table 10 shows the variables and the adjustment values assigned for each of the eight variables

Table 10. Adjustment coefficients for means of dependent variables for four groups.

Variable	Prior Knowledge Adjustment Coefficients	Mental Ability Adjustment Coefficient
TOUS 1	.020	.062
TOUS 2	.024	.067
TOUS 3	.043	.067
SATS 1	.083	-.144
SATS 2	.095	-.022
SATS 3	.074	-.114
SATS 4	.198	-.175
SATS 5	.031	-.071

$$T = 77.27$$

$$W = 77.16 \text{ for } H_2, \lambda = .902$$

$$F_{720}^{16} = 5.69$$

under consideration. One column shows the values used to adjust the mean scores due to prior knowledge while the second column shows the values used to adjust the mean scores due to mental ability. These values are inserted into the following formula to produce Table 11, the adjusted means of the eight variables.

$$A.M._{ij} = M_{ij} - [B_k(MG_k - M_{ik}) + B_a(MG_a - M_{ia})]$$

where

- $A.M._{ij}$ = adjusted mean value of the "i"th group and the "j"th dependent variable
- M_{ij} = mean value of the "i"th group and the "j"th dependent variable
- B_k = adjustment coefficient due to prior knowledge
- B_a = adjustment coefficient due to mental ability
- MG_k = pooled group mean value on prior knowledge
- M_{ik} = mean value of the "i"th group on prior knowledge
- MG_a = pooled group mean value on mental ability
- M_{ia} = mean value of the "i"th group due to mental ability.

The values shown in Table 10 appear in the formula as B_k and B_a . An examination of the formula indicates that a rather large coefficient is required to make much change in the eight dependent variables. Table 11 was prepared to show the adjusted mean values of the eight variables for the three different groups of students of this study.

Table 11. Adjusted means of eight variables for three groups.

Variable	General Course Mean	Traditional Mean	PSSC-CHEMS Mean
TOUS 1	8.32	8.59	9.33
TOUS 2	9.39	10.10	9.86
TOUS 3	8.69	9.24	9.56
SATS 1	45.39	42.25	47.58
SATS 2	38.49	38.20	40.50
SATS 3	40.87	40.66	44.02
SATS 4	54.76	53.27	58.88
SATS 5	39.04	39.49	41.66

$T = 77.27$ $W = 77.16$ for H_2 $\lambda = .902$

$F_{720}^{16} = 5.69$

An examination of Table 11 shows that the recalculated values have brought about the greatest change in SATS 4, Student Needs. The figures below the table indicate that there are still significant differences between the three groups of students after adjustment due to prior knowledge and mental ability. While the overall effect of the covariance adjustment was to bring the three groups closer together, differences between the groups are still evident.

An examination of Table 11 shows that there is a reversal in the order of achievement on TOUS 2, with the students following the traditional course scoring higher, after adjustment for prior knowledge and mental ability, than either the PSSC-CHEMS group and the General Course group. For the other sub-test on the Understanding Science, the order remains, PSSC-CHEMS, Traditional and General Course. There is no change in the order of student responses on SATS 1 Text, after adjustment, with the order being PSSC-CHEMS, General Course and Traditional. The interpretation given is that the students following the traditional program are not as satisfied with their textbook as are students in the other two courses.

Further examination of Table 11 indicates that there is little difference in how the General Course students and the Traditional Course students view the content of the course. Their scores hover around a neutral position. However, students following the PSSC-CHEMS program have a

positive view about the content of their course, and score well above the other two groups.

There is little difference in how the General Course group and the Traditional Course group view their interest in the course. Both show a low or negative interest. The PSSC-CHEMS group shows a positive interest in the course. The adjusted means of SATS 4, Needs, shows that the PSSC-CHEMS group feel that their needs are being met adequately by the course content. The General Course students show a positive reaction to their needs being met, more so than do the students taking the Traditional Course. Neither of the latter two groups score as well as the PSSC-CHEMS group.

There is very little difference in the scores of the General Course group and the Traditional Course group on SATS 5, Laboratory Work. The PSSC-CHEMS group rate the laboratory work higher than do either of the previous two groups.

Table 11 shows that by removing the effect of prior knowledge and mental ability, students of the PSSC-CHEMS course have a better understanding of science, have a more positive outlook toward the text used in the course, and toward the content of the course. In addition they are more interested in their course work, and indicate that their needs are being met by the course. The table also shows that the Traditional Course students have a better understanding of science than do the General Course students.

While the General Course students have a more positive reaction to the text material, there is slight difference between the reaction of the two groups toward the content of the course, toward their needs being met and toward the laboratory work performed. These differences are not due to prior knowledge of science nor to the mental ability of the students but seem to be inherent in the courses.

Determination of Order of Best Discriminants

The previous analysis indicated that even after adjustment of mental ability and prior knowledge, there were still discernable differences in the groups. These differences were on the scores on the eight variables used in the study. It became uneconomical to run further discriminant function analysis on all three groups. It was thought that little additional information was to be gained in further analysis of the combined PSSC-CHEMS group. Further reasons for dropping the PSSC-CHEMS group from the study was provided by the decision of the Department of Education to replace the PSSC-CHEMS at the tenth grade level with another program. The reason for this decision was that it was felt that only the top students in a school could handle the course. This study shows that the top students do better in the course work but it does not necessarily follow that the program is only for the top students.

The writer confines his attention to the traditional course of study and to the general course in sciences. The question asked in this case was which variable was the best discriminator of the two groups--the General Course group and the Traditional group. Table 12 reports the order of the best discriminator. The SATS sub-test 1, which pertains to the student textbook, is the best discriminator between these two groups. This is followed in order by the TOUS sub-test 1--Understanding About Scientists and TOUS 3--Understanding About the Aims and Methods of Science. It is interesting to note that TOUS 1--Understanding About the Scientific Enterprise is the least reliable in discriminating between these two groups.

It may be that neither group scores high on the TOUS scale and so neither course is particularly suited to the development of and understanding about science as measured by this instrument. On the other hand, the close approximation to the norms established by these who constructed the test would indicate that the students in both groups are doing nearly as well as the population sampled.

The SATS 5, the scale concerned with laboratory work, ranks fourth in the ability to discriminate. It is noteworthy that the laboratory work ranks above the content of the course as a discriminator between the two groups. Student involvement, measured by SATS 6 ranks seventh, while student needs measured by SATS 3 ranks eighth.

Table 12. Rank order of discriminators for General Course and Traditional Course groups.

Variable	Coefficient	Order
TOUS 1	.301	9
TOUS 2	4.853	2
TOUS 3	3.844	3
SATS 1	5.058	1
SATS 2	1.650	5
SATS 3	.559	8
SATS 4	1.128	6
SATS 5	1.697	4
SATS 6	.865	7

Not reported in Table 12, but calculated by means of a discriminate program set up for a computer as the best discriminator after all others have been eliminated, is TOUS 2, Test on Understanding About Scientists. The inter-effects and correlations of each of the test items are taken into consideration by the elimination of each of the lowest rank order discriminants. It is interesting to note that the rank order changes in the final stages of analysis to give TOUS 2, TOUS 3 and SATS 1 as the order of discriminators between these two groups.

Summary

Chapter V has considered the data associated with the study. The analysis of the data shows three distinct groups who are identified by the course of study in science they are following. These groups are the PSSC-CHEMS group, the General Course group and the Traditional Course group.

An analysis of the response of the General Course group, the experimental group, and the combined PSSC-CHEMS and Traditional groups on the three sub-tests of the Test on Understanding Science was undertaken graphically. First indications were that there were few differences between the responses of the groups on the test. The high degree of similarity in response necessitated a more detailed examination of the data.

The criterion variables were shown for each of the three groups, followed by presentation of the correlation matrices for the total group, and for each of the three groups of this study. Differences were noted because the significant correlations of the thirteen variables considered in the study. Different patterns were discussed.

A consideration of the test equality of dispersions of the variables between the three groups and of the equality of central tendencies were represented in tabular form. The generalized Wilks' Lambda test showed that there were differences between the three groups as measured by eight variables. Even when these variables were adjusted for prior knowledge and for mental ability there was still a significant difference between the groups.

The question then was asked, which of these tests is the best discriminator between the experimental group and the control group? The best single discriminator turns out to be TOUS 2 or Test On Understanding About Scientists. Of the entire battery of tests, the rank order places the SATS 1 or student attitude about the text in first position with TOUS 1 in the last position.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

In summary, 872 students enrolled in grade ten science courses in Manitoba schools were given an achievement test, a mental abilities test, a Test On Understanding Science, and a Student Attitude Toward Science test. The students were enrolled in three different science courses. Of this sample of Manitoba grade ten students, 458 were taking the General Course, 349 were enrolled in the Traditional Course and 65 were taking the PSSC-CHEMS program.

In general, the purpose of the study was to develop techniques in evaluating existing and experimental science programs. To this end the Student Attitude Toward Science instrument was devised 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.

In particular the study used statistical techniques to test pupil achievement in the three different courses 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 in shortened form with the results of the testing.

- I. There is no significant difference in the response of students of the experimental and control groups on the three sub-tests of the Test On Understanding Science.

Students in the control group which was composed of 65 students taking the PSSC-CHEMS program and 349 students taking the traditional course, scored consistently higher on the three sub-tests on the Test On Understanding Science than did the 458 students of the experimental group who were taking the General Course science program.

- II. There are no significant correlations to be found between the thirteen variables by members of the total sample population, the General Course science group, the Traditional science group and the PSSC-CHEMS group.

Significant correlations were found between the thirteen variables used in this study. There was a highly significant correlation between the sub-tests of TOUS and the total score on TOUS, indicating that the instrument was a consistent measure. There were also highly significant correlations between the sub-tests of SATS and the total score on SATS, indicating that the instrument was also measuring consistently. On the other hand, in the total sample, there was seldom any significant correlation between the sub-tests of TOUS and the sub-tests of SATS indicating that the two instruments were measuring different attributes of students' responses. Thus the TOUS instrument is a measure of student understanding of the aims and methods of science, of the scientific enterprise and of the role of the scientists, while the SATS instrument is a measure of student reaction to a course of study.

The negative correlation coefficients shown in the responses of the traditional science group to the SATS instrument indicate a general dissatisfaction with the traditional science course. This dissatisfaction is evident in the negative relationships with regard to text materials, to the laboratory work in the course and to the extent of student involvement in the course. The low response in these three areas would indicate that the traditional science course in Manitoba schools is not meeting the needs of the students.

The General Course students also show a negative attitude toward the course they are following in science. While it might be stated that, in general, the students taking the General Course have higher values on the SATS test than the students taking the Traditional Course, their needs are not being met. In particular both groups indicate a low interest in their science courses. It is also evident from this study that the text material in the General Course meets favor more readily than does the text material of the Traditional Course.

The PSSC-CHEMS group show both strongly positive and positive attitudes toward the course of study they are taking with an overall increase in significant correlations over the other two groups.

An analysis of the results of the different groups on the thirteen variables shows that the PSSC-CHEMS group has the highest pre-test scores, highest I.Q.'s, score highest on the TOUS tests and highest on the SATS tests. The Traditional Course group have higher pre-test scores, have higher I.Q.'s, score higher on the TOUS instrument, and have higher scores on SATS 2, Course Content than do the General Course group. The General Course group, on the other hand score higher on SATS 1, Text, SATS 3, Interest, SATS 4, Needs, SATS 5, Laboratory Work and SATS 6, Involve-ment, than does the traditional group. Both groups score below the PSSC-CHEMS group.

III. There are equal dispersions of the three groups on the eight variables of the three sub-test of TOUS and five sub-tests of SATS. This null hypothesis was the H_1 test.

The H_1 test of equality of dispersions of the three groups on the eight variables was barely significant at the five per cent level. One might either accept or reject the hypothesis from the figures indicated, an F ratio of 1.67. The H_1 test was rejected because of the results of the H_2 considered concurrently.

IV. There is an equality of population centroids of the three groups on the unadjusted means of the eight variables tested by the H_2 test and measured by the statistic termed Wilks' Lambda.

The H_1 test of equality of dispersion of the three groups related to the H_2 test. Since there is a great difference in the F ratios, H_1 with an F ratio of 1.67, and H_2 with an F ratio of 14.53, the interpretation is that the three groups have equal population dispersions but do not have equal population centroids. In other words, the three groups have about the same cluster size of test results but have different central tendencies or centroids.

V. There is an equality of population centroids, the H_2 --Wilks' Lambda test, after covariance adjustment by the two independent variables, prior knowledge and mental ability.

The results of the covariance adjustment show that there are still differences between the central tendencies of the three groups based on the eight variables. The hypothesis that the equality of central populations is due to chance is rejected.

VI. There is no discernable order of discrimination between the control group and the experimental group in the dependent variables.

The rank order of discriminators shows that SATS 1, Text, is the best discriminator when all variables are used between students taking the General Course science program and those taking the Traditional Course science program. The single best discriminator, after the elimination of the others is TOUS 2, Test On Understanding About Scientists.

Conclusions

It has been shown that after adjusting the scores on the sub-tests of TOUS and on the sub-tests of SATS due to prior knowledge and mental ability, discernable differences are to be found between the three groups of students. The PSSC-CHEMS group have a better understanding about the scientific enterprise, and a better understanding about the methods and aims of science than do the General Course group or the Traditional Course group. The students following the Traditional Course have a better understanding about scientists.

It has also been shown that the students following the PSSC-CHEMS program accept more readily the text of the course, the content of the course and the laboratory work in the course. In addition the students taking the PSSC-CHEMS program are more involved in the course, are more interested in the course and feel that the course satisfied their needs as they perceive them.

It has also been shown that while the General Course students do not achieve as well as the other students on the Test On Understanding Science, they accept the text in the course, the content of the course, the laboratory work of the course more readily than do the students following the traditional science program. While they show little interest in the course, they feel that the content of the course meets their needs more than do the students taking the Traditional Course.

It must also be concluded that students following the traditional science courses and the general science courses do not view their course work as positively as do those taking the PSSC-CHEMS. It is interesting to note that the one course which seems successful as measured by the variables used in this study, the PSSC-CHEMS science program, is being discontinued at the grade ten level in Manitoba schools.

From the data reported in this study, one must conclude that the traditional science course and the general

science course require immediate attention and revision if these courses are to satisfy the needs of students in Manitoba schools.

It must also be concluded that this study has shown it is possible to evaluate different science courses to show which are effective and acceptable to students. Statistical techniques have been used in the study which could be used in other studies of curriculum research. The use of the computer to calculate correlation coefficients to show relationships to be further investigated is but one of the developments of this study. In addition, the covariance adjustment of prior knowledge and mental ability on test scores indicates how it is possible to remove the effect of two very significant factors in any curriculum research. Researchers are frequently confronted with the problem of equating groups and selecting equated samples, equated on the basis of prior knowledge and mental ability, so that statistical comparisons may be made. This study has shown application of existing statistical techniques by which it is possible to select a sample and remove the effects of these two factors. It has also applied discriminant function analysis to determine the best discriminator of the groups under consideration. Finally, the study has shown that science curriculum revision is indicated for Manitoba schools.

Recommendations

The results of this study leave certain gaps in the investigation. Many different teachers taught the students selected for the study. It was hoped that the wide sampling would tend to remove teacher influence but the reverse may have been true. It is recommended that a further investigation be undertaken to include the relationship between teacher factors of knowledge, warmth, demand and motivational techniques, student understanding of science and student attitude toward science courses.

It is interesting to speculate that only the PSSC-CHEMS group were taught by teachers who had taken science institutes to qualify them for instruction in either PSSC Physics or CHEMS programs. The PSSC-CHEMS group was the only group showing strongly positive statements toward the science course it was following. It must be noted that this group was better prepared, more intelligent, studied more abstract forms of science and was involved in laboratory work more than students in the other groups. A study of the factors leading to acceptance of the PSSC-CHEMS programs would be a natural sequence to this study.

It is strongly recommended that curriculum revision in both the General Course and the Traditional Course science programs be undertaken at the earliest possible time. This study shows that the revision should take place along the motivational factors of the study of science.

The revision should include a change of content, increased emphasis on the amount of student involvement in the course, attention to suitable laboratory experiences to secure the involvement of students, and the selection of topics of study which will satisfy the student needs. The revision of the course along the lines suggested also requires a determination of the role of the textbook in science courses. For example, attention might be directed toward the development of a science course based on such large problems as world populations, with the resultant problems of genetic defects, of food, of energy, of land resources, and of water resources to mention but a few of the problems associated with an exploding population.

Such a program should be developed and tested on a pilot basis. In addition to the subjective judgement of those associated with the curriculum revision, the techniques of this study might be applied to the proposed pilot study to shorten the period of time necessary to evaluate the effectiveness of the program. Science curricula for Manitoba schools must change if an educated citizenry is to be developed for responsible social action.

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APPENDIX A

DIRECTIONS FOR ADMINISTERING SATS

THE SATS INSTRUMENTS

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 teacher 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. These are special electrographical ones for machine scoring. Have enough for all students to be tested, plus a few extra ones.

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 obtain 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 17/3/49) 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:

You have been given a special pencil. You must use this pencil in marking your answers otherwise your test paper will not score properly.

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 and pencils.

Package the answer sheets separately and forward them to the following address:

R. L. Hedley,
Faculty of Education,
University of Manitoba
Winnipeg 19, Manitoba.

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

SATS

STUDENT ATTITUDE TOWARD SCIENCE

Form A - (Revised)

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 directions 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 homework 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.

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 programs.

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 programs or do something else more often than you watched hockey. It would also indicate that you did watch the program 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 programs.

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 that 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.

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APPENDIX B

TOPICAL OUTLINE OF THE GENERAL COURSE SCIENCE PROGRAM

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

¹J. 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), p. 1.

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 favorable 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

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,
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

Time

- (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

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

* Mentioned only. No special emphasis

Time

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
- *- 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 thunder-shower

* Mentioned only. No special emphasis

Time

- 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

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 super-saturated solutions

Time

- 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
- 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

Time

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

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

Time

- drier
- color
- latex paints
- alkyd paints
- silicone paints
- water paint
- varnish
- enamels
- lacquers
- stains
- linoleum and oil cloth
- wallpaper

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

Time

- sources of nitrogen compounds
 - the Haber process
 - the Cyanamide process
 - sources of phosphorous compounds
 - soil often needs lime
 - plant hormones
 - soil conditioners
 - analyzing soils
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
- *- the electroscope
- *- 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
- magnetic poles
- magnetic attraction and repulsion
- the magnetic field and lines of force
- *- magnetic permeability
- nature of magnetism
- theory of magnetism
- magnetic 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 | <p>C. Measurement</p> <ol style="list-style-type: none"> 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 | <p>D. Systems of Measurement</p> <ol style="list-style-type: none"> 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. | <p>E. Making Measurements</p> <ol style="list-style-type: none"> 1. Method of making measurements
Laboratory work |
| 25 periods | <p>F. Work, Power, Energy and Machines</p> <ol style="list-style-type: none"> 1. Work and Friction <ul style="list-style-type: none"> - work - friction - coefficient of friction - how friction is reduced - efficiency of machines 2. Inclined Plane <ul style="list-style-type: none"> - inclined plane - advantages - work done on the inclined plane - mechanical advantage 3. Lever <ul style="list-style-type: none"> - 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.

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