THE UNIVERSITY OF MANITOBA

A COMPARISION OF THE EFFECT ON STUDENT ATTITUDE TOWARDS SCIENCE AND UNDERSTANDING OF SCIENCE OF TWO APPROACHES TO THE TEACHING OF AN ATOMIC MODEL OF MATTER

by

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Murdo Macdonald

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CHAPTER I

INTRODUCTION

Background to the Study

"Much more use could be made of the history of science, its adventure and dramatic action, which appeal strongly to young peoples' interests and arouse their imagination."[1] Paul DeHart Hurd, in his assessment of the weaknesses of the new science curricula such as the Introductory Physical Science (IPS), Physical Science Study Committee (PSSC) Physics and Chem Study Chemistry, stated that "...the courses do not motivate the majority of students towards an interest in science."[2] A possible explanation of this deficiency, in his opinion, was the fact that the new science programs were "...not sensitive to the way in which science serves man. There is an apparent lack of relevance to the real world and a separation of science from humanistic context."[3]

There has been no significant change in the materials studied in the Grade Ten IPS program in Manitoba since the course was introduced in 1966.

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[1]Paul DeHart Hurd, New Directions in Teaching Secondary School Science (Chicago: Rand, McNally and Company, 1969), p. 26.

[2]Ibid. p. 97.

[3]Ibid.

An earlier study by Charlesworth[4] indicated that students in Manitoba reacted favorably to the IPS program in its first year. One feature, the high degree of student involvement in laboratory work, might account for the more positive attitude towards science shown by IPS students in Charlesworth's study.

The course is an investigative approach in which students work cooperatively and share their findings to arrive at conclusions based on experimental data. At least 70 per cent of the total time is spent in the laboratory or on discussions relating to laboratory work. Each laboratory investigation is preceded by a pre-lab discussion to clarify the purpose of the experiment and to decide on the best experimental approach for collecting the necessary data. Conclusions are frequently based on shared class data rather than on individual results. The conclusions are generally arrived at after a post-lab discussion. The many problems at the end of each chapter are intended to serve as good introductory questions relating to the experiments while other questions are designed to help consolidate and develop new concepts.

The strong emphasis on individual laboratory experiments, often reported to be the very backbone of the course,

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[4]Kenneth J. Charlesworth, "An Investigation of Student Achievement in and Attitude Toward Grade Ten Science Programs in Manitoba Secondary Schools." (Unpublished Master's Thesis, University of Manitoba, Winnipeg, 1969).

is also a source of criticism. Joseph S. Schwab, at the conclusion of his Inglis Lecture in 1962, emphasized the importance of different modes of enquiry and cautioned that:

> ...there is a growing tendency to escape the diversities of enquiry by conceiving it as primarily a matter of simple controlled experiment of precision and of technical proficiency. Under the sway of this false simplicity many science classrooms are being converted into research microcosms in which every high school student regardless of interest and competence is supposed to act, on a small scale, like a scientist.[5]

Paul F. Brandwein, in the Burton Lecture of the same year, stated that:

> Scientists do not investigate all the time, they do not rush to the lab once a problem occurs; they often ask others, use the library, attend meetings, phone, reflect, use mathematical tools; they take shortcuts - scientists are human.[6]

Statement of the Problem

The purpose of the study was to compare experimentally two instructional approaches in presenting evidence for an atomic model of matter with respect to their effects on student attitude towards science, student understanding of science and student process skill ability in science. The IPS control group followed the regular IPS program for Chapters Six, Seven and Eight. The experimental group followed the multi-phase historical approach based

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[5]Joseph S. Schwab and Paul F. Brandwein, The Teaching of Science (Cambridge: Harvard University Press, 1964), p. 102.

[6]Ibid. p. 120.

on Unit Five of the Project Physics Course. The questions of interest to the study were the following:

1. Do the two instructional approaches differ in the extent to which they influence students' attitude towards science, understanding of science and process skill ability in science?

2. Do students of differing levels of initial ability in science differ in post-instructional attitude towards science, understanding of science and process skill ability in science, regardless of the type of instructional approach used?

3. Were the two instructional methods differentially effective for different initial ability levels when students' attitude towards science, understanding of science and science processes skills were assessed?

Hypotheses Tested

The following multivariate hypotheses were tested in the study:

$H_0 1.0$:

There are no significant differences in post-test scores between the experimental group and the IPS group with respect to:

1. students' attitude towards science

2. students' understanding of the scientific enterprise

3. students' understanding of the scientist

4. students' understanding of the aims and methods of science

5. students' mastery of science processes skills

H_O2.0:

There are no significant differences in post-test scores between the higher level science ability student and lower level science ability student with respect to:

1. students' attitude towards science

2. students' understanding of the scientific enterprise

3. students' understanding of the scientist

4. students' understanding of the aims and methods of science

5. students' mastery of science processes skills

H_O3.0:

There are no significant differences in post-test scores differentially between instructional method and science ability level with respect to:

1. students' attitude towards science

2. students' understanding of the scientific enterprise

3. students' understanding of the scientist

4. students' understanding of the aims and methods of science

5. students' mastery of science processes skills

Statement of Significance

Although the Introductory Physical Science course has been taught successfully at all grade levels from seven to ten in North America, the majority of students in Manitoba study the course at the Grade Ten level. The course was chosen primarily because of its potential as a preparatory course for PSSC Physics and Chem Study. It was intended to help students acquire good laboratory techniques and certain basic skills which would enable them to function and cope more successfully with the new programs in the physical sciences. The purpose of the program was to give the students a beginning knowledge of physical science and to offer some insight into the means by which scientific knowledge was acquired. The theme of the course is the development of evidence for an atomic model of matter.

The model of the atom which the Grade Ten student has after completing the IPS course is Dalton's model. The IPS program does not capitalize on the excitement of the development of a more recent model of the atom. The proposed type of instruction would extend the historical approach so as to provide the student with a model of matter which is similar to that of the modern scientist.

The method of presentation of an atomic model of matter in Unit Five of Project Physics deserves consideration. In addition to its logical, historical and humanistic style the learning alternatives are so varied that the students and teacher can choose between a variety of paths to achieve a goal. They may vary course content, select materials and decide on the approach which best meets their needs.

It was felt that this greater flexibility would lead to desirable changes both in the affective and cognitive domain for students. It was anticipated that these changes could be translated into test scores for purposes of analysis. The results of such analysis could be used to indicate the direction of change that could best accomodate both the varied needs of the individual student and the equally demanding requirements of a healthy society for future citizens with a respect for truth, a positive attitude and the necessary learning skills that would enable them to cope with and adjust to change successfully.

The Core Committee (on the reorganization of the secondary schools of Manitoba) made two suggestions regarding the curriculum which are of interest. The first states:

> In general, however, the Committee believes that the kind of secondary school program conceived in its recommendations would best be served by the addition of courses that would place greater emphasis on problems, issues and values and courses that would draw upon several disciplines rather than one.[7]

The second suggestion states:

> ...at the same time, the Core Committee believes that schools should be free, within provincial guidelines, to modify existing programs and also develop entirely new programs to meet local needs as these are necessary.[8]

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[7]Core Committee on the Reorganization of the Secondary Schools, _A Proposal for the Reorganization of the Secondary Schools of Manitoba_ (Winnipeg, Manitoba: Department of Youth and Education, 1970), p. 5.

[8]_Ibid_.

Although the first of these statements is concerned with the introduction of new courses, the proposed instructional approach has some features which help meet some of the expressed needs. There is a strong historical and humanistic emphasis. The greater variety of learning styles provided, the emphasis on individual learning and the provision of opportunities for better social interaction help meet the needs in all developmental areas.

This study has even more direct significance in relation to the issue of modifying existing programs. If the Introductory Physical Science program had educational merit six years ago, and teacher and student response suggest that it did, it must still retain much of its value. It is more economical to modify an existing program than it is to abandon it in favor of another program. The decision as to the educational value of a course of study must be made on the basis of many findings, some of which should be related to the conditions in Manitoba and within the context of the aims and objectives of science education for the province.

This study is designed to improve the quality of instruction in the classroom and it seeks to measure the effectiveness of the instruction without bias. Curricular decisions on science education can be made with more confidence if findings related to local conditions can be consulted in addition to the wealth of research material available from outside sources.

Assumptions

There were several assumptions that had to be made in this study relating to students, instruments and procedures that were followed.

1. Students answered all questions on pre-test and post-test to the best of their ability and they followed the instructions that they were given.

2. Occasional absences from class did not affect post-test scores of students significantly.

3. The students interpreted questions on the tests correctly.

4. The students in this study were not significantly different from other Grade Ten high school students who study the IPS course in Manitoba schools.

5. The instruments that were used in the study measure the categories that they are designed to measure.

6. It was assumed that students' responses were not significantly affected by the time of day at which they were tested nor previous school experiences just prior to testing.

Limitations

There were several conditions regarding this study which were limiting factors.

1. One of three science groups was chosen as the experimental group on the basis of its average mean score in science achievement tests. It was not possible to select students from the school population to the sample at random, nor was it practicable to assign students

from the sample randomly to the experimental group.

2. The experimental group was affected by the lack of an adequate supply of the recommended books, films, film loops and equipment.

3. The study was affected by the loss of some students from classes due to field trips, athletic competitions and end of year preparations. This did create problems with the post-testing.

4. The results of the post-test may have been affected by use of the same form of the Student Attitude Towards Science instrument and the Test of Science Processes.

5. The loss of some low achievement students from the IPS group at the end of the term was a limiting factor.

6. The use of one teacher is a limitation. There may be a tendency to overcompensate in trying to overcome any bias in favor of the experimental group.

Treatment of the Problem

This study was designed to compare the effects of two separate instructional procedures on students' attitude towards science, students' understanding of science and students' ability in science processes skills.

The sample consisted of ninety Grade Ten students at St. John's High School, Winnipeg, who had been studying the IPS course from September, 1971 till the end of February, 1972. They had completed the first five chapters of the course by this time and the experimental group was chosen from the three groups on the basis of the groups' average mean score in three objective tests in science. They were the middle group and it was anticipated that findings for this group would be more generally applicable to the IPS school population and most of the IPS students in Winnipeg schools. The tests Student Attitude Towards Science (SATS) and Test on Understanding Science (TOUS) were administered prior to the commencement of the experimental instruction in early March. Those tests were administered again at the conclusion of the experimental instruction early in June. An additional test, Test of Science Processes, was given both before and after the experimental treatment. The purpose of this test was to check on possible loss of processing skills in the experimental group due to a reduction in the time for individual experimentation.

The IPS control group of sixty students followed the regular IPS program in Chapters Six, Seven and Eight. The instructional procedure was an enquiry approach in which students, working in pairs, performed certain prescribed experiments. The data obtained was shared, so that the decision as to the conclusions to be drawn from the experimental data, could be based on many results.

The experimental instruction group followed a program of instruction which had a multi-phase approach within a historical and humanistic context. It was based on Unit

Five of the Project Physics Course. The development of the atomic model of matter was researched using an enquiry approach. The library was used as a source of ready reference initially to motivate the students and to create interest. The mode of instruction and the material was varied for this group and included the preparation of research profiles of famous scientists, demonstration experiments, films, film strips, overhead transparencies, scientific journals and small group presentation to give a balanced program.

Multivariate analysis of covariance was used to test three multivariate hypotheses using seven covariates. The hypotheses were tested by computer analysis using the Finn Program.[9] A correlation matrix was constructed using all variables of interest.

Organization of the Thesis

The background to the study was described initially and the problem and related questions were followed by an initial statement of hypotheses to be tested. The significance of the study, assumptions and limitations of the study preceded the description of the treatment of the problem.

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[9]Jeremy D. Finn, Multivariate: Fortran Program for the Univariate and Multivariate Analysis of Variance and Covariance (Buffalo, New York: Department of Educational Psychology, State University of New York at Buffalo, 1967).

The relevance of science curricula were examined in Chapter II. A description of the aims, objectives and early planning of the Introductory Physical Science course and experimental research relating to the course were outlined. This was followed by an examination of the literature which revealed weaknesses in the Introductory Physical Science and similar programs. The Project Physics approach and its aims and objectives were also examined and the literature supporting the experimental approach was reviewed. The variables of interest in the study were examined briefly in the later stages of Chapter II.

The characteristics and selection of the sample was described in Chapter III. The mode of instruction for the two groups was also described. The choice of measuring instruments was explained along with their characteristics. The research design and the procedures of the investigation, which included collection and analysis of data, followed.

Chapter IV was concerned with the arrangement of the sample into four cells and the analysis of the data was based on this division of the sample.

The final chapter contained the summary of the results of the hypotheses testing and the conclusions that were drawn from the hypotheses. A brief general discussion of the study followed. Specific discussion of implication of the study as well as recommendations for future research completed Chapter V.

CHAPTER II

REVIEW OF THE LITERATURE

The first part of this chapter examines the relevance of the Manitoba science curricula. The next section describes the development, purposes, specific goals, approach and materials of the Introductory Physical Science (IPS) course. This is the regular Grade Ten program. Research findings, related to the IPS program and weaknesses in our present curricula, are reviewed in the following sections. A description of the development of the Project Physics Course is given since the approach with the experimental group is similar to that of the Project Physics Course. This is followed by an overview of that part of the literature which suggested or seemed to support the choice of instructional material and mode of presentation for the experimental group. An examination of the characteristics of variables of interest to the study and a brief summary conclude the chapter.

Relevance of Science Curricula

Science curricula would probably be more relevant if students and teachers were involved in future curricular changes. A study by Peter H. Huston[1] in London, Ontario

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[1]Peter H. Huston, "A Study of Value Orientations as a Characteristic of Secondary School Students and Teachers of Chemistry" (A paper presented at the National Association for Research in Science Teaching annual meeting, Chicago, 1972).

illustrates the gap between what the student is taught and what he learns and particularly what he wants to learn. Huston's study was concerned with value orientation of students and chemistry teachers to the humanistic, theoretical and technological aspects of chemistry. The conclusion that has most implication for curricular revision was based on the finding that present abstract and theoretical chemistry curricula were much closer to the teachers' value orientation than it was to that of the students. The students had, not surprisingly, indicated a very strong preference for the humanistic and technological approaches over the more theoretical approach of the chemistry curriculum.

Klopfer, describing the goals of Individualized Science, stated:

> For a science learning system to be complete it must be consciously and conscientiously directed toward the realization of a set of goals that are attuned to the needs and interests of the student, to the development of the child and to the circumstances of the 1970's.[2]

Gallagher claimed that the curricular changes of the early sixties failed to help students understand the scientific enterprise:

> One of the results of the course improvement activities of recent years has been to eliminate technology from the instructional program in science. This was a reaction against the emphasis of technology and paucity

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[2]Leopold E. Klopfer, "Individualized Science: Relevance for the 1970's," Science Education, LV (Oct.-Dec., 1971), p. 442.

> of basic science in traditional courses. But perhaps in attempting to make over science courses in the image of 'pure' science, some realism and relevance has been lost.[3]

Those curricula, according to Gallagher, did not show the dynamic nature of science and its cultural implications.

Michael Agin and Milton O. Pella accused the authors of science curricula of presenting science in a social vacuum by ignoring the inter-relationships of science, technology and society.[4]

Little, alarmed at the decreasing school physics population in the United States, was more specific in pointing out the failure of the Physical Science Study Committee (PSSC) Physics course to reconcile the needs of society and those of the individual:

> Although not specifically designed for the future Ph.D. in physics the PSSC course demands a dedication with a level of abstraction and symbol manipulative skill which is a characteristic trait of the Ph.D. physics program. To the secondary teachers and students alike the course apparently is not a part of the liberal education which every student should have.[5]

Brandwein implied that curriculum architects of the

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[3]James J. Gallagher, "A Broader Base for Science Teaching," <u>Science Education</u>, LV (July-Sept., 1971), pp. 329-338.

[4]Michael L. Agin and Milton O. Pella, "Teaching Inter-relationships of Science and Society Using a Socio-Historical Approach," <u>School Science and Mathematics</u>, LXXII (April, 1972), pp. 320-333.

[5]R. N. Little, "Trends in Physical Science " (a paper presented at the American Association of Physics Teachers meeting, New York, Feb., 1971).

sixties had failed to meet their own objectives of making the inquiry process a part of the "..substance, structure and style of the science curriculum."[6] He based the following observation on investigation over five years involving over one thousand school systems:

> In fewer than 5 per cent of the schools was a single student given the opportunity to experiment in the sense of the term used here. Inquiry as the relentless pursuit of a hypothesis in proof or disproof was generally not practised.[7]

In the same article Brandwein suggested that the library and the laboratory were both essential for true scientific enquiry.

Introductory Physical Science (IPS)

The Grade Ten Science 100 course in Manitoba entails the study of the IPS program, which was developed by Educational Services Incorporated, Boston, Massachusetts. The course is intended to serve both as a terminal course in physical science and as a pre-requisite for Grade Eleven Chemistry 200, Physics 200 and Biology 200. The course was introduced in Manitoba in September, 1966 as a controlled pilot project. The following year it was accepted as the recognized Grade Ten course for students in the university entrance science program. The course was developed

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[6]Paul F. Brandwein, "Observations on Teaching: Overload and the Methods of Intelligence," The Science Teacher, XXXVI (Feb., 1969), pp. 38-40.

[7]Ibid.

in the United States by a small group of scientists and science teachers under the direction of Uri Haber-Schaim. Development started in 1963 and the commercial version of the book was published by Prentice-Hall, Inc. in 1967. The course content is intended to provide a unified model of the atom. The stated goals for IPS are:

1. to develop a feeling for the kind of human effort involved in the development of science
2. to have students recognize that the root of all science is in the exploration of natural phenomena
3. to provide experience in scientific investigation
4. to learn how, where appropriate, to generalize from observation
5. to understand how to construct models or theories which can be used logically and which may serve to raise new questions
6. to recognize the advantages and limitations of laboratory experiments.[8]

Some of the specific objectives of the course are:

1. to develop basic laboratory skills
2. to provide experience in making observations
3. to provide opportunities to apply elementary mathematics to experimental results and similar related problems
4. to provide opportunities for correlating an abstract idea to a concrete situation
5. to familiarize students with order of magnitudes
6. to provide students with choices where they have to judge what is important and what is not important
7. to give the students the opportunities to realize that all measurements in science are approximations
8. to encourage students to use scientific notation and slide rule to simplify calculations
9. to attempt to relate science to real life and the students' own life.[9]

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[8] Paul De Hart Hurd, New Directions in Teaching Secondary School Science (Chicago: Rand, McNally and Company, 1969), p. 147.

[9] Ibid.

Students in the IPS program are expected to spend 75 per cent of the class time in the laboratory or on questions relating to laboratory experiments. The experiments use simplified and comparatively inexpensive equipment, which can be used in a regular classroom.

Research Related to IPS

Although many articles have been written on the IPS program and some experimental studies have been reported in the literature, only five studies were examined in any detail here. At least one of the measuring instruments used in this thesis Student Attitude Toward Science (SATS), Test On Understanding Science (TOUS) or the Test of Science Processes was also used in the selected studies. Kenneth J. Charlesworth[10] used both the SATS and TOUS instruments. The SATS instrument was used to compare differences in attitude towards science between students following the IPS program in its introductory experimental year and two other physical science programs which were being used at the Grade Ten level. The SATS total mean score for the IPS was the highest of the three groups. Another finding revealed that the IPS program was equally popular with both sexes. This result

[10] Kenneth J. Charlesworth, "An Investigation of Student Achievement In and Attitude Toward Grade Ten Science Programs in Manitoba Secondary Schools," (Unpublished Master's Thesis, University of Manitoba, Winnipeg, 1969).

did not apply to the other two groups. The TOUS total mean favored the IPS group. Both the SATS and TOUS instruments were found to be consistent measures as there were highly significant correlations between the sub-tests and total scores for both instruments. The author interpreted the correlation between the SATS and TOUS sub-test scores for the IPS group to mean that the IPS program developed in the students an inter-dependence of understanding and attitude which did not occur with the students who followed the other two programs. In the words of the author:

> The students of group A, using the textbook, Introductory Physical Science, had very positive and significant correlation coefficients indicating a general acceptance of the program being followed. This was in marked contrast to the results obtained from the other two programs.[11]

The report of an investigation by John W. Butzow and Leyton E. Sewell is of particular interest here because of its conclusions and recommendations:

> This study has reported many more changes in process learning for lower ability groups. It is our observation that the IPS program is often adopted for higher ability groups. School administrators generally tell us that such programs should not be wasted on non-academic students. We recommend that programs such as IPS are more likely to enhance the science learning of lower ability students. We think that laboratory learning is more necessary for the lower ability groups because they may still be learning very simple science processes. Once these processes are learned it may be possible for students to work entirely at the level of

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[11] Ibid.

abstraction.[12]

The authors cautioned that replication on a much larger sample would be needed before the findings could be applied to the IPS program as a whole.

The project was conducted to determine if process learning was changed during the period when ninety-two Grade Eight students were studying the first five chapters of IPS. The data gathering procedures involved the administration of the Test of Science Processes prior to any IPS instruction and again after all classes had completed Chapter Five of IPS. The classes with lower intelligence level showed the greater change in process learning and this finding alone may have prompted the conclusions and recommendations made by the authors.

Milton O. Pella and Jack Shermann[13] compared the effectiveness of the manipulative approach against the non-manipulative approach of teaching IPS. The non-manipulative group were not allowed to touch the apparatus or to do any of the experiments. They collected data from projected color

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[12] John W. Butzow and Leyton E. Sewell, The Process Learning Components of Introductory Physical Science-A Pilot Study, a paper presented at the 44th annual meeting of the National Association for Research in Science Teaching, Silver Springs, Maryland, March, 1971 (Washington: Office of Education, 1971).

[13] Milton O. Pella and Jack Shermann, "Two Methods of Utilizing Laboratory Activities in Teaching the Course IPS," School Science and Mathematics, LXIX (April, 1969), pp. 303-313.

slides of sequences of the same laboratory activities as those performed by the manipulative group.

The hypotheses tested by Pella and Shermann stated that there was no significant difference due to method in the (1) attainment of critical thinking skills, (2) understanding of science, (3) development of selected laboratory skills, (4) attainment of concepts presented in IPS, and (5) expression of interest. No significant differences resulted from the employment of the manipulative or non-manipulative methods in the laboratory activities, when judged in terms of student progress as reflected in test scores related to critical thinking skills, understanding of science, academic achievement of knowledge and concepts presented in IPS nor in the development and expression of interest in science. Both groups experienced a decrease in interest in science following instruction. The manipulative method was significantly superior to the non-manipulative method of utilizing the laboratory for the development of selected laboratory skills.

There were fifty Grade Eight students of average or above average intelligence in each group and the implication of the study was that the acquiring of certain learning behaviors did not depend on the students performing the experiments themselves.[14]

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[14]*Ibid.*

A study by Williams[15] concluded that IPS did not accomplish all it claimed to do. Students, who had followed the IPS program the previous year, did not perform better academically in Biological Science Curriculum Study (BSCS) Biology nor did they show higher qualities of cooperation, leadership, initiative, helpfulness and self-reliance. The Watson-Glazer test results did not reveal any superior problem-solving skill on the part of IPS students. The study was confined to two groups of thirty students taking BSCS Biology in Ohio.

A similar study by Zabolotny[16] indicated that students who had followed the IPS program the previous year performed better in Chem Study than students that had followed another physical science course. The results did not indicate any such positive relationship between previous IPS exposure and success in PSSC Physics in the same study.

Inadequacy of Present Science Programs

One weakness, revealed in the last section, was the failure to translate the heavy emphasis on laboratory work in IPS into significant gains on most criteria. The course

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[15]Byron P. Williams, "IPS as Preparation for BSCS Biology," American Biology Teacher (November, 1971), pp. 494-496.

[16]Richard A. Zabolotny, "An Investigation of the Effect of Introductory Physical Science on the Achievement of Grade XI Students in Chemistry and Physics," (unpublished Master's thesis, University of Manitoba, Winnipeg, 1971).

did not appear to be the ideal science preparation for students of physics and biology. The findings by Butzow and Sewell[17] indicated that the IPS program may be better suited to meet the needs of low ability students or less mature students.

What knowledge is of most worth? is as critical a question today as it was when Herbert Spencer first raised it. An equally important question must be asked regarding the efficiency of our methods of instruction and learning.

The contemporary validity of both questions lends support to the statement by Hurd that, "...science curricula are not permanent nor should they necessarily have a long life."[18]

Hurd claimed that the present curriculum was no longer serving the needs of either students or society and that a major goal of high school science should be to acquaint students with the role of science in the development of western civilization and to help them understand and appreciate the role of science today.[19]

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[17]John W. Butzow and Leyton E. Sewell, The Process Learning Components of Introductory Physical Science - A Pilot Study, a paper presented at the 44th annual meeting of the National Association for Research in Science Teaching, Silver Springs, Maryland, March, 1971 (Washington: Office of Education, 1971).

[18]Paul DeHart Hurd, New Directions in Teaching Secondary School Science (Chicago: Rand, McNally and Company, 1969) p. 12.

Hurd described the new education philosopher as a subject specialist, who sought only to improve the high school course matching his own research interest. As a result of this bias the approach taken in formulating the 'new' science curricula such as IPS, PSSC, Chem Study and BSCS was discipline-centred.[20]

Some of the weaknesses which some of those science courses had revealed over the years were the following:

1. The courses were overly sophisticated and too abstract for the typical high school student
2. Courses were designed as preprofessional courses oriented towards a career and further study in the subject area
3. They served more to weed out the nonscientific mind than to provide a general education in the sciences for the greatest number of students
4. The courses did not motivate the students towards an interest in science
5. The new courses were not sensitive to the way that science served man
6. There was a lack of apparent relevance to the real world and a separation of science from humane and humanistic contexts
7. Each new course was confined to a narrow range of student interests and ability
8. There was practically no serious effort to evaluate the learning effectiveness of the new courses
9. The needs of society were by-passed in favor of professional needs
10. The prestige of a national science committee tended to create an unquestioned acceptance of its course recommendations.[21]

A recent conference, directed by Ernest Burkham[22] of

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[20] Ibid., p. 15.

[21] Ibid., pp. 96-99.

[22] Ernest Burkham, "New Directions for the High School Science Program," The Science Teacher, XXXIX (February, 1972), pp. 42-44.

the Florida State University, concluded that there was an urgent need to design an alternative form of science teaching for the schools. The conference, while acknowledging the beneficial effects of many of the changes of the 1960's, agreed that the high school science programs which emerged are not suitable for the educational needs of the 1970's. The matter of greatest concern was the fact that many students were becoming more and more negative in their attitudes towards science.

Some of the specific criticisms levelled by the conference at science education were:

1. Science teaching was mostly group centred and teacher directed. Variations in interests, in ability, in learning styles of students were not accomodated
2. The social implications of science and technology were ignored despite the fact that students lived in a world that is dominated by technology and social conflict
3. The high school science program should not have been limited to physics, chemistry and biology
4. Instructional materials tended to be inflexible and the assumption was inherent in the programs that every school would follow the same identical procedures
5. Instructional goals were not clearly defined and accountability as to the effectiveness of the program could not be made satisfactorily due to inadequate evaluation procedures
6. The curricula of the 1960's failed to increase the percentage of students who had received science instruction and for this reason most high school graduates had not received an adequate general education in science.[23]

The conclusions of a fairly recent study by Campbell[24]

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[23]Ibid.

[24]James Reed Campbell, "Is Science Curiosity a Viable Outcome in Today's Secondary School Science Program?" School Science and Mathematics, LXXII (February, 1972), pp. 139-147.

present a challenge to science teachers at all levels. The specific questions that were asked in the study were:

1. Are secondary school students more curious about science as they proceed from junior to senior high?
2. To what depth will students at both junior and senior high levels be willing to go to satisfy their curiosity?

A Scientific Curiosity Inventory instrument was used to measure how far along a hierarchy of behaviors students were prepared to go to satisfy their curiosity.

The results of comparisons between the junior high students and the senior high students in Campbell's study showed that senior high students had higher scores on the lowest level (receiving) but lower scores on both of the more advanced affective domain levels. The author's assessment of the evidence from these studies was that:

> ...the development of higher affective objectives are not being accomplished to any significant degree in the secondary school. This is particularily true at the value level. The results show that students do seem to become more aware of what to be curious about as they take more and more science courses but unfortunately show lower and lower levels of involvement as they take these courses. The net result in terms of scientific curiosity is that the science program produces declines rather than increased levels of development.[25]

The failures revealed in this last section, and particularly the failure of the PSSC Physics course to appeal to the majority of high school students, led to the development of Harvard Project Physics.

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[25] Ibid.

The Project Physics Course

The Project Physics Course was developed from the ideas and research data of the Harvard Projects Physics curriculum development group. The three co-directors, Gerald Holton, James Rutherford and Fletcher Watson were able to bring together professionals from all parts of the United States to work on the program. The program was supported financially at varying stages of its development by the Carnegie Corporation, the United States Office of Education and the National Science Foundation. The chief purposes of the course are:

1. to design a humanistically oriented physics course
2. to develop a course that would attract a large number of high school students to the study of introductory physics
3. to contribute to the knowledge of the factors that influence science learning.[26]

The assumptions about the role of physics in education set the tone for the course. Introductory physics, like other subjects, should contribute to the liberal education of the student. An introductory physics course should instil in students a desire for learning science throughout their lives even if they are not heading towards scientific careers and it should provide them with the necessary learning skills for doing so.[27]

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[26] G. Holton, F. J. Rutherford, F. G. Watson, Directors, About the Project Physics Course (New York: Holt, Rinehart and Winston, Inc., 1971), p. 3.

[27] Ibid., p. 5.

Some of those assumptions about the educative role of physics are reflected in the specific goals of the Project Physics Course. The course and materials were designed:

1. to help students to increase their knowledge of the physical world by concentrating on the ideas that characterize physics as a science at its best
2. to help students see physics as the many-sided human activity that it really is. This means presenting the subject in historical and cultural perpective, and showing that the ideas of physics have not only a tradition but methods of adaptation and change
3. to increase the opportunity for each student to have immediate rewarding experiences in science while gaining knowledge and skill that will be useful throughout life
4. to make it possible for teachers to adapt the physics course to the wide range of interests and abilities among their students
5. to recognize the importance of the teacher in the educational process and the vast spectrum of teaching situations that prevail.[28]

The learning materials in the course include texts, student handbooks of laboratory and other activities, programmed instruction, film loops, overhead transparencies, supplemental units and books of selected readings for each of the six units. The six unit texts are intended to be student guides. The experiments may be teacher demonstration, teacher-group experiments or student experiments. The instructional approach is the responsibility of the teacher. The multi-media systems approach has as one of its objectives the encouragement of individual instruction. This

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[28]*Ibid*. p. 5.

multi-phase approach makes use of laboratory stations, small group discussions and it enables the student to choose the source of information from a variety of available material.

Literature Supporting Choice of New Instructional Approach

Milton O. Pella and Michael L. Agin in the introduction to their study "Teaching Interrelationships of Science and Society Using a Socio-Historical Approach"[29] stated that science education of the last decade had almost excluded any emphasis on the interrelationships of science, technology and society. They claimed that science had been presented in such a way that students were unaware of the meaning of science and its effect on their lives. They made the assertion that:

> ...the emphasis in science education for the 1970's and beyond appears to be turning from products and processes toward broader consideration of science and its activities. The new trend is toward teaching science in a social matrix in which science-society interactions, societal implications of science and the social responsibilities of the scientist are studied.[30]

A statement from another source continued in the same vein:

> A recent survey indicates that in many institutions of higher learning, including some of the most prestigious universities in America, history of science is rapidly

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[29]Michael L. Agin and Milton O. Pella, "Teaching Interrelationships of Science and Society Using a Socio-Historical Approach," School Science and Mathematics, LXXII (April, 1972), pp. 330-333.

[30]*Ibid.*, p. 320.

becoming a firmly established discipline.[31]

Vandervliet's statement may not be the most convincing argument in favor of introducing the history of science into the curriculum at the high school level, but there are other valid reasons for doing so according to the same author. Encouragement of a better perspective towards the rapid changes occurring today, and man's changing attitudes towards his own place in the universe, would follow an understanding of the history of science. The history of science should also foster some unity in a fragmented curriculum and help bridge the gap between science and the humanities. An additional outcome anticipated by Vandervliet would be a more positive set of attitudes and values towards intellectual pursuits generally.[32]

Klopfer, looking ahead to the type of science background that the effectively functioning citizen of the next century must have, wrote:

> In addition to an emphasis on the processes of scientific inquiry, science teaching for the 21st century must definitely include a strong component of instruction concerned with science and its cultural context.[33]

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[31]Glenn Vandervliet, "History of Science: Its Significance for the Secondary School," School Science and Mathematics, LXIX (April, 1972), pp. 281-286.

[32]*Ibid.*, p. 282.

[33]Leopold E. Klopfer, "Teaching Physics for the 21st Century: Science and Its Cultural Context," School Science Mathematics, LXV (May, 1968), pp. 358-359.

The author suggested that new instructional materials and techniques were necessary to meet those needs and he welcomed the major contribution that Project Physics had made in the design and preparation of the materials.

The most widely advanced argument in favor of a historical content within a science course is concerned with replacing the austerity of the traditional course in physics by a course that can bridge the science-humanities gap. Lester G. Paldy,[34] in a paper on the role of physics in physics education, spoke in favor of the inclusion of history to enrich the students' intellectual and emotional development.

> If we are perceptive, we will understand that, a student can profit greatly from an exposure to the philosophy and approach to physics (and life) of more than just his own teacher. A student should be provided with the opportunity to learn how physicists of other times and places have contributed to the evolution of physical theory and man's general understanding of the world. If our introductory course structures are such that the human character of these contributions is de-emphasized or obscured, or if we imply that one need only learn the physics and not the context in which the work was done, we only make it difficult for the student to acquire the sense of historical continuity that is basic to the development of mature personality and intellect.[35]

Paldy's statement lends support to the heavier historical emphasis, which has been a part of the experi-

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[34]Lester G. Paldy, The Use of History in Secondary School Physics, paper presented at the International Working Seminar on the Role of History Of Physics in Physics Education at M.I.T., July, 1970 (Washington: Office of Education, 1971).

[35]Ibid.

mental instructional approach, and which goes beyond the Project Physics Course. This part of the experimental approach is outlined in Chapter III and again in more detail in Appendix R.

Variables of Interest

Attitudes towards science. An article by Lewis R. Aiken, Jr. and Dorothy Aiken[36] provides a summary of research just prior to 1969 in the general area of science attitudes.

Attitude is a somewhat elusive characteristic to measure and careful definition is required before one can be certain as to which one of the many meanings is being evaluated. The most frequent type of study, according to the article, has been concerned with the very superficial "like vs dislike" student reaction to certain aspects of science education.

The type of devices that have been used in attempting to measure attitudes concerning science vary from the empirically-based Attitude Scales, Semantic Differential and Projective Methods, and Multiple Measures to the theory-based measures.

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[36]Lewis R. Aiken Jr. and Dorothy R. Aiken, "Research on Attitudes Concerning Science," Science Education, LIII (Oct., 1969), pp. 295-305.

Both Allen and Bell reported positive relationships between intelligence and favorable attitudes towards science and scientists. Although this same relationship had been established by other researchers such as Baumel and Berger, their findings did not suggest that students with negative attitudes had lower marks on achievement tests. The article also related the findings by Myers that a more extensive background in science did not guarantee a positive attitude towards science.

The effects of different approaches in teaching science is of particular interest to this study. Aiken and Aiken reported several findings of such studies. Charen compared an inductive open-end approach with a traditional deductive approach in teaching chemistry laboratory work. Students, using the inductive approach in chemistry were more positive in their approach as it supposedly made them "...think and feel like real chemists, gave them more freedom in the laboratory, and was more challenging, interesting, enjoyable and stimulating than the traditional approach."[37] The findings of a study by Murphy on the differential effects of content-centred and process-centred approaches to the teaching of biology laboratories at the college level indicated there were no gains on a measure of attitudes and no differences in gains in attitude, between the groups.

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[37]Ibid. p. 301.

An examination of the effectiveness of films in teaching science did not reveal any significant differences in attitude changes between the experimental and control groups when the experimental group viewed one film a week for a period of ten weeks.

The authors, Aiken and Aiken, although failing to find any highly consistent picture of the nature, causes and development of science attitudes, advised a continued search for means whereby these attitudes could be improved and such improvements measured, preferably over a period of years.

Samuel Tolpin, searching the causes of the "unhappy experiences" that cause students to lose their enthusiasm for science, attributed the students' disenchantment with chemistry to a failure to organize science instruction in terms of todays' life problems. He stated:

> If we continue to expose our student population in high school to ever-increasing amounts of facts and concepts of chemistry that are filling the newer enlarged textbooks, we will further alienate the students from studying science.[38]

Tolpin related the dependence of curiosity and drive for continued learning to the attitudes and emotions of the student. He suggested that the solution to getting students to think creatively and critically about science was to

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[38]Samuel Tolpin, "Attitude-The Key to Chemical Education is Formed at the High School Level," School Science and Mathematics, LXIX (Nov., 1969), pp. 680-682.

emphasize the applications of chemistry and other sciences to solving social problems such as housing, crime, transportation, quality of the environment, pollution and health.

Understanding Science. Marshall D. Herron implied that it was virtually impossible and probably undesirable to attempt to define the nature of scientific knowledge when he stated, "Perhaps our need for consensus has surpassed our need for precision of language." He continued in the same vein:

> I am convinced that the first thing we should expect to find is that anything as complete as the nature of scientific knowledge, or 'inquiry', is capable of being seen from a variety of points of view.[39]

The scope and range of possible interpretations prevent a conclusive examination of the characteristics of this variable.

Science Processes. Gallagher in explaining the processes by which scientists acquire facts, which are then formulated into concepts, expressed the view that:

> ...the processes which scientists use to acquire facts and formulate them into concepts play an important part in learning science as it is known to scientists. By exploring scientific ideas as they have evolved, processes such as observing, measuring, inferring, predicting, formulating hypotheses, defining operationally, experimenting, collecting and interpreting data and formulating models become evident, not as abstractions, but as skills for acquiring and organizing knowledge

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[39]Marshall D. Herron, "Nature of Science: Panacea or Pandora's Box," Journal of Research in Science Teaching, VI (1969), pp. 105-107.

about the environment.[40]

The processes of science, he claimed, were intellectual skills which cut across the artificial boundaries of disciplines. They had a generality of application both in the sciences and in other areas of education. The processes also have a permanency which concepts did not have. The concept may grow and change as the processes are used to answer additional questions that have been asked or questions that have arisen due to new information.

The processes of science are essentially processes of inquiry, which would be shown by the student, whether his inquiries are within the realm of science or outside it.

Klopfer expected students to be at the stage where they could use their process skills to acquire new concepts and carry out "genuine investigations"[41] by the time they graduated out of junior high school.

Summary

An attempt was made in this chapter to describe the research related to the relevance of the senior high science curricula in Manitoba. The philosophy, goals and methods of the Introductory Physical Science course were outlined and some research findings related to the course were examined and the Project Physics Course, which served as the model for

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[40] Gallagher, op. cit., p. 331.

[41] Klopfer, op. cit., p. 444.

the experimental instructional approach was described. The latter part of the chapter was devoted to a description of recent articles which lean towards a historical, humanistic approach in science teaching. An examination of the characteristics of the variables of interest concluded the chapter.

CHAPTER III

EXPERIMENTAL DESIGN

The purpose of this chapter is to describe the student sample and the characteristics of the variables and measuring instruments used in the study. It also explains the design of the study, the collection of data and the analysis of the data.

Population and Sample

The sample consisted of ninety Grade Ten students following the Introductory Physical Science (IPS) course at St. John's High School in Winnipeg, Manitoba. Students were assigned to one of six IPS groups by computer solely on the basis of meeting the time-tabling requirements of student and teacher. Three groups, averaging thirty students each, were assigned to the author of this study. The experimental group was selected on the basis of its average performance with respect to the other groups, in three objective tests based on the IPS program. The first test was an objective test covering the materials in Chapters One to Three and valued at 25 per cent. The second test, covering Chapters Four and Five, was also assigned a value of 25 per cent. The third test included materials from all five chapters and was valued at 50 per cent. The middle group, on these tests, was chosen as the experimental group because it was anticipated that findings for this middle group would be more generally applicable to the IPS school population and most student groups following the IPS program in other Winnipeg schools. The remaining sixty students were assigned to the regular IPS program for the remainder of the school year. The selection of the experimental group had been made prior to the commencement of the pre-testing on March 14, 1972.

Variables Used in the Study

Covariables. Randomization of the sample was not possible in this study and consequently the equivalence of the groups was in doubt. The use of certain initial student scores as covariables in the analysis of the data served to adjust for any initial differences that existed between the two groups.

Differential Aptitude Test Score (DATS). The sub-test on numerical ability and verbal reasoning is one of the tests administered to all Grade Nine students in Winnipeg schools. Since it measures abilities that are considered important in understanding science it was anticipated that this score would serve as a good covariable when adjusting for differences between the groups. The test scores were obtained from school records.

The pre-test scores of the five dependent variables were also used as covariables when adjusting for differences between the groups. All pre-test scores were obtained prior to the commencement of different types of instruction for the two groups.

Pre-SATS Score. This score is a measure of student attitude towards science as measured by the Student Attitude Towards Science (SATS) instrument, described elsewhere in this chapter.

Pre-TOUS 1 Score. This measure of the students' understanding of the scientific enterprise was obtained by administering the Test On Understanding Science (TOUS). It is the score on the first of the three parts which comprise the total test.

Pre-TOUS 2 Score. This measures the students' understanding of the type of work performed by scientists and the abilities needed by scientists. It is the score on the second part of the TOUS instrument.

Pre-TOUS 3 Score. The students' understanding of the aims and methods of science is measured using the third portion of the TOUS instrument.

Pre-Process Score. This score is a measure of students' process skills as measured by the Test of Science Processes.

Independent Variables

All subjects followed the regular IPS program for the first five chapters of the textbook.

IPS Instructional Approach. The control group followed the regular IPS program in Chapters Six, Seven and Eight. The approach is an enquiry approach in which students, usually working in pairs, perform certain prescribed experiments. The apparatus for these experiments is very easily assembled and there is a minimum of danger if students follow directions. The data obtained is usually shared with the rest of the group so that a decision as to the conclusions to be drawn can be based on many results. The students also use the knowledge that they have acquired in previous chapters to make decisions in their remaining work. A brief description of the IPS program for Chapters Six, Seven and eight appears in Appendix S.

Experimental Instructional Approach. The experimental group followed a program of instruction which had a multi-phase approach within a historical and humanistic context. It was based on Unit Five - Models of the Atom - of the Project Physics Course. One of the specific goals of the Project Physics Course is:

> ...to help students see physics as the many-sided human activity that it really is. This means presenting the subject in historical and cultural perspective and showing that the ideas of physics have not only a tradition but methods of adaptation and change.[1]

One of the chief purposes of the course is to present:

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[1]About the Project Physics Course, Gerald Holton, F. James Rutherford and Fletcher G. Watson, Directors, (New York: Holt, Rinehart and Winston Inc., 1971). p. 5.

> ...the science of physics in its proper light as a broadly based intellectual activity that has firm historical roots and that profoundly influences our whole culture.[2]

The course is designed as a serious and demanding physics program for the student who will study physics at the university level but it is also designed to meet the needs of the future educated citizen who may not be exposed to any further physics training. One of the oldest problems of science, that regarding the nature of matter, has not been completely solved and the search for the secret has been one of the most exciting science dramas of the last century. The experimental instructional approach attempted to capture some of this excitement by increasing the historical content of the Project Physics Course and varying the style of presentation in order to achieve greater impact. Except for this departure, the logical sequence of the Project Physics Course was followed. The approach is a multi-media systems approach. The historical-humanistic emphasis is reflected in the content of the Project Physics Course and the special unit reader which is also designed to promote both humanistic and historical interest. The content of Unit Five of the Project Physics Course is outlined in Appendix T.

The multi-media systems approach is one of three alternative approaches suggested in the Teacher Resource

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[2] Ibid.

Book.[3] It utilizes the many learning resources of the course. It is designed to allow the teacher to have control of the program while permitting students freedom in the style of learning that they find best for them. A daily schedule suggests how different resources can be used to provide both the teacher and the student with a choice of methods and materials. A description of the schedule that was followed by the experimental group is outlined.

Student-student interaction and student-teacher interaction were promoted by assigning each student a project on the lives of two scientists. This assignment, together with the list of scientists that were to be researched, is found in the Appendix R.

This assignment on scientists was supplementary to the Project Physics materials. It was intended to serve several purposes. It was hoped that it would encourage students' use of the library facilities, create interest, help students to see scientists as interesting people, encourage small group discussions and provide a guideline of the effect of new discoveries on man's interpretation of the nature of matter. The students' presentation of findings was firstly in the form of a research paper which was evaluated

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[3]Gerald Holton, F. James Rutherford and Fletcher G. Watson, Directors, Teacher Resource Book Unit Five - Models of the Atom (New York: Holt, Rinehart and Winston, 1971), p. 18-19.

by the teacher. The student was also required to introduce the scientist to other members of his class. The majority of students chose to use a combination of experimental demonstration, role-playing and interview techniques to acquaint the other students with their assigned scientist. The student presentations were repeated to small groups of three or four students at a time. The informality of this mode of presentation was preferred by nearly all students and it encouraged the greatest participation in discussion.

The student presentations of this nature were an integral part of the mode of instruction and they occurred periodically in a lab station setting. The availability of two large adjoining laboratories equipped with suitable tables meant that several students' presentations were taking place at the same time. The lab stations were used by students to demonstrate certain important experiments or to acquaint their fellow-students with the lives of great scientists. An experiment, designed to measure the charge of the electron, was demonstrated by the student who had elected to do the research on Robert A. Millikan. Another student conducted an experiment to illustrate Faraday's laws of electrolysis. Einstein's contributions to science were discussed at a third lab station while other students discussed the dangers of radiation and Linus Pauling's work at another location. The students moved from one station to another until they had completed their investigations at all stations.

The remainder of the experimental program followed the multi-media systems approach similar to the outline given in The Teacher Resource Book for Unit Five.[4] The daily activities by the group is outlined in Appendix S. The film strips and films that were used are listed in Appendix T, and some of the student laboratory activities are given in Appendix Q. The multi-media approach to instruction is informal and non-authoritative and much of the teacher's time can be devoted to questions raised by individuals and groups or by suggesting questions that are worth answering. Teacher presentations were necessarily more frequent than would be the case if more resource materials had been available. Those teacher presentations involved a variety of media and materials to give a better balance. Films, film strips, overhead transparencies, scientific journals and a good supply of library books, student and teacher demonstrations, role playing, small group placement and laboratory stations were intended to present the study of science as a many-faceted series of exciting experiences.

Dependent Variables. The dependent variables enable one to measure and attribute differences to the independent variables. They measure the characteristics under investigation. The elements under investigation in this study and the measuring dependent variables are described briefly in

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[4] Ibid.

terms of the measuring instruments. All five post-test scores were obtained at the conclusion of the instruction period.

Post-SATS Score. This score measures the students' attitude and it was obtained using the only available form of the SATS instrument.

Post-TOUS 1 Score. This score was obtained using the TOUS instrument. It measures understanding of the scientific enterprise, which includes the human element in science, communication in science and the interaction of science and society.

Post-TOUS 2 Score. This was the second part of the TOUS instrument score. It measures the students' understanding of the type of work performed by scientists and the abilities needed by scientists.

Post-TOUS 3 Score. This score indicates students' understanding of the aims and methods of science and it was obtained using the third part of the TOUS instrument.

Post-Process Score. This score measures the mastery of science process skills using the Test of Science Processes.

Characteristics of the Instruments

Student Attitude Towards Science (SATS). The SATS test was selected to measure the attitude of the experimental instruction group and the IPS instructional group both before and after the experimental instruction. The instrument was constructed by R. L. Hedley[5] in the course of research at Michigan State University in 1966. The test is designed to test six areas of attitude and interest towards a science course thus:

1. Student attitude towards the textbook
2. Student attitude towards course content
3. Student interest in course content
4. Student attitude towards value of information
5. Student attitude towards laboratory work
6. Student involvement in course work.

The test consists of seventy-two statements. The students are asked to answer on a five-point scale. The letters A to E are used on the answer sheet with A as the most positive reaction of strongly agree and E as the most negative reaction of strongly disagree. Values of one to five were assigned to each question with three representing the neutral position. The assigning of values, when marking the instrument, was based on the Likert Method of summated ratings. In some cases A was assigned a value of one with E assigned a value of five, while in other questions A was assigned a value of five and E was assigned

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[5]Robert L. Hedley, "Student Attitude and Achievement in Science Courses in Manitoba Secondary Schools" (unpublished Doctoral dissertation, Michigan State University, 1966).

a value of one. In all cases C had a value of three and it represented the neutral position. The SATS total was used as a criteria variable in determining the changes brought about as a result of difference in instructional methods. The test is found under Appendix A.

Test on Understanding Science (TOUS). The TOUS instrument Form W, developed by W. W. Cooley and L. E. Klopfer[6] of the Graduate School of Education, Harvard University, was designed to test and measure three areas.

1. Understanding of the scientific enterprise
2. Understanding about the role of the scientist
3. Understanding about the aims and methods of science.

"The challenge to science education is to bring to the full range of young people a comprehension of the nature of science as a humanistic enterprise."[7] The TOUS instrument attempts to measure how far the student has gone in meeting this challenge and goal of all science education. There are sixty statements and four choices for each statement. The student is asked to select the best answer to complete the statement. Students are allowed forty minutes to complete the test. The instrument was chosen because of the wide range of measures it performs; nature of science, the aims and methods of science and the

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[6] W. W. Cooley and L. E. Klopfer, Test on Understanding Science Form W, (Princeton, New Jersey: Educational Testing Service, 1961).

[7] J. T. Robinson, The Nature of Science and Science Teaching, (Belmont, Calif.: Wadsworth, 1968), p. 12.

role of scientists. The reliability of the TOUS sub-scores using the Kuder-Richardson formula 20, are:

TOUS 1 0.58

TOUS 2 0.52

TOUS 3 0.58

The TOUS test is found under Appendix B.

Test of Science Processes. This test was developed by Robert Tannenbaum[8] of Teachers' College, Columbia University, New York. The instrument was designed to determine achievement and to diagnose weaknesses in the use of science processes. The eight processes evaluated were Observing, Comparing, Classifying, Quantifying, Measuring, Experimenting, Inferring and Predicting.

The instrument has the following characteristics in the words of the author:

> (1) It consists of ninety-six multiple choice (five choice) questions; (2) It requires a total testing time of seventy-three minutes; (3) The test booklet is printed with black and white illustrations and for the twelve questions which require color, 35mm color slides are used; and (4) Scoring of the instrument yields a total score (Kuder-Richardson formula 20) reliability 0.91.[9]

Although designed to test junior high students this instrument was constructed using the process skills which

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[8]Robert S. Tannenbaum, "The Development of the Test of Science Process" (unpublished Doctoral dissertation, Columbia University, 1968).

[9]Ibid.

the IPS course attempts to develop. The test was chosen to test the process skills of students both before and after the experiment. The Test of Science Processes is found under Appendix C.

Collection of Data

Information such as age, intelligence quotient and Differential Aptitude Test Scores (DATS) were obtained from school records. The Student Attitude Towards Science (SATS) test was administered to the student sample on March 14, 1972. The Test On Understanding Science (TOUS) was completed the following day. The test of Science Processes required two periods for completion. All tests were conducted under close supervision and complying with all test requirements. Pre-testing was completed by March 21, 1972 except for some students who had been absent for the test. Those students completed the tests within two days.

Design of the Study

Since this study involved intact groups it was decided to use the analysis of covariance technique to eliminate differences and the pre-test and DATS scores were used as covariates in this multivariate analysis of covariance design. Achievement scores on the first five chapters of IPS were used as criteria to separate the total student sample into two levels of equal population. The divisions based on type of instruction and level of achievement created four cells. The composition of these cells is indicated in Table I in the early portion of the next chapter.

Analysis of Data

The following information was transferred to punch cards for computer analysis:

1. Student number
2. Differential Aptitude Test Score
3. Achievement in science score
4. Pre-SATS total score
5. Pre-TOUS sub-test 1 score
6. Pre-TOUS sub-test 2 score
7. Pre-TOUS sub-test 3 score
8. Pre-TOUS total score
9. Pre-Test of Science Process total score
10. Post-SATS total score
11. Post-TOUS sub-test 1 score
12. Post-TOUS sub-test 2 score
13. Post-TOUS sub-test 3 score
14. Post-TOUS total score
15. Post-Test of Science Process total score

The computer centre personnel at the University of Manitoba assisted in the preparation of all data and control cards required for the computer programming. The data was analysed by computer using the Finn Program for the multivariate analysis of covariance. This program yielded two types of F-ratios and the corresponding p values. The first type of F-ratio, called the multivariate F-ratio, was critical in testing the hypotheses as failure to reject the null hypothesis for a given set of dependent variables precluded further testing on the second F-ratios called univariate F-ratios.

This second F-ratio determined whether the means for a given dependent variable were significantly different between instructional groups. The multivariate F-ratio indicated whether or not all of the dependent variables taken together were significantly different between instructional groups. A correlation matrix was obtained along with means and standard deviations. The .05 level of significance was chosen as the rejection region for hypothesis testing.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this chapter is to provide a description of the sample and to describe the composition of the cells, when the sample was divided according to instructional treatment and achievement level in science. The pre-test information and the post-test scores are compared. The correlation matrix for the fourteen variables under consideration for the total group is examined and correlations of interest are reviewed. The hypotheses first stated in Chapter I are restated. The data analysis relating to hypotheses follows. The next part of the chapter compares the effects of the two instructional treatments when the population sample is divided according to sex. A summary concludes the chapter.

Sample of the Population

The total sample, seventy Grade Ten students at St. John's High School, Winnipeg, consisted of twenty-nine females and forty-one males. Sixty of the seventy students were within six months of sixteen years prior to pre-testing at the beginning of March, 1972. There were twenty-six males and seventeen females in the IPS instructional group, for whom all scores were available at the completion of post-testing. The experimental instructional group had twenty-seven members for whom all the necessary data was available on June 7, 1972. Further information regarding age, sex, science achievement scores and DATS scores may be obtained from the information given in Appendices D and E.

There was a loss of twenty students from the sample for various reasons. Three students from the experimental instructional group and two students from the IPS instructional group were absent for most of the period of experimental instruction. Ten students from the IPS instructional group were excused from all post instructional testing so as to enable them to raise their level of achievement in the course work in science. Five students were omitted because either IQ scores or DATS scores were not available for them.

Composition of Cells

Achievement scores on the first five IPS chapters were the criteria used to separate the total group into two levels of equal population. When the division was made at the median of achievement scores the four cells with the composition illustrated in Table I resulted.

TABLE I CELL COMPOSITION

	Type of Treatment	IPS	EXPERIMENTAL
INITIAL	HIGH	CELL #1 22	CELL #3 13
IPS	LOW	CELL #2 21	CELL #4 14
ACH	Sub-Total	43	27

Pre-Test and Post-Test Scores

The mean scores and the standard deviations for each of the variables in the four cells is shown in Table II. The Differential Aptitude Test Scores (DATS) measure mathematical aptitude and language reasoning ability. The means of the two high level groups (cells #1 and #3) are quite close. The two low level groups (cells #2 and #4) are also near the same level and well below the high level mean score.

The SATS score is a measure of students' attitude towards science. The mean score of three of the cells lie above the neutral score of 216 in both pre-tests and post-tests.

The low IPS control group was in the neutral position in the pre-test and dropped slightly in the post-test. The high IPS group improved its relative mean score advantage over the high experimental group in the post-test by virtue of a slight gain in its mean score and a drop in the mean score of the high experimental group.

There were ninety-six questions asked on the Test of Science Processes described in some detail in Chapter III. All means are quite high initially and there was a noticeable improvement in the scores on the post-test for all cells. The means for both high level groups are equivalent both in the pre-test and in the post-test. This also applies to the low level groups. A complete breakdown of partial and total

TABLE II

MEANS AND STANDARD DEVIATIONS
FOR THE FOUR CELLS

	GROUP A (IPS)				GROUP B (EXP)			
	HIGH		LOW		HIGH		LOW	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1.DATS	69.77	16.80	50.00	19.36	73.77	11.92	48.21	17.61
2.Ach. Sc.	72.91	9.40	48.38	7.41	69.85	7.88	48.43	5.50
3.Pre-SATS	238.68	19.87	215.52	21.05	229.54	30.63	219.36	22.74
4.Post-SATS	239.77	24.64	214.86	22.20	223.15	33.09	217.14	25.53
5.Pre-Process	70.23	6.57	63.48	8.07	71.00	7.60	64.00	6.19
6.Post-Process	75.36	9.15	67.67	7.32	74.23	4.53	68.79	7.71
7.Pre-TOUS 1	10.36	2.42	9.52	2.27	10.77	3.32	9.14	1.70
8.Post-TOUS 1	10.95	3.02	10.24	2.28	11.69	2.78	9.64	2.13
9.Pre-TOUS 2	7.68	2.66	7.19	2.62	8.85	1.99	7.79	2.55
10.Post-TOUS 2	8.09	2.62	7.24	2.49	8.46	2.60	7.50	2.77
11.Pre-TOUS 3	11.45	3.32	10.90	3.74	12.31	3.57	9.36	3.61
12.Post-TOUS 3	10.18	3.70	11.52	2.62	12.69	3.38	11.57	3.37
13.Pre-TOUS T	29.50	6.46	27.62	5.18	31.92	6.75	26.29	5.99
14.Post-TOUS T	29.23	6.96	29.00	4.65	32.85	7.24	28.71	5.97

scores on both pre and post tests of science processes is found in Appendices J, K, L and M.

The TOUS 1 portion of the Test On Understanding Science measures the students' understanding of the scientific enterprise. The maximum score is eighteen. The maximum score of eighteen also applies to the TOUS 2 subtest which measures students' understanding of scientists. TOUS 3 contains twenty-four questions on the methods and aims of science. The maximum possible total mark is sixty.

The means for all four cells were above the 50 per cent mark for TOUS 1 and all four means showed noticeable increases. The biggest increase occurred with the high experimental group (cell #3).

The eight mean scores on the TOUS 2 test were all below the 50 per cent level. The two experimental cells dropped slightly while the two IPS cells showed a slight gain in mean scores. More detailed information on TOUS scores is available in Appendices N and O.

Study of Correlation Matrix

Several correlations in Table III were examined. The IPS achievement score showed a positive correlation, significant at the .05 level of significance, to the DATS score, the Pre-test Process score, the TOUS 1 Post-test score and the TOUS Post-test total score. The IPS achievement test, which had been used to divide the groups into levels, was measuring some of the same components as

TABLE III

CORRELATION MATRIX FOR THE FOURTEEN VARIABLES IN THE TOTAL GROUP

	DATS	ACH	Pre-SATS	Post-SATS	Pre-PROC	Post-PROC	Pre-TOUS1	Pre-TOUS2	Pre-TOUS3	Pre-TOUS4	Post-TOUS1	Post-TOUS2	Post-TOUS3	Post-TOUS4
DATS	1.00	0.26*	0.06	0.10	0.37**	0.37**	0.29*	0.27*	0.00	0.23	0.21	0.31*	-0.05	0.19
ACH		1.00	0.13	-0.03	0.31*	0.19	0.21	-0.04	0.13	0.14	0.25*	0.07	0.19	0.25*
Pre-SATS			1.00	0.71**	0.24*	0.03	0.09	0.14	0.15	0.18	0.29*	0.12	0.21	0.28*
Post-SATS				1.00	0.24*	0.04	0.06	0.17	0.28*	0.26*	0.18	0.21	0.13	0.23
Pre-PROC					1.00	0.53**	0.32**	0.10	0.20	0.29*	0.25*	0.25*	0.32**	0.38**
Post-PROC						1.00	0.27*	0.22	0.07	0.24*	0.31*	0.11	-0.06	0.13
Pre-TOUS1							1.00	0.26*	0.30*	0.69**	0.54**	0.31*	0.34**	0.55**
Pre-TOUS2								1.00	0.19	0.63**	0.19	0.39**	0.09	0.30*
Pre-TOUS3									1.00	0.78**	0.25*	0.22	0.40**	0.42**
Pre-TOUS4										1.00	0.45**	0.42**	0.40**	0.59**
Post-TOUS1											1.00	0.26*	0.36**	0.73**
Post-TOUS2												1.00	0.19	0.63**
Post-TOUS3													1.00	0.77**
Post-TOUS4														1.00

r greater than .20 significant at .10 level
r greater than .24 significant at .05 level
r greater than .32 significant at .01 level
r greater than .39 significant at .001 level
* significant at 5% level
** significant at 1% level

those other tests. The DATS score showed six such positive correlations at the .05 level of significance. This indicated the DATS instrument was measuring even more of the same common elements than the IPS test and consequently would be a better predictor for those other areas. The highest of the pre-post correlations was the level of 0.71 for the SATS scores while the lowest was 0.53 for Science Processes scores. This correlation can be considered as a measure of reliability and indicates the higher reliability for the SATS instrument. The high consistent correlations of 0.78 and 0.77 between the TOUS 3 sub-test and TOUS total pre-tests and post-tests suggested that TOUS 3 sub-test was probably the best of the three sub-tests in measuring the cumulative understanding of science.

Introduction to the Testing of Hypotheses

The multivariate analysis of covariance design, that was employed in this analysis, employed the covariates to adjust for initial differences between groups. Tests were conducted to determine the effective contribution of each covariable in adjusting for the initial difference. In general the associations between dependent and control variables were highly significant with a p-value less than .0001. The covariates that were most effective in adjusting for initial differences were:

DATS with a p-value less than .0118

SATS with a p-value less than .0001

Process with a p-value less than .0002

TOUS 1 with a p-value less than .0020

The three major hypotheses first stated in Chapter I, were tested as multivariate hypotheses but the analysis also provided for examination of the component univariate hypotheses.

The Effect of the Type of Instruction

The effect of the type of instruction was determined by considering the data relative to the following multivariate hypothesis:

$H_o1.0$:

There are no significant differences in mean post instructional scores between the experimental group and the IPS group with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods of science as measured by TOUS 3
5. students' mastery of science process skills as measured by the Test of Science Processes.

The multivariate test of the hypothesis simultaneously examined the following associated univariate hypotheses:

$H_o1.1$:

There is no significant difference in the students' attitude towards science, as measured by the SATS total score between the IPS group and the experimental group.

$H_o1.2$:

There is no significant difference in the students' understanding of the nature of science, as measured by TOUS 1, between the two groups.

$H_o1.3$:

There is no significant difference in the students' understanding of scientists in our society, as measured by TOUS 2, between the two groups.

$H_o1.4$:

There is no significant difference in students' understanding of the aims and methods of science, as measured by TOUS 3, between the two groups.

$H_o1.5$:

There is no significant difference in the students' mastery of science processes skills, as measured by the Test of Science Processes, between the two groups.

The data presented in Table IV showed that the F-ratio for the multivariate test of equality of mean vectors was equal to 0.7127. This ratio produced a p value less than 0.6409. Since the level of significance had previously been set at .05 the multivariate null hypothesis of the effect of instructional treatment could not be rejected. The univariate analysis are also listed in Table IV. Failure to reject the multivariate null hypothesis $H_o1.0$ automatically eliminates the possibility of rejection of any one of the five univariate hypotheses $H_o1.1$ to $H_o1.5$.

Effect of Initial Level of Achievement in Science

The second multivariate hypothesis of interest in this study was the effect introduced by stratifying the students according to their prior achievement in IPS science. The effect of level of achievement in science was determined by considering the data related to the second multivariate hypothesis.

TABLE IV

MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS ASSOCIATED WITH INSTRUCTIONAL TREATMENT EFFECT

F-RATIO FOR MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS = 0.7127

D.F. = 6 and 54 P less than 0.6409

(The null hypothesis can not be rejected since P is greater than the significant level of .05)

UNIVARIATE TESTS FOR SIGNIFICANCE

VARIABLE	HYPOTHESIS MEAN SQ.	UNIVARIATE F	P LESS THAN	STEP DOWN F	P LESS THAN
1. Post-SATS	598.2695	1.8765	0.1760	1.8765	0.1759
2. Post-Process	19.3154	0.4520	0.5041	0.4917	0.4860
3. Post-TOUS 1	3.2371	0.6729	0.4154	0.8092	0.3722
4. Post-TOUS 2	0.1328	0.0233	0.8792	0.0120	0.9132
5. Post-TOUS 3	19.1008	2.2834	0.1361	0.9302	0.3391

$H_o2.0$

There are no significant differences in mean post instructional scores between the higher level science ability student and lower level science ability student with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods of science as measured by TOUS 3
5. students' mastery of science processes skills as measured by the Test of Science Processes.

The data presented in Table V showed the F-ratio for the multivariate test of equality of mean vectors was equal to 0.7917. The ratio produced a p value less than 0.5805. Since the level of significance had been set at .05 the multivariate null hypothesis of the effect of levels of achievement in IPS science could not be rejected. The F-ratio and p-values of the five univariate hypotheses associated with the multivariate hypothesis $H_o2.0$ are listed in Table V for reference purposes.

The Differential Effect of Instructional Treatment on Level of Initial Achievement in Science (Interaction Effect)

The third and final multivariate hypothesis was concerned with the possibility of interaction between the type of treatment and the levels of achievement in science. The differential effects of instructional treatment on level of initial achievement in science was determined by analysing the data related to the third multivariate hypothesis.

TABLE V

MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS ASSOCIATED WITH LEVELS OF INITIAL ACHIEVEMENT IN IPS SCIENCE

F-RATIO FOR MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS = 0.7917

D.F. = 6 and 54 P less than 0.5805

(The null hypothesis can not be rejected since P is greater than the significant level of .05)

UNIVARIATE TESTS FOR SIGNIFICANCE

VARIABLE	HYPOTHESIS MEAN SQ.	UNIVARIATE F	P LESS THAN	STEP DOWN F	P LESS THAN
1. Post-SATS	533.0898	1.6721	0.2010	1.6721	0.2010
2. Post-Process	12.5364	0.2934	0.5902	0.3273	0.5695
3. Post-TOUS 1	0.4414	0.0918	0.7631	0.1327	0.7171
4. Post-TOUS 2	0.0193	0.0034	0.9538	0.0073	0.9323
5. Post-TOUS 3	31.0059	3.7065	0.0591	2.5168	0.1184

$H_0 3.0$:

There are no significant differences in mean post-instructional scores differentially between instructional method and science ability level with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods of science as measured by TOUS 3
5. students' mastery of science processes skills as measured by the Test of Science Processes.

The data presented in Table VI show the F-ratio for the multivariate test of equality of mean vectors was equal to 1.0106. The ratio produced a p value less than 0.4283. Since the level of significance had been set at .05 the multivariate null hypothesis of the differential effects of instructional treatment on level of achievement in science could not be rejected. The F-ratios and p values for the five univariate hypotheses associated with the multivariate hypothesis $H_0 3.0$ are found in Table VI.

Additional Analysis of Data

Since none of the multivariate hypotheses could be rejected an additional analysis was performed. The student sample was divided according to sex and instructional treatment. This division of the sample resulted in four cells with the composition illustrated in Table VII.

The pre-test and post-test mean scores and the standard deviations are shown in Table VIII. The data presented in Table IX could be used to test the effect of students' sex on treatment. Table X could be used to test

TABLE VI

MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS ASSOCIATED WITH THE INTERACTION EFFECT OF INSTRUCTIONAL TREATMENT AND INITIAL ACHIEVEMENT LEVEL IN SCIENCE

F-RATIO FOR MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS = 1.0106

D.F. = 6 and 54 P less than 0.4283

(The null hypothesis can not be rejected since P is greater than the significant level of .05)

UNIVARIATE TESTS FOR SIGNIFICANCE

VARIABLE	HYPOTHESIS MEAN SQ.	UNIVARIATE F	P LESS THAN	STEP DOWN F	P LESS THAN
1. Post-SATS	845.4180	2.6518	0.1088	2.6517	0.1088
2. Post-Process	39.8069	0.9315	0.3385	0.9788	0.3267
3. Post-TOUS 1	5.6355	1.1715	0.2835	1.4362	0.2357
4. Post-TOUS 2	1.0850	0.1905	0.6642	0.2508	0.6185
5. Post-TOUS 3	18.3733	2.1964	0.1437	0.5494	0.4618

TABLE VII

CELL COMPOSITION

	IPS	EXPERIMENTAL
MALE	CELL #1 26	CELL #3 15
FEMALE	CELL #2 17	CELL #4 12

TABLE VIII

MEANS AND STANDARD DEVIATIONS FOR THE FOUR CELLS FORMED ON THE BASIS OF SEX AND INSTRUCTIONAL TREATMENT

	GROUP A (IPS)				GROUP B (EXP)			
	MALE		FEMALE		MALE		FEMALE	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1.DATS	64.81	19.52	52.94	20.39	62.60	22.39	57.92	16.44
2.Ach. Sc.	65.12	14.06	54.53	14.42	61.40	14.62	55.42	9.53
3.Pre-SATS	228.58	23.02	225.53	24.46	231.13	23.16	215.67	29.51
4.Post-SATS	228.65	28.17	226.00	24.19	224.53	23.94	214.42	34.58
5.Pre-Process	68.35	7.51	64.76	8.50	69.27	8.97	65.00	4.99
6.Post-Process	73.19	8.81	69.18	9.22	74.53	5.91	67.50	6.02
7.Pre-TOUS 1	10.42	2.19	9.23	2.49	10.73	2.79	8.92	2.27
8.Post-TOUS 1	10.77	2.85	10.35	2.45	11.33	2.44	9.75	2.70
9.Pre-TOUS 2	7.96	3.10	6.65	1.37	8.13	2.42	8.50	2.28
10.Post-TOUS 2	8.38	2.64	6.59	2.06	8.33	2.89	7.50	2.43
11.Pre-TOUS 3	12.08	3.61	9.82	2.92	10.87	4.01	10.67	3.75
12.Post-TOUS 3	11.15	3.53	10.35	2.80	12.40	3.94	11.75	2.56
13.Pre-TOUS T	30.47	6.19	25.71	4.04	29.73	7.32	28.08	6.46
14.Post-TOUS T	30.38	6.27	27.18	4.73	32.07	7.13	29.00	6.28

TABLE IX

MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS ASSOCIATED WITH STUDENTS' SEX

F-RATIO FOR MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS = 1.1372

D.F. = 6 and 54 P less than 0.3537

UNIVARIATE TESTS FOR SIGNIFICANCE

VARIABLE	HYPOTHESIS MEAN SQ.	UNIVARIATE F	P LESS THAN	STEP DOWN F	P LESS THAN
1. Post-SATS	50.2188	0.1476	0.7023	0.1475	0.7023
2. Post-Process	73.0012	1.7763	0.1878	1.7533	0.1907
3. Post-TOUS 1	1.4189	0.2913	0.5915	0.6785	0.4136
4. Post-TOUS 2	9.0820	1.6356	0.2060	2.6991	0.1060
5. Post-TOUS 3	0.0142	0.0016	0.9684	0.4276	0.5159

TABLE X

MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS ASSOCIATED WITH THE INTERACTION EFFECT OF INSTRUCTIONAL TREATMENT AND STUDENTS' SEX

F-RATIO FOR MULTIVARIATE TEST OF EQUALITY OF MEAN VECTORS = 0.4894

D.F. = 6 and 54 P less than 0.8135

UNIVARIATE TESTS FOR SIGNIFICANCE

VARIABLE	HYPOTHESIS MEAN SQ.	UNIVARIATE F	P LESS THAN	STEP DOWN F	P LESS THAN
1. Post-SATS	6.3984	0.0188	0.8915	0.0188	0.8916
2. Post-Process	75.1426	1.8284	0.1815	1.7930	0.1858
3. Post-TOUS 1	3.2888	0.6751	0.4146	0.3264	0.5701
4. Post-TOUS 2	0.7776	0.1400	0.7096	0.0526	0.8194
5. Post-TOUS 3	0.9875	0.1106	0.7407	0.0010	0.9743

possible differential effects of instructional treatment of sex.

Summary

The primary purpose of the chapter was to analyse data relating to the three multivariate hypotheses proposed. The first hypothesis compared effects due to treatment as revealed by mean post-test scores on each of the SATS, TOUS 1, TOUS 2, TOUS 3 and Test of Science Processes. Those same scores were used to test the differences of treatments when students were divided according to previous level of achievement in science and finally to determine the interaction between the levels of achievement in science and the instructional treatment. None of the three null hypotheses could be rejected.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to assess and to compare experimentally the results of two different methods of teaching the atomic model of matter. The effects that were of interest were students' attitude towards science and students' understanding of science. The assessment of the development of science process skills was also conducted in the study.

The ninety students, from St. John's High School, Winnipeg, in this study were assigned to one science teacher. All ninety students completed the first five chapters of the IPS science program, a recommended preparatory course for further science studies in Chem Study, Physical Science Study Committee (PSSC) and Biological Science Curriculum Study (BSCS) at the Grade Eleven level in Manitoba. One group of thirty students was selected as the experimental group prior to pre-testing in March, 1972.

The review of the literature and other considerations revealed the failure of science curricula to meet the needs of the general student population. Many aspects of science education, such as cultural, technological, historical and humanistic phases, had been ignored. The affective domain had been largely neglected resulting in intellectual and emotional isolation from the spirit of science.

It was felt that an approach similar to the multiphase historical approach of the Project Physics Course could be adapted to meet this need at the Grade Ten level. It was also felt that by emphasizing the historical approach in presenting evidence for an atomic model some of the drama and the excitement of the great discoveries in physics could be captured and translated into fresh interest.

The experimental group followed a program based on Unit Five, Models of the Atom, of the Project Physics Course.

The multiphase humanistic approach was oriented strongly towards a historical context to promote interest, extend the science horizon of students and to encourage informal social interaction between students and also between students and teacher. The other group followed the regular IPS program for Chapters Six, Seven and Eight. The main emphasis in IPS is on individual experimentation in the laboratory with conclusions based on group findings.

Both pre-test and post-test instruments were administered to provide scores for the testing of hypotheses of interest in the study. The total testing time for the student completing all tests was almost seven hours.

Changes in students' attitude and understanding of science and its requisite processes skills were measured by using a series of instruments on a pre-test - post-test basis.

Five pre-test scores and a Differential Aptitude Test Score (DATS), measuring language reasoning and mathematical aptitude, were used as covariates to adjust for initial differences of the groups. A multivariate analysis of covariance, using the Finn Program, was used to test three multivariate hypotheses. These hypotheses related to the effects of different instructional approaches, the levels of ability in science and interaction between levels of ability in science and instructional approach used. The computer analysis provided a correlation matrix for all variables of interest to the study. The means and standard deviations of all four cells were examined for meaningful trends.

None of the three multivariate hypotheses relating to instructional approach, level and interaction could be rejected at the .05 level of significance.

The conclusions reflect the failure to reject the stated hypotheses. The attitude of students was not greatly affected by their experiences in science during the experimental period. The study of the lives of great scientists, involved in the development of atomic theory, did not result in better understanding of today's scientists and their role in society. Both instructional approaches were favorable to the development of science process skills but the improvement could not be attributed to the type of instruction.

Summary of the Results of Hypotheses Testing

The hypotheses were tested using multivariate analysis of covariance. The Finn Program was used to analyse data by computer. All multivariate hypotheses were tested at the

.05 level. The three multivariate hypotheses tested are reproduced in this chapter with the results of the statistical analysis. Only the five univariate hypotheses associated with hypothesis $H_o1.0$ are restated here.

$H_o1.0$:

There are no significant differences in mean post-instructional scores between the experimental group and the IPS group with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods science as measured by TOUS 3
5. students' mastery of science process skills as measured by the Test of Science Processes.

The null hypothesis was not rejected at the .05 level. No significant changes in attitude, understanding of science or development of process skills were detected as a result of the different instructional approaches.

Rejection of the multivariate hypothesis implies rejection of the following univariate hypotheses. If the univariate hypotheses had been considered the following results would have been obtained.

$H_o1.1$:

There is no significant difference in the students' attitude towards science, as measured by the SATS total score between the IPS group and the experimental group.

The null hypothesis could not be rejected. No appreciable change was detected in attitudes of the IPS control group. There was a slight decrease in attitude scores for the experimental group.

$H_0 1.2$:

There is no significant difference in the students' understanding of the nature of science, as measured by TOUS 1, between the two groups.

The null hypothesis was not rejected although both the IPS group and the experimental group made slight gains.

$H_0 1.3$:

There is no significant difference in the students' understanding of scientists in our society, as measured by TOUS 2, between the two groups.

The null hypothesis was not rejected. The direction of the slight changes favored the IPS group in their understanding of the role of scientists in society.

$H_0 1.4$:

There is no significant difference in students' understanding of the aims and methods of science, as measured by TOUS 3, between the two groups.

The null hypothesis was not rejected. The direction of the difference indicated the experimental group improved faster than the IPS group.

$H_0 1.5$:

There is no significant difference in the students' mastery of science processes skills, as measured by the Test of Science Processes, between the two groups.

The null hypothesis was not rejected. Both groups improved considerably in their scores. The experimental group did not suffer in their development of processes skills despite the demands on their time due to a greater variety of instruction, more difficult science concepts to contend with and consequently more limited exposure to laboratory experiments and problem solving sessions.

$H_O2.0$:

There are no significant differences in mean post-instructional scores between the higher level science ability student and lower level science ability student with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods of science as measured by TOUS 3
5. students' mastery of science processes skills as measured by the Test of Science Processes.

The null hypothesis was not rejected at the .05 level. The high experimental group accounted for the drop in the mean score testing students' attitude. The most impressive positive change occurred with the low experimental group in their understanding of the aims and methods of science.

Since the multivariate null hypothesis could not be rejected none of the five univariate hypothesis associated with level of achievement in science could be rejected at the .05 level of significance.

$H_O3.0$:

There are no significant differences in mean post-instructional scores differentially between instructional method and science ability level with respect to:

1. students' attitude towards science as measured by the SATS instrument
2. students' understanding of the scientific enterprise as measured by TOUS 1
3. students' understanding of the scientist as measured by TOUS 2
4. students' understanding of the aims and methods of science as measured by TOUS 3
5. students' mastery of science processes skills as measured by the Test of Science Processes.

The null hypothesis failed to be rejected at the .05 level. The only test that revealed any noticeable interaction was TOUS 3 which tested the students' understanding of the aims and methods of science.

Since the multivariate analysis failed to indicate any interaction between levels of achievement in science and instructional treatments none of the five univariate hypotheses associated with interaction effects could be rejected.

Conclusions

The following conclusions are based on the findings of this study.

1. The attitude of students in this study towards science was not affected appreciably by their experiences in science during the experimental period whether they were following the IPS regular program or the experimental program.

2. There was no significant improvement in students' understanding of science for both groups as a result of their science experiences within the period between pre-test and post-test as measured by the TOUS 1 instrument.

3. Increased awareness and acquaintance with the lives and contributions of great scientists of recent times, by the experimental instructional group, did not result in better understanding of the abilities needed by scientists, their role in society and their human qualities.

4. The comparable increases in the development of science process skills by both the IPS and the experimental

group suggest that both instructional methods promote these skills. There is, however, no difference in science process skills development between the two groups.

Discussion

Curiosity must surely be one of the distinguishing attributes of the scientist. The early scientists were curious about the world and studied it because they loved nature. Whatever the motive, the scientist and the person in whom the spirit of science breathes must always search out new challenging horizons.

James R. Campbell[1] in a study, previously reported in Chapter II, deplored the fact that affective outcomes had been neglected in secondary school science education in recent years. "The affective level is vital if we are to increase the scientific literacy of the average citizen."[2] His conclusion to this study was that senior high students of science showed much less curiosity than their counterparts in junior high school.

Since curiosity and attitude towards science are so closely related findings regarding curiosity would also

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[1]James R. Campbell, "Is Science Curiosity a Viable Outcome in Today's Secondary School Science Program?" School Science and Mathematics, LXXII February, 1972. p. 147.

[2]*Ibid*.

apply to attitude towards science. If there is a general decrease in curiosity and willingness to get involved as a result of maturation this would account partly for the failure of the experimental group to show gains in attitude scores. The results for the experimental group are difficult to reconcile with the high degree of interest and lively discussion generated by their assignments on scientists.

There were some factors which might have counteracted any instructional-type positive gains by the experimental group. Some concepts were difficult and a source of anxiety. Some films were not favorably received because of difficulty with content. The laboratory work was more demanding and some students had difficulty in coping with the many lab stations. Individual students, who did accept full responsibility for demonstrating and explaining experiments, were frustrated by having to modify science equipment. Some students were not willing or able to budget their time so as to make the necessary preparations for individual or group demonstrations.

James R. Irving, writing on "The Role of History in Science Teaching",[3] stated that one of the finest philosophies of science education is found in John 8:32 "...and ye

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[3]James R. Irving, "The Role of History in Science Teaching," School Science and Mathematics, LXXI (October, 1971), pp. 601-612.

shall know the truth and the truth shall make you free." In testing for an understanding of science it is difficult to structure questions that test an individual's grasp or perception of the way things are and his conceptualization of how they fit together.

It is difficult to determine why the scores on TOUS 2, understanding about scientists, should drop for the experimental group, considering their greater exposure to the study of the lives of so many great scientists. It may be that the students did see those great scientists as 'giants' of their time and that the "romance, intrigue and thrill",[4] associated with these men and women of genius, distorted and restricted their view of the scientist who may work in a steel mill, a packing plant, an oil refinery or a university.

The experimental group's knowledge of the lives of scientists may be responsible for their greater gains both in understanding science and the aims and methods of science. No explanation is offered as to why the lower achievement level increased so much more in its understanding of the aims and methods of science. The gain in score at all levels and for both treatments in the Test of Science Processes indicated that both groups reacted positively in developing processing skills during the experimental time period.

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[4] Ibid, p. 601.

Implications of the Study

The following implications, based on data collected, the findings of this study, review of the literature and direct observation are presented.

1. The imposition of a packaged program of study in science with a very biased experimental approach and a rigid prescribed mode of instruction runs contrary to the essence of science and may hamper individual or local initiative. Diversity of techniques of instruction and instructional materials should be encouraged.

2. The IPS program is group-centred. Curriculum reforms in recent years have stressed the importance of the development of the individual. The introduction of new materials such as those available from Project Physics would facilitate individual study either to compensate for some deficiencies of IPS or to allow for student differences.

3. The IPS and similar science programs, such as PSSC and Chem Study are discipline-centred courses, created to train young scientists, disciplined in the art of research. It is felt that a more diversified approach is needed to meet the needs of a wider spectrum of the school population.

4. This type of approach meets some of the expressed needs for courses that cut across disciplinary boundaries. It has a unity which presents science within its historical context and it provides opportunities for individual social

development and the deepening of social values.

Recommendations for Future Investigations

The following recommendations, based on findings, conclusions, review of literature and implications from this study, deserve some consideration.

1. It is recommended that the existing rigid curriculum in the sciences be assessed for deficiences in promoting growth in the affective domain as well as the cognitive domain and that any such assessment should include students' reactions to the relevance of the instruction.

2. It is recommended that a similar type of study be initiated allowing for more student participation in the structuring of the course and the type of instruction favored. This should promote student initiative and develop a sense of responsibility.

3. It is recommended that, wherever possible, studies of this nature should involve more students for a longer time. The last school term is not the best time for this type of study.

4. It is recommended that this type of instructional approach be implemented on an experimental basis in order to assess its effectiveness in overcoming some of the deficiencies in the Manitoba Science 201 course.

5. It is recommended that the IPS program be presented so as to integrate some of the technological advances of recent years. It would be of interest to evaluate student

reaction to such an innovation.

6. It is recommended that more research should be directed towards students who may not be oriented towards science.

7. It is recommended that a study be conducted to determine the modifications that would be required to make the Introductory Physical Science a suitable course for junior high school students in Manitoba.

8. This study defied measurement of the affective changes generally and it is recommended that a further study attempt to measure such positive features as social interaction and the stimulating climate in the classroom created by this type of study.

BIBLIOGRAPHY

BIBLIOGRAPHY

Agin, Michael L. and Milton O. Pella. "Teaching Interrelationships of Science using a Socio-Historical Approach," School Science and Mathematics, LXXII (April, 1972), pp. 320-333.

Aiken, Lewis R. Jr. and Dorothy R. Aiken. "Research on Attitudes Concerning Science," Science Education, LIII (Oct., 1969), pp. 295-305.

Anderson, Hans O. and Paul G. Koutnik. Toward More Effective Science Instruction in Secondary Education. New York: MacMillan Co., 1972.

Baez, Albert V. "The Spirit of Science-Worldwide," The Science Teacher XXXVI (April, 1969), pp. 15-18.

Brandwein, Paul F. "Observations on Teaching: Overload and the Methods of Intelligence," The Science Teacher, XXXVI (Feb., 1969), pp. 38-40.

Bruner, Jerome S. "Liberal Education for all Youth," The Science Teacher, XXXII (Nov., 1965), pp. 19-21.

Burkham, Ernest. "New Directions for the High School Science Program," The Science Teacher, XXXIX (Feb., 1972), pp. 42-44.

Butzow, John W. and Leyton E. Sewrll. The Process Learning Components of Introductory Physical Science - A Pilot Study. A paper presented at the 44th annual meeting of the National Association for Research in Science Teaching, Silver Springs, Maryland, March, 1971, (Washington: Office of Education, 1971.

Campbell, Donald T. and Julian C. Stanley. "Experimental and Quasi-experimental Designs for Research on Teaching" Handbook of Research on Teaching, Edited by N. L. Gage, Chicago: Rand, McNally and Co., 1963.

Campbell, James R. "Is Science Curiosity a Viable Outcome in Today's Secondary School Science Program?" School Science and Mathematics, LXXII (Feb., 1972), pp. 139-147.

Campbell, William G. Form and Style in Thesis Writing. Boston: Houghton, Mifflin, 1954.

Charlesworth, Kenneth J. "An Investigation of Student Achievement In and Attitude Toward Grade Ten Science Programs in Manitoba Secondary Schools." Unpublished Master's thesis, The University of Manitoba, Winnipeg, 1969.

Cooley, W. W. and Leopold E. Klopfer. Test on Understanding Science. Princeton N.J.: Educational Testing Service, 1961.

Downie, N. M. and R. W. Heath. Basic Statistical Methods. New York: Harper and Row, 1959.

Finn, Jeromy D. Multivariate: Fortran Program for the Univariate and Multivariate Analysis of Variance and Covariance. Buffalo, New York: Dept. of Educational Psychology, State University of New York at Buffalo, 1967.

Fox, David J. The Research Process in Education. New York: Holt, Rinehart and Winston, Inc., 1969.

Gallagher, James J. "A Broader Base for Science Teaching," Science Education, LV (July - Sept., 1971), pp. 329-338.

Haber-Schaim, Uri. Introductory Physical Science. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967.

Hedley, Robert L. "Student Attitude and Achievement in Science Courses in Manitoba." Unpublished Doctor's dissertation, Michigan State University, 1966.

Herron, Marshall D. "Nature of Science: Panacea or Pandora's Box," Journal of Research in Science Teaching, VI (1969) pp. 105-107.

Holton, Gerald, F. James Rutherford and Fletcher G. Watson. The Project Physics Course Text and Handbook Unit 5 Models of the Atom. New York: Holt, Rinehart and Winston, Inc., 1971.

________. F. James Rutherford and Fletcher G. Watson. The Project Physics Course Teacher Resource Book Unit 5. New York: Holt, Rinehart and Winston, Inc., 1971.

________. F. James Rutherford and Fletcher G. Watson. The Project Physics Course Reader Unit 5 Models of the Atom. New York: Holt, Rinehart and Winston, Inc., 1971.

Hurd, Paul DeHart. New Directions in Teaching Secondary School Science. Chicago: Rand, McNally and Company, 1969.

Huston, Peter H. "A Study of Value Orientations as a Characteristic of Secondary School Students and Teachers of Chemistry." A paper presented at the National Association for Research in Science Teaching annual meeting, Chicago, 1972.

Irving, James R. "The Role of History in Science Teaching," School Science and Mathematics, LXXI (Oct., 1971), pp. 601-612.

Jevons, F. R. The Teaching of Science: Education, Science and Society. London: Allen and Unwin, Ltd., 1969.

Klopfer, Leopold E. "Individualized Science: Relevance for the 1970's," Science Education, LV (Oct.-Dec., 1971), pp. 441-452

________. "Teaching Physics for the 21st Century: Science and its Cultural Context," School Science and Mathematics, LXV (May, 1968) pp. 353-359.

Krathwohl, David E., Benjamin S. Bloom and Bertram B. Masia. The Classification of Educational Goals Handbook II - Affective Domain. New York: David McKay Co., Inc., 1964.

Little, R. N. "Trends in Physical Science." A paper presented at the American Association of Physics Teachers meeting, New York, Feb., 1971.

Paldy, Lester G. The Use of History in Secondary School Physics. Paper presented at the International Working Seminar on the Role of History of Physics in Physics Education at M.I.T., July, 1970 Washington: Office of Education, 1971.

Payne, John G. "Physics Just for Fun - An Individualized Course Using Harvard Project Physics," The Physics Teacher, X (March, 1972), pp. 138-140.

Pella, Milton O. and Jack Shermann. "Two Methods of Utilizing Laboratory Activities in Teaching the Course IPS," School Science and Mathematics, LXIX (April, 1969), pp. 303-313.

Popham, W. James. Educational Statistics Use and Interpretation. New York: Harper and Row, 1967.

Robinson, J. T. The Nature of Science and Science Teaching. Belmont, California: Wadsworth, 1968.

Schwab, Joseph S. and Paul F. Brandwein. The Teaching of Science. Cambridge: Harvard University Press, 1964.

Shulman, Lee S. and Evan R. Keislar. Learning by Discovery: A Critical Appraisal. Chicago: Rand, McNally and Co., 1966.

Tannenbaum, Robert S. "The Development of the Test of Science Processes." Unpublished Doctor's dissertation, Columbia University, 1968.

Vandervliet, Glenn. "History of Science: Its Significance for the Secondary School," School Science and Mathematics, LXIX (April, 1969), pp. 281-286.

Williams, Byron P. "IPS as Preparation for BSCS Biology," American Biology Teacher, XXXIII (Nov., 1971), pp. 494-496.

Zabolotny, Richard A. "An Investigation of the Effect of Introductory Physical Science on the Achievement of Grade XI Students in Chemistry and Physics." Unpublished Master's thesis, University of Manitoba, Winnipeg, 1970.

APPENDIX

APPENDIX A

STUDENT ATTITUDE TOWARDS SCIENCE

(SATS)

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

DIRECTIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

64. I usually look forward to my science classes.

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

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

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

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

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

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

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

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

APPENDIX B

TEST ON UNDERSTANDING SCIENCE

(TOUS)

612500

TOUS

TEST ON UNDERSTANDING SCIENCE

Form W

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8. The principal function of scientific societies is to

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

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

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

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

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

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

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

12. The principal aim of science is to

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SPECIAL DIRECTIONS FOR ITEMS 31 TO 37

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

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

Summary of Directions

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

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

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

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

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

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

40. A scientific society is

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

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

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

42. In regard to intelligence, most scientists

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

GO ON TO THE NEXT PAGE

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

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

DIRECTIONS

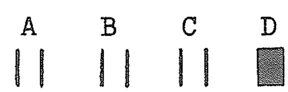
This is a test of your general knowledge about science, scientists, and the ways in which scientists do their work.

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

Example:

XX. The main thing that a scientist does is to

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

XX. 

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

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

Please do not mark this test booklet in any way.

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

Item No. 612500

APPENDIX C

TEST OF SCIENCE PROCESSES

DO NOT TURN THE PAGE UNTIL THE TEACHER TELLS YOU TO DO SO

TEST OF SCIENCE PROCESSES

INSTRUCTIONS

This test is called the Test of Science Processes. "Processes" are ways of doing things. For example, scientists have to be able to look at things very carefully and tell what they see. Scientists have to be able to measure and use numbers. And scientists have to be able to plan and understand experiments. This is a test of how well YOU can do some of the things scientists have to do. It is NOT a test of how many facts you know about science.

You should have a pencil, an answer sheet, a piece of scrap paper for doing any figuring, and this test booklet. If you do not have any of these things, raise your hand and the teacher will get what you need. PLEASE DO NOT WRITE IN THE TEST BOOKLET.

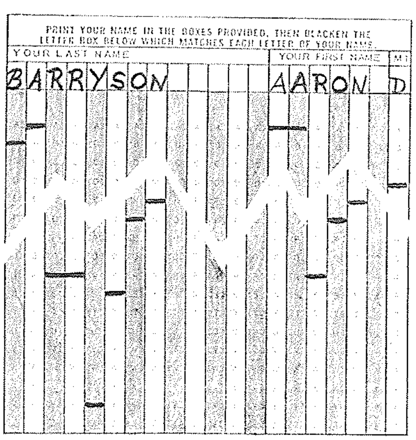
Now look at the picture of the answer sheet below. It shows the only right way to fill in answers. Only numbers 146 to 150 are filled in correctly. You must use a pencil and you must make your answers black and they must fill the box completely and not overflow. Do NOT make any of the mistakes shown in numbers 151 to 155. Do NOT make an "X." Do NOT make your answers too light. Do NOT miss the box. Do NOT circle the answer or make a check mark. Erase your mistakes completely. There is only one right way to fill in your answers -- COMPLETELY AND BLACKLY WITH A PENCIL. Do NOT wrinkle your answer sheet. It is going to be read by a machine and the machine can not read wrinkled papers. The machine can only read penciled answers so DO NOT USE INK.

Now look at your answer sheet. Find where it says "GRADE." It is next to where some of the numbers are already blackened in. Now blacken in the number that tells which grade you are in. Now print your name in the correct boxes and blacken in the letter boxes under each letter in your name. Look at the way it is done in the picture of the answer sheet on this page. Be very careful to blacken the right letter boxes.

Most of the questions on this test have pictures that go with them. The first few are in color. The teacher will show you the color pictures and read the questions WITH you. Then you will have about half a minute to think about the question and mark your answer. Always be careful to mark your answer in the right place on your answer sheet. If you make a mistake or change your mind, be sure to erase the wrong answer completely and then mark your new answer. NEVER mark more than one answer for each question. Be sure to keep up with the teacher. If you can not think of an answer, either guess or skip it. Do not spend too much time on any one question. If you have difficulty with a question, go on to the next one and come back to the hard one later. Every so often, the teacher will tell you about which question you should be working on. PLEASE DO NOT WRITE IN THE TEST BOOKLET. If you need to do any figuring, you may do it on the scrap paper.

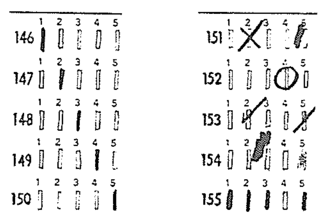
IF YOU HAVE ANY QUESTIONS, RAISE YOUR HAND NOW.

SAMPLE NAME GRID

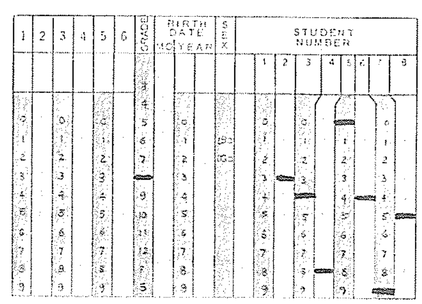


SAMPLE ANSWERS

RIGHT WRONG



SAMPLE GRADE AND NUMBER



DO NOT TURN THE PAGE UNTIL THE TEACHER TELLS YOU TO DO SO

ALL OF THE QUESTIONS ON THIS PAGE REFER TO COLOR PICTURES. YOU SHOULD LOOK AT THE PICTURES AS THE TEACHER SHOWS THEM TO YOU AND THEN ANSWER THE QUESTIONS.

1.
BE SURE YOU ARE USING ANSWER SPACE 1
This is a picture of 5 shirts. Which choice includes only the shirts you would wear if you wanted to be seen easily in the dark?

1. 1 and 4
2. 2 and 3
3. 1, 3, and 5
4. 2, 4, and 5
5. 2, 3, and 5

2.
This is a picture of 8 pieces of paper. Which is the only group of two pieces that you can take away so that you have taken away all of one color and all of one shape?

1. 1 and 6
2. 2 and 8
3. 2 and 7
4. 1 and 3
5. 4 and 5

3.
This is a picture of 5 objects. Which choice is a way they are the <u>same</u>?

1. They are all used for eating.
2. They are all the same color.
3. They are all made of wood.
4. They are all about the same size.
5. They are all about the same shape.

4.
This is a picture of 8 pieces of paper. Which choice includes only the pieces which are red and have a triangular hole?

1. 1, 4, and 6
2. 1, 2, 3, 4, and 6
3. 5 and 8
4. 1, 4, 6, and 8
5. 4 and 6

5.
BE SURE YOU ARE USING ANSWER SPACE 5
Look at the picture of the 8 pieces of paper again. Which choice includes only those pieces that are <u>NOT</u> red and have square holes?

1. 2, 3, 5, and 7
2. 5 and 7
3. 5, 7, and 8
4. 1, 3, 5, 7, and 8
5. 2, 3, 4, and 8

6.
This is a picture of 10 beads. Which is the only group of 3 beads that you can take away so that your three are all one color and none of the 7 you leave is that color?

1. 4, 6, and 7
2. 2, 6, and 8
3. 1, 3, and 5
4. 3, 5, and 10
5. 4, 7, and 9

7.
This is a picture of 5 pieces of paper that are slightly different. Which choice tells <u>exactly</u> how they are different?

1. 4 is a different color.
2. 2 is smaller.
3. 2 is smaller than all the others and 4 is a different color.
4. 1, 3, 4, and 5 are the same size.
5. 4 and 2 are different from each other.

8.
This is a picture of some cut flowers. They are called Anthurium. The red parts are called bracts. <u>Just from what you see in the picture</u>, which of the following statements can you make?

1. Anthurium have either red or white bracts and green leaves.
2. All Anthurium have red bracts and green leaves.
3. All Anthurium have green leaves.
4. Anthurium bracts may be red, or white, or any color in between, but the leaves are always green.
5. None of these, because you do not have enough information.

9.
This is a picture of 8 pieces of paper. If you group them by color, what is the smallest number of groups you can make?

1. 1
2. 2
3. 3
4. 4
5. 5

10.
BE SURE YOU ARE USING ANSWER SPACE 10
Look at the picture of 8 pieces of paper again. If you group them by shape, what is the smallest number of groups you can make?

1. 1
2. 2
3. 3
4. 4
5. 5

11.
This is a picture of 7 toy cars. Cars 1, 2, 4, and 6 make up a special group. This group is special because it includes all the cars that

1. have wheels.
2. are not blue and have wheels.
3. are red.
4. are not blue.
5. are red and white.

12.
This is a picture of pieces of paper which were left in the sun for different numbers of days. Which is the <u>only</u> thing you can say for <u>sure</u>, <u>based on what you see in the picture</u>?

1. Blue paper fades more than red paper.
2. All paper will continue to fade forever the longer you leave it in the sun.
3. Any paper left in the sun will fade.
4. This paper faded more by day 5 than it had by day 2.
5. Paper will fade in the sun, but cloth will not.

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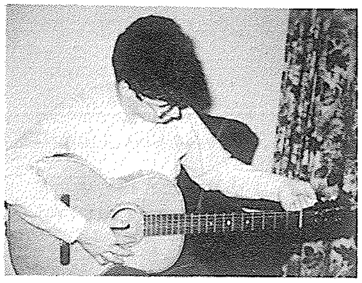
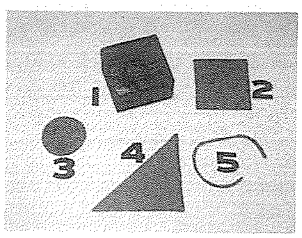
THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN LOOK AT THINGS AND HOW CAREFULLY YOU CAN TELL WHAT YOU SEE.

13. 

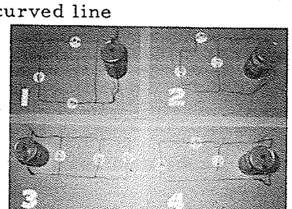
This is a picture of a boy studying what happens when he tightens or loosens the strings of a guitar. Which one of the following is <u>most</u> important to his study?

1. The lengths and thicknesses of the strings
2. The size of the guitar
3. The temperature of the strings
4. What the guitar and strings are made of
5. The age of the guitar

14. 

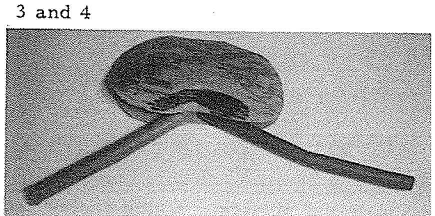
This is a picture of 5 things. Which of them has <u>volume</u>?

1. The block
2. The square
3. The circle
4. The triangle
5. The curved line

15. 

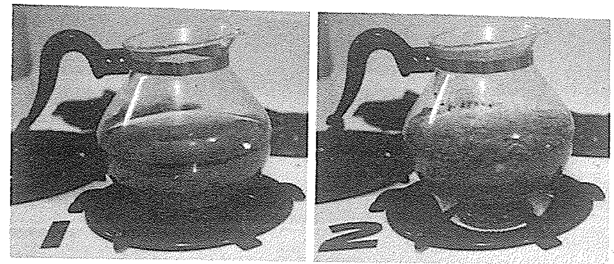
This picture shows 4 ways of arranging 3 bulbs and a battery. Which two ways are the same?

1. 1 and 4
2. 2 and 4
3. 1 and 2
4. 3 and 2
5. 3 and 4

16. 

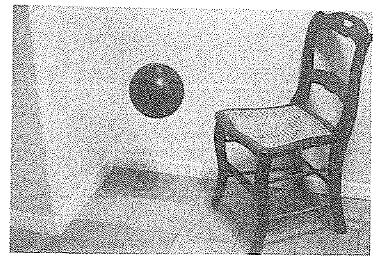
This is a picture of a growing seed. Which choice best describes what you <u>see</u>?

1. The seed is growing.
2. Someone planted and watered the seed.
3. The seed coat has split and a root and a stem are coming out of the seed.
4. A root is growing down and a stem is growing up.
5. The seed has germinated.

17. 

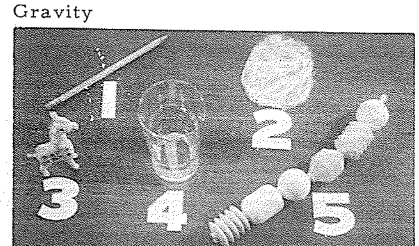
These are two pictures of a pot of water on a stove. Picture 2 was taken 5 minutes after picture 1. Which choice is the best way of telling that there has been a <u>change</u>?

1. The water is boiling in picture 2.
2. The gas is on in picture 2.
3. The water gets hot when the gas is on.
4. The water is not boiling in picture 1.
5. The water is boiling in picture 2, but it is not boiling in picture 1.

18. 

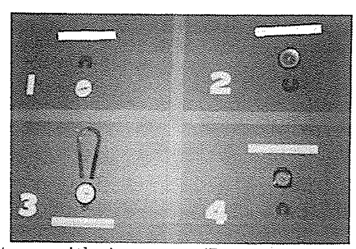
This is a picture of a ball that has just bounced off the wall and will bounce on the floor. Which one of the following is <u>LEAST</u> important to someone studying the bouncing?

1. What the ball is made of
2. What the floor is made of
3. What the wall is made of
4. How high the wall is
5. Gravity

19. 

This is a picture of 5 objects. Which of them is <u>NOT</u> in the same phase of matter (solid, liquid, gas) as all the others?

1. The pencil
2. The water
3. The toy giraffe
4. The glass
5. The beads

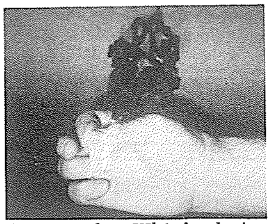
20. 

This is a picture with 4 parts. Each part shows a compass, a bar magnet, and a horseshoe magnet. In which two parts are the three things arranged in the <u>same</u> way?

1. 1 and 3
2. 2 and 4
3. 1 and 4
4. 2 and 3
5. 1 and 2

BE SURE YOU ARE USING ANSWER SPACE 20

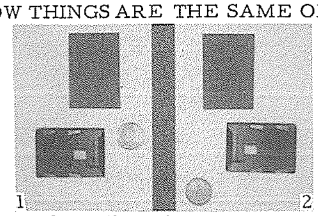
GO ON TO PAGE 4

21. 

This is a picture of a match. Which choice tells all that you can see in the picture and no more?

1. Someone is holding a match which is burning and giving off smoke.
2. Someone has just lit a match.
3. Someone is holding a burning match.
4. Someone is about to be burned by the match he is holding.
5. A match is burning and giving off light and heat.

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN TELL HOW THINGS ARE THE SAME OR DIFFERENT.

22. 

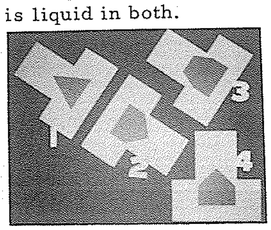
Which choice best describes these two pictures?

1. Different things are in both pictures, and they are arranged differently.
2. Different things are in both pictures, but they are arranged in the same way.
3. The same things are in both pictures, but they are arranged differently.
4. The same things are in both pictures, and they are arranged in the same way.
5. Picture 2 is a mirror image of picture 1.

23. 

This is a picture of two things happening. Which choice is a way they are the <u>same</u>?

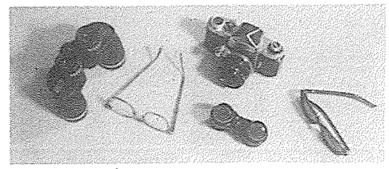
1. Something is burning in both and heating something else.
2. Glass is used in both.
3. There is a solid burning in both.
4. Something is cooking in one, but in the other something is being lit.
5. There is liquid in both.

24. 

This is a picture of 4 objects. Which are the <u>same</u>?

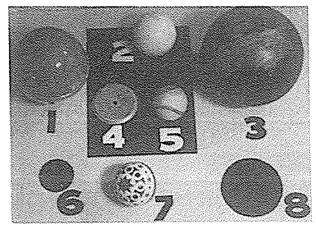
1. 1 and 4
2. 2 and 3
3. 1, 2, and 4
4. None
5. 2 and 4

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN PUT THINGS INTO GROUPS.

25. 

This is a picture of 5 objects that are alike in one special way. How are they alike?

1. They are all the same shape.
2. They all help you see things that are far away.
3. They are all made of metal.
4. They all have lenses.
5. They all make things look smaller.

26. 

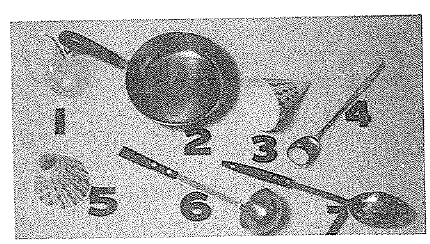
This is a picture of 8 objects. Which choice includes all the objects that are round like a ball and <u>NONE</u> of the objects that are flat?

1. 1, 2, 3, 4, 5, 7, and 8
2. 2, 3, 5, 7, and 8
3. 4, 6, and 8
4. 2, 3, and 5
5. 1, 2, 3, 5, and 7

27. 

This is a picture of 5 objects. Which choice includes only those that would make good paper weights?

1. 1, 3, 4, and 5
2. 3 and 4
3. 1, 2, and 5
4. 1 and 5
5. 1, 4, and 5

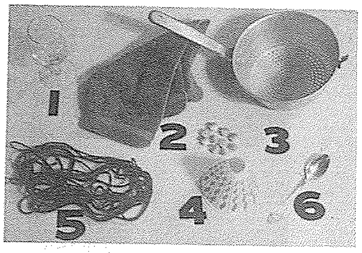
28. 

This is a picture of 7 objects. Which choice includes only those that can be used for carrying more than just a few drops of water?

1. 1, 2, 3, 6, and 7
2. 1, 2, 3, 4, and 6
3. 1, 2, 3, 4, 5, and 6
4. 1, 2, 3, 4, 6, and 7
5. 1, 2, 3, and 6

GO ON TO PAGE 5

29.



This is a picture of 10 marbles and 6 other objects. Which choice includes only those that can be used to carry all 10 marbles at the same time?

1. 1, 3, and 6
2. 1 and 3
3. 1, 3, and 5
4. 1, 2, and 3
5. 2, 3, 4, and 5

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN USE NUMBERS.

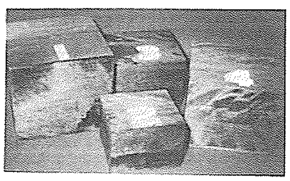
30.

BE SURE YOU ARE USING ANSWER SPACE 30

Which number below is five hundred sixteen thousand, three hundred seventy-two?

1. 516,312
2. 572,316
3. 516,372
4. 372,516
5. 516,370

31.



Here is a picture of 4 blocks. Which choice lists the blocks <u>from smallest to biggest</u>?

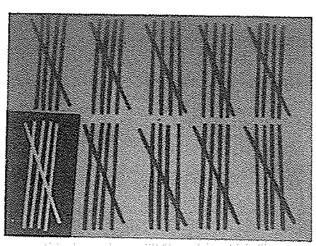
1. 1, 4, 3, 2
2. 2, 4, 3, 1
3. 2, 3, 1, 4
4. 2, 3, 4, 1
5. 3, 2, 4, 1

32.

Which one of these temperature readings is 25 degrees <u>lower</u> than $15^{o}F$?

1. $-10^{o}F$
2. $15^{o}F$
3. $-25^{o}F$
4. $0^{o}F$
5. $40^{o}F$

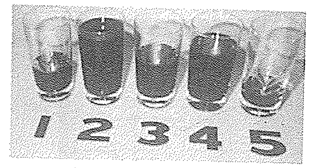
33.



This picture shows 50 straws. What fraction of the straws are on the dark paper?

1. 1/5
2. 50/5
3. 10/25
4. 2/50
5. 1/10

34.



This is a picture of 5 glasses of colored water. Which choice lists the glasses <u>from most</u> water <u>to least</u> water?

1. 5, 3, 1, 4, 2
2. 2, 4, 3, 5, 1
3. 5, 4, 3, 2, 1
4. 4, 2, 3, 1, 5
5. 2, 4, 3, 1, 5

35.

Which one of these decimals is equal to 15/100?

1. .0015
2. .015
3. 15.0
4. 1.5
5. .15

36.

If the 17th of March is Monday, what day of the week is the 23rd of March?

1. Sunday
2. Monday
3. Tuesday
4. Thursday
5. Friday

37.

If there are 25 children in a class and 5 are absent, what percent of the class is present?

1. 95%
2. 80%
3. 75%
4. 25%
5. 20%

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN USE GRAPHS AND CHARTS.

38.

NAME	number of moons	approximate number of hours in a day	approximate length of a year (in earth years)
JUPITER	12	10	12
SATURN	9	10	29
MARS	2	24	2
URANUS	5	11	84
MERCURY	0	1400	1/4

This is a chart of information about 5 planets. Which of these planets has the longest year?

1. Jupiter
2. Saturn
3. Mars
4. Mercury
5. Uranus

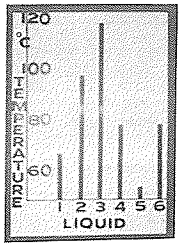
39.

Look at the chart again. Which two planets have about the same length of day?

1. Jupiter and Saturn
2. Mars and Jupiter
3. Mars and Uranus
4. Mercury and Uranus
5. No two

GO ON TO PAGE 6

40.



BE SURE YOU ARE USING ANSWER SPACE 40

This is a graph of the boiling temperatures of 6 different liquids. Which liquid has the <u>lowest</u> boiling temperature?

1. Liquid 1
2. Liquid 3
3. Liquid 4
4. Liquid 5
5. Liquid 6

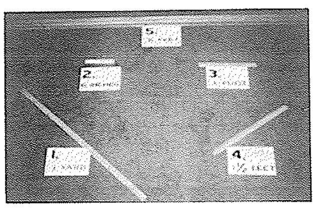
41.

Look at the graph again. Which two liquids have the same boiling temperature?

1. 6 and 4
2. 3 and 4
3. 1 and 5
4. 2 and 1
5. 3 and 5

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN MEASURE.

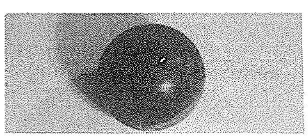
42.



This is a picture of 5 different rulers. Which one would be best for measuring how tall you are?

1. 1
2. 2
3. 3
4. 4
5. 5

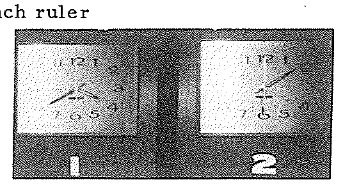
43.



This is a picture of a ball. Which of these would be best for measuring the distance around this ball?

1. Tape measure
2. Meter stick
3. Yard stick
4. 1-foot ruler
5. 6-inch ruler

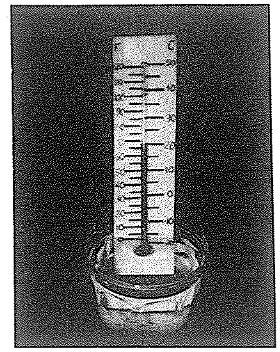
44.



These are two pictures of a clock. In picture 1, it is 3:40 in the afternoon. In picture 2, it is 6:10 that evening. How much later was picture 2 taken?

1. 2 hours and 30 minutes
2. 6 hours and 10 minutes
3. 3 hours and 40 minutes
4. 9 hours and 50 minutes
5. 9 hours and 30 minutes

45.



This is a picture of a thermometer in a glass of water. What is the temperature of the water?

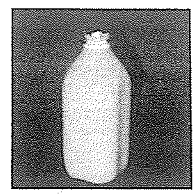
1. $50^{o}F$
2. $90^{o}F$
3. $20^{o}C$
4. $20^{o}F$
5. $0^{o}C$

46.

Which one of these units would be best to use in measuring the weight of a loaded freight car?

1. Pounds
2. Liters
3. Tons
4. Kilograms
5. Grams

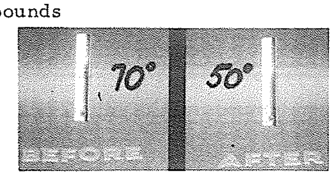
47.



This is a picture of a quart of milk. About how much does the milk weigh?

1. 10 milligrams
2. 1 gram
3. 5 ounces
4. 10 liters
5. 2 pounds

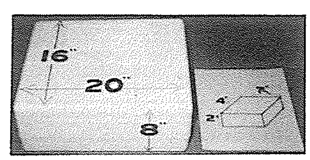
48.



These two pictures show a thermometer before and after it was cooled for 10 minutes. If its temperature went down at a steady rate, what was the rate?

1. 1 degree per hour
2. 1 degree per minute
3. 1 degree per second
4. 2 degrees per minute
5. 20 degrees per minute

49.



This is a picture of a box with its dimensions shown on it and a scale drawing of the box. One dimension is left out of the scale drawing. What should it be?

1. 1 inch
2. 2 inches
3. 3 inches
4. 4 inches
5. 5 inches

GO ON TO PAGE 7

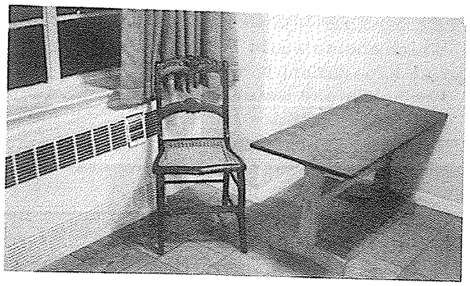
50.

BE SURE YOU ARE USING ANSWER SPACE 50

This is a picture of a little boy holding a ball. About how big is the ball?

1. 4 inches across
2. 5 centimeters across
3. 1/2 yard across
4. 1 meter across
5. 9 inches across

51.



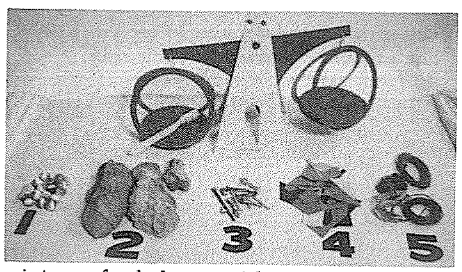
This is a picture of a room. Pretend that you are in this room and you want to measure its size, but you do not have a ruler. Which choice is NOT something you could use?

1. Your foot lengths
2. Floor tile lengths
3. Chair lengths
4. Window lengths
5. Table lengths

52.
Which one of these units is used in measuring area?

1. Inch
2. Cubic Centimeter
3. Yard
4. Square Kilometer
5. Meter

53.



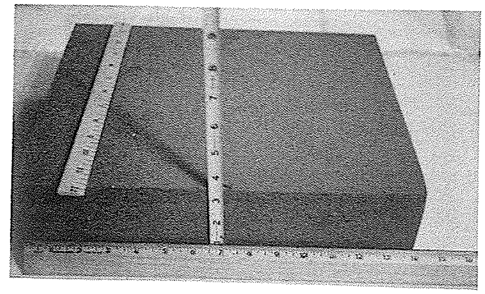
This is a picture of a balance with a toothbrush on one side. If you wanted to weigh the toothbrush, which group of objects would be best to use?

1. The marbles
2. The stones
3. The screws
4. The paper
5. The wires

54.
Which one of these units is NOT used in measuring weight?

1. Kilogram
2. Gram
3. Milligram
4. Kilometer
5. Pound

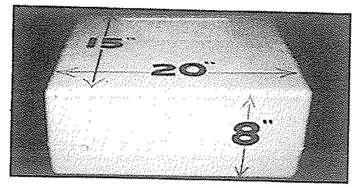
55.



This is a picture of a block. What are its dimensions?

1. 18 inches by 12 inches by 6 inches
2. 14 inches by 11 1/2 inches by 3 1/2 inches
3. 14 inches by 12 inches by 6 inches
4. 15 1/2 inches by 10 1/2 inches by 3 inches
5. 18 inches by 11 1/2 inches by 4 inches

56.



This is a picture of a box with its dimensions shown on it. What is the area of the top of the box?

1. 20 square inches
2. 300 square inches
3. 35 cubic inches
4. 160 square inches
5. 35 square inches

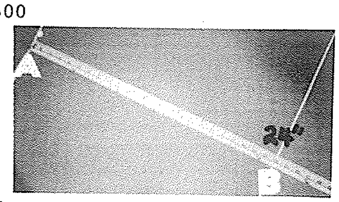
57.
Look at the picture of the box again. Which of these is NOT the volume of the box?

1. 15 inches times 20 inches times 8 inches
2. 300 square inches times 8 inches
3. 2, 400 cubic inches
4. 160 square inches times 15 inches
5. 15 inches plus 20 inches plus 8 inches

58.
Which one of these is the number of seconds in an hour?

1. 2, 400
2. 60
3. 600
4. 86, 400
5. 3, 600

59.



This picture shows a marble and a ruler. If the marble rolls from A to B in 2 seconds at a steady speed, how fast is it going?

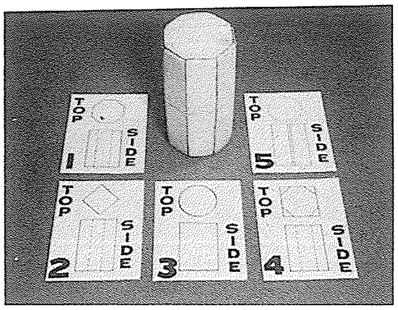
1. 12 inches per 2 seconds
2. 24 inches per second
3. 2 feet per second
4. 1/2 foot per second
5. 1 foot per second

60.
Which one of these units would be best to use in measuring the distance from the earth to the moon?

1. Yards
2. Feet
3. Inches
4. Miles
5. Light Years

BE SURE YOU ARE USING ANSWER SPACE 60

GO ON TO PAGE 8

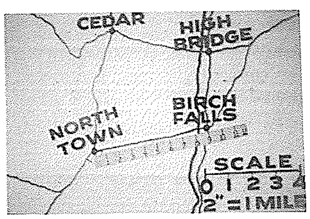
61. 

This is a picture of a box and 5 drawings. Which is the best drawing of the box?

1. 1
2. 2
3. 3
4. 4
5. 5

62.
Which one of these units is used in measuring length?

1. Centimeter
2. Gram
3. Square Yard
4. Acre
5. Quart

63. 

This picture shows a part of a map. How far is it from North Town to Birch Falls?

1. 9 miles
2. 18 miles
3. 4 1/2 miles
4. 27 miles
5. 6 3/4 miles

64.
Look at the map again. If you were using the same scale to draw another map, how far apart would you place two towns which are actually 5 miles from each other?

1. 10 inches
2. 2/5 inches
3. 5 inches
4. 15 inches
5. 1 foot

65.
In which pair below are the measurements closest in size?

1. 2 1/2 kilograms and 1 pound
2. 2 1/2 centimeters and 1 inch
3. 5 kilometers and 1 mile
4. 5 liters and 1 quart
5. 10 yards and 1 meter

66.
In which pair below are the units closest in size?

1. Pound and kilogram
2. Yard and meter
3. Meter and mile
4. Gram and liter
5. Centimeter and foot

THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN PLAN AND UNDERSTAND EXPERIMENTS.

67. 

This is a picture of two ice cube trays. One is filled with very hot water and one with cold water. Many people say: "HOT WATER MAKES ICE CUBES QUICKER THAN COLD WATER." Which choice would be the best statement for helping you plan an experiment to test this?

1. The hotter the water you start with, the faster it will freeze into ice cubes.
2. Hot water freezes into ice cubes fast.
3. Hot water freezes at higher temperatures than cold water.
4. Hot water freezes into ice cubes faster because it turns on the refrigerator.
5. Hot water makes steam which keeps the refrigerator going.

68.
If you wanted to test the statement you chose in the last question, which factor listed below is the only one you should allow to change during the experiment?

1. The temperature of the water you use.
2. The amount of water in each tray.
3. The position of the trays in the freezer.
4. The refrigerator in which you put the trays.
5. The kind of trays you use.

69.
Some things that can change during your experiment are listed below. Which one changes because of all the others?

1. The kind of trays you use.
2. The refrigerator in which you put the trays.
3. The time it takes for freezing.
4. The temperature of the water you use.
5. The amount of water in each tray.

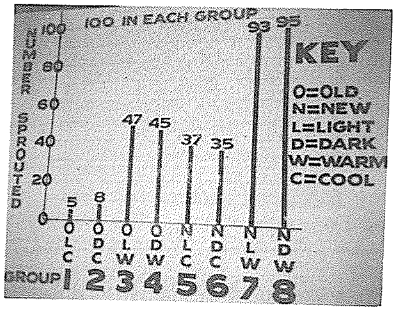
70. 

BE SURE YOU ARE USING ANSWER SPACE 70
This is a picture of 5 objects. If you want to study the relationship between the length of a pendulum and how long it takes to complete one swing, which things would be best to use?

1. C and D only
2. A, B, and E only
3. A, C, and D only
4. A and B only
5. All of the things

GO ON TO PAGE 9

71.



This is a graph of the results of an experiment. 400 seeds that were 10 years old and 400 new seeds were planted in good soil and watered each day.
100 old seeds and 100 new seeds were put in a dark cool place.
100 old seeds and 100 new seeds were put in a light cool place.
100 old seeds and 100 new seeds were put in a dark warm place.
100 old seeds and 100 new seeds were put in a light warm place.

Five things which may affect the growth of seeds are: water, heat, soil, age, and light. Which of these were tested?
1. Heat, age, and light only
2. Soil, heat, and light only
3. Heat, soil, age, and light only
4. Water and soil only
5. Water and age only

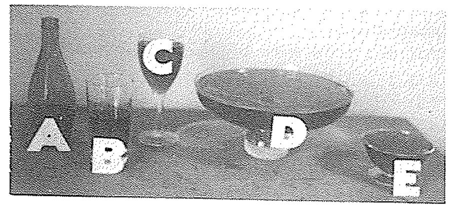
72.
Look at the graph again. Here are some things you can see on the graph:
A. 365 seeds sprouted.
B. 400 seeds were 10 years old.
C. 400 seeds were new.
D. 400 seeds were kept cool.
E. 400 seeds were kept warm.
F. 400 seeds were kept in the light.
G. 400 seeds were kept in the dark.
Which one happened because of all the others?
1. A
2. B
3. D
4. F
5. G

73.
Look at the graph once more. Here are 5 statements about this experiment:
A. More new seeds sprout than old seeds.
B. Heat makes a difference in how many seeds sprout.
C. Light makes a difference in how many seeds sprout.
D. Water does not make a difference in how many seeds sprout.
E. Light does not make a difference in how many seeds sprout.
Which of these can you find from the graph?
1. A only
2. A, B, and D only
3. D and E only
4. C and D only
5. A, B, and E only

74.
Look at the graph again. Listed below are some other experiments you could do. Which one is NOT based on the experiment shown in the graph?
1. A study of seeds of several ages.
2. A study of the effect of different numbers of hours of light and dark on seeds.
3. A study of the heights of plants.
4. A study of the effect of different amounts of water on seeds.
5. A study of the effect of different temperatures on seeds.

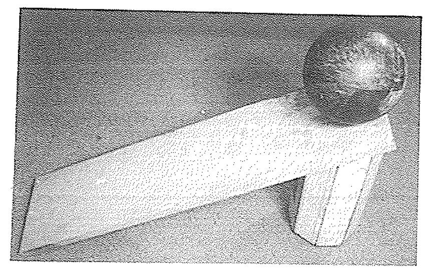
75.
Look at the graph again. Why were 800 seeds used?
1. 800 makes 8 groups of exactly 100 each, and 100 is a round number.
2. Experiments require exactly 100 samples in each group.
3. 800 were all the seeds that were available.
4. The groups needed to be large enough so that what was found out was not wrong due to chance.
5. 800 happened to be the number taken out of the bag.

76.



This picture shows 5 containers that were left out in a storm. The rainwater has been colored so that you can see it better. Which is the best container to use to find out how many inches of rain fell?
1. A
2. B
3. C
4. D
5. E

77.



This is a picture of a ball at the top of a slope. If you want to find out the average time it takes for the ball to roll all the way down the slope, about how many times should you let it roll down and time it?
1. 1
2. 2
3. 15
4. 250
5. 1, 000

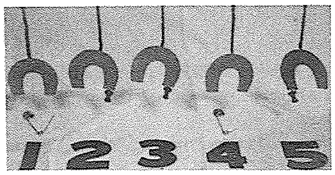
THE NEXT QUESTIONS ARE TO FIND OUT HOW WELL YOU CAN FIGURE OUT AND PREDICT, WHEN YOU ARE GIVEN SOME FACTS. BE VERY CAREFUL TO THINK ABOUT YOUR ANSWERS. MAKE SURE THEY ARE BASED ON WHAT YOU SEE IN THE PICTURE OR CHART.

78. WIND DIRECTION

	SUN	MON	TUE	WED	THU	FRI	SAT
NOON	E	N E	E	E	S E	calm	E
MIDNIGHT	S W	W	W	calm	N W	W	W

This is a chart of wind direction at noon and midnight for one week. Which is the most general statement you can make based on this chart?
1. The direction of the day winds is 180° different from the direction of the night winds.
2. The direction of the wind is different at night than it is during the day at this place.
3. There is always a wind in this place.
4. Day winds come from the east and night winds come from the west.
5. It is warmer during the day than it is at night.

GO ON TO PAGE 10

79. 

This is a picture of 5 pins and 5 magnets. Which statement CANNOT be made just from looking at the picture?

1. Pins 2 and 5 have big heads.
2. Pins 2, 3, and 5 are sticking to their magnets.
3. Some pins are made from a metal which is not magnetic.
4. All the pins with big heads shown in this picture are sticking to their magnets.
5. Pins 1 and 4 are not sticking to their magnets.

80.
BE SURE YOU ARE USING ANSWER SPACE 80
Look at the picture again. What else must you do to prove that pins 2 and 5 are attracted to magnets?

1. See if pins 2 and 5 are magnetic.
2. See if magnets 2 and 5 are really magnets.
3. Take a magnet that you know is good and see if it attracts pins 2 and 5.
4. See if pins 2 and 5 attract each other.
5. See if magnets 2 and 5 attract each other.

81.
Look at the picture once more. Here are 6 possible facts:
A. Magnet 1 is a strong magnet.
B. Magnet 1 is NOT a magnet.
C. Pin 1 is glued to the table.
D. Pin 1 is loose on the table.
E. Pin 1 is made of steel.
F. Pin 1 is NOT made of steel.
Which facts must you know in order to be sure that pin 1 is NOT attracted to magnets?

1. B and C only
2. A and D only
3. F only
4. B and E only
5. D and F only

82

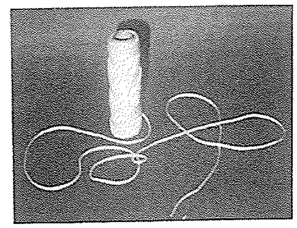
COUNTRY	AVERAGE RAINFALL INCHES PER YEAR
A	5.4
B	56.7
C	143.1
D	95.4
E	9.0
F	78.3
G	62.5

This is a chart of average yearly rainfall in 7 countries. Which countries are probably mostly desert?

1. A and B
2. B, D, F, and G
3. B and E
4. A and E
5. C and D

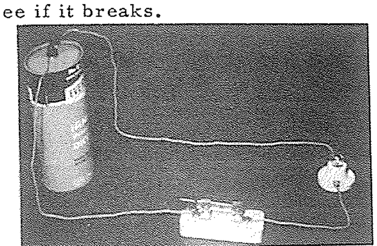
83.
Look at the chart again. Here is a list of some other facts which you can get about these countries:
A. Fertility of the soil
B. Number of farmers
C. Value of farm crops
D. Size of the country
E. Average temperature
Which would help you decide what kinds of plants probably grow in each country?

1. B only
2. A, C, and E only
3. A and B only
4. C, D, and E only
5. A and E only

84. 

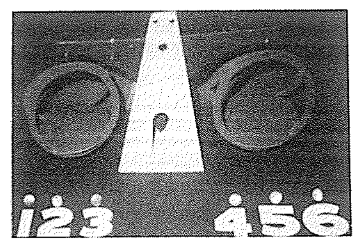
This is a picture of some string. The manufacturer claims it will hold at least 100 pounds. What is the best way to check this?

1. Hang a weight of 75 pounds on the string, and keep adding 1-pound weights until it breaks.
2. Hang a 100-pound weight on the string, and see if it breaks.
3. Let two 100-pound boys pull on each end of a piece of the string, and see if it breaks.
4. Hang 101 pounds on the string and see if it breaks.
5. Double the string and hang 50 pounds from it, and see if it breaks.

85. 

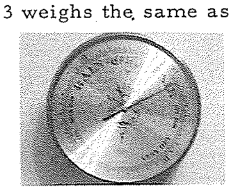
This is a picture of a bulb that is not lit even though the switch is closed. Which of these statements is NOT a possible explanation?

1. The bulb is not screwed in tightly.
2. The battery is wired into the circuit backwards.
3. The bulb is burned out.
4. The battery is dead.
5. A wire is not making good contact.

86. 

This is a picture of a balance and 6 marbles. Marbles 1, 2, and 3 all weigh the same. When marbles 1, 2, and 3 are put on one side and 4, 5, and 6 are put on the other side, they balance. Which other facts do you need to know in order to say that all the marbles weigh the same?

1. Marble 5 weighs the same as marble 2.
2. Marble 5 weighs the same as marble 2 and marble 1.
3. Marble 3 weighs the same as marble 6.
4. Marble 4 weighs the same as marble 5 and marble 6.
5. Marble 3 weighs the same as marble 5.

87. 

This is a picture of a barometer. From reading it, which of the following statements about the weather can you make?

1. The barometric pressure is rising.
2. You do not have enough information to tell what will happen.
3. The weather is changing.
4. It will rain in two days.
5. The barometric pressure is falling.

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88.

A METAL BAR

TEMPERATURE	LENGTH
10°C.	100 cm
30°C.	101 cm
50°C.	102 cm
90°C.	104 cm

This is a chart of the change in length of a metal bar as it is heated. Use the chart to figure out what its length is at 40°C.

1. 101 centimeters
2. 101.5 centimeters
3. 102 centimeters
4. 102.5 centimeters
5. 103 centimeters

89.

Use the chart to figure out what the length of the bar probably is at 100°C.

1. 103.5 centimeters
2. 104 centimeters
3. 104.5 centimeters
4. 105 centimeters
5. 105.5 centimeters

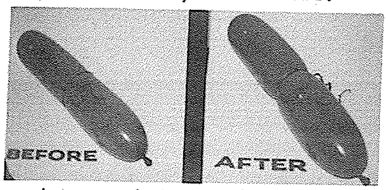
90.

BE SURE YOU ARE USING ANSWER SPACE 90

What is the best way to check the answers you gave to the last two questions?

1. Measure the bar at 100°C, and then graph all the numbers to check your answers.
2. Put your answers on the chart and see if they look correct.
3. Measure the bar at 120°C, and then make a graph of all the numbers to check your answers.
4. Measure the bar at least 5 times at other temperatures, and compare what you find with your answers.
5. Measure the bar at 40°C and at 100°C and compare what you find with your answers.

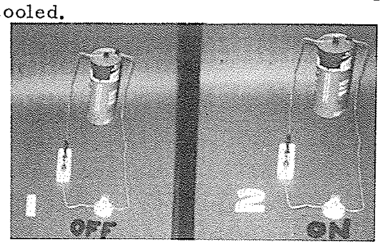
91.



These are two pictures of a blown up balloon taken before and after heating. When you heat the balloon, it gets bigger. When you cool the balloon, it gets smaller. Why?

1. Gasses get bigger when heated and smaller when cooled.
2. All things get smaller when heated and bigger when cooled.
3. Liquids get bigger when heated and smaller when cooled.
4. Plastics get bigger when heated and smaller when cooled.
5. Solids get bigger when heated and smaller when cooled.

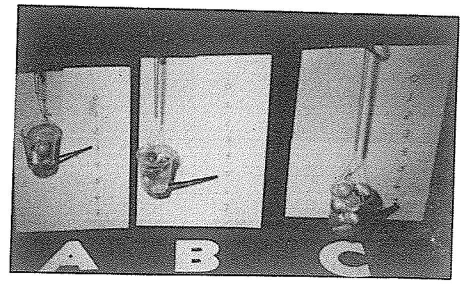
92.



These are two pictures of a battery, a bulb, a switch, and some wires. Which is the only thing you can be sure is different between picture 1 and picture 2?

1. The bulb was replaced.
2. The wires were tightened.
3. The bulb was screwed in.
4. The battery was electrically recharged.
5. Electricity is flowing through the bulb.

93.



This is a picture of three rubber-band scales which are all alike. Scale A has 3 marbles on it. Scale B has 5 marbles on it. Scale C has 7 marbles on it. If you put another marble on scale B, the pointer will probably point to about "6." Why?

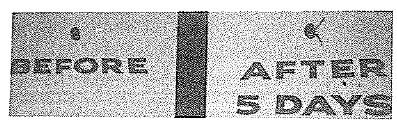
1. "6" is halfway between "5" and "7."
2. The amount a rubber band stretches depends on how much weight is pulling it.
3. Rubber bands stretch.
4. Then there will be one more marble on scale B.
5. The numbers on the scales were put on after trying out different numbers of marbles.

94.

In order to prove that "NOT ALL THINGS GET BIGGER AS YOU HEAT THEM," which of the following would you need to do?

1. Find one thing that does not get bigger when it is heated.
2. Find all the things that do not get bigger when they are heated.
3. Find one thing that gets bigger when it is heated.
4. Find all the things that get bigger when they are heated.
5. Find all the things that do not change size when they are heated.

95.



These are two pictures of a been seed taken 5 days apart. What is most likely to have caused the change in the seed?

1. Light
2. Fertilizer
3. Heat
4. Water
5. Plant food

96.

In order to make this statement: "THE COLDER A CITY IS, THE MORE SNOW IT HAS," which of the following do you need to know about some cities?

1. The average temperature of each city and the number of snowplows each has.
2. The number of days school was closed in each city because of snow.
3. The average temperature and precipitation of each city.
4. The average temperature and average snowfall of each city.
5. The average number of times it snows in each city.

MAKE SURE THAT YOUR ANSWERS ARE BLACK AND COMPLETELY FILL THE SPACES. MAKE SURE THAT YOU HAVE COMPLETELY ERASED ANY MISTAKES OR STRAY MARKS ON YOUR ANSWER SHEET. YOU MAY GO BACK AND WORK ON ANY SECTION OF THE TEST UNTIL TIME IS CALLED BY THE TEACHER.

APPENDIX D

PRE-TEST INFORMATION FOR IPS GROUP

Subject	Sex	Age(Y-Mo)	DATS Score	Ach. Score In Science
28.	F	16-2	25	43
29.	M	16-2	25	59
30.	M	15-9	55	60
31.	M	15-4	70	58
32.	F	16-8	25	36
33.	M	16-4	75	75
34.	F	16-0	75	50
35.	M	15-11	50	68
36.	F	15-11	65	57
37.	F	17-2	40	80
38.	F	15-10	55	46
39.	F	15-10	45	42
40.	M	15-7	70	76
41.	F	15-11	45	50
42.	M	16-0	85	86
43.	F	15-2	85	61
44.	F	16-1	20	42
45.	F	15-11	50	56
46.	F	16-0	75	81
47.	F	15-10	55	80
48.	F	15-11	70	55
49.	M	15-11	90	73
50.	M	16-11	65	80
51.	M	15-3	80	82
52.	M	15-9	70	72
53.	M	15-10	85	84
54.	M	16-11	60	73
55.	F	15-8	40	40
56.	M	15-9	50	56
57.	M	16-1	90	59
58.	F	15-3	85	63
59.	F	15-8	45	45
60.	M	15-6	85	52
61.	M	15-10	75	69
62.	M	16-0	80	62
63.	M	16-3	75	71
64.	M	15-6	35	57
65.	M	16-8	70	53
66.	M	15-8	40	43
67.	M	15-8	60	45
68.	M	15-7	65	56
69.	M	15-6	15	34
70.	M	15-9	65	90

APPENDIX E

PRE-TEST INFORMATION FOR EXPERIMENTAL GROUP

Subject	Sex	Age(Y-Mo)	DATS Score	Ach. Score In Science
1.	M	16-5	85	79
2.	F	16-2	80	63
3.	F	16-2	70	55
4.	M	15-7	20	51
5.	M	17-2	75	91
6.	F	15-9	50	44
7.	M	15-9	40	50
8.	M	15-10	60	38
9.	F	16-1	40	55
10.	F	15-9	40	45
11.	M	16-0	20	50
12.	F	15-9	75	65
13.	M	16-1	80	62
14.	F	16-2	75	67
15.	F	15-4	30	47
16.	M	15-2	80	71
17.	F	16-2	45	47
18.	M	16-0	60	51
19.	M	15-8	70	73
20.	M	16-3	75	42
21.	F	15-11	65	45
22.	M	15-11	60	68
23.	M	15-11	99	72
24.	M	15-8	60	58
25.	F	15-11	65	67
26.	F	15-11	60	65
27.	M	15-8	55	65

APPENDIX F

PRE-SATS TEST FOR IPS GROUP

Subject	Sub-Test 1 13 Q.	Sub-Test 2 12 Q.	Sub-Test 3 14 Q.	Sub-Test 4 17 Q.	Sub-Test 5 11 Q.	Sub-Test 6 5 Q.	Sub-Test T 72 Q.
28.	37	34	45	38	39	17	210
29.	48	36	37	51	45	15	232
30.	27	27	38	37	36	18	183
31.	32	34	39	51	40	17	213
32.	51	34	34	39	29	14	203
33.	35	45	39	48	37	16	220
34.	37	38	51	47	40	20	233
35.	36	39	32	45	40	11	203
36.	41	45	32	38	43	11	210
37.	47	42	45	69	39	17	259
38.	50	48	37	56	42	17	250
39.	21	23	34	50	35	16	179
40.	58	36	34	57	42	15	242
41.	40	31	45	52	38	19	225
42.	51	41	37	50	38	18	235
43.	47	48	40	62	47	17	261
44.	46	36	44	68	44	19	252
45.	36	32	40	51	28	18	205
46.	39	36	39	53	40	18	235
47.	30	39	37	58	35	18	217
48.	31	37	35	42	39	14	198
49.	47	43	39	61	43	17	250
50.	49	40	39	57	41	19	245
51.	48	34	51	62	31	20	246
52.	37	43	42	60	34	16	232
53.	49	44	37	55	41	19	245
54.	55	38	40	61	45	19	258
55.	41	40	42	62	46	16	247
56.	26	34	38	55	37	17	207
57.	52	51	43	58	43	17	264
58.	48	43	43	52	42	18	246
59.	37	26	37	46	45	13	204
60.	43	44	42	58	42	20	249
61.	41	46	36	44	46	17	230
62.	45	35	37	67	46	21	251
63.	55	38	36	56	37	14	236
64.	33	48	37	31	37	12	198
65.	35	32	34	47	34	13	195
66.	21	36	37	44	35	17	190
67.	48	34	35	32	46	12	217
68.	32	44	48	54	38	15	231
69.	38	36	41	50	34	11	210
70.	48	43	41	61	47	21	261

APPENDIX G

POST-SATS TEST FOR IPS GROUP

Sub-ject	Sub-Test 1 13 Q.	Sub-Test 2 12 Q.	Sub-Test 3 14 Q.	Sub-Test 4 17 Q.	Sub-Test 5 11 Q.	Sub-Test 6 5 Q.	Sub-Test T 72 Q.
28.	42	36	41	42	41	18	220
29.	48	47	39	49	43	16	242
30.	31	32	40	40	37	17	197
31.	35	38	38	51	38	13	213
32.	44	37	32	45	35	15	208
33.	33	43	31	43	36	17	203
34.	41	36	46	56	44	20	243
35.	34	37	32	39	39	14	195
36.	34	39	40	41	40	9	203
37.	49	37	42	59	35	14	236
38.	39	39	44	53	41	20	236
39.	33	29	31	33	36	19	181
40.	48	38	40	56	37	18	237
41.	40	35	45	54	38	20	232
42.	44	43	33	49	41	15	225
43.	52	58	44	66	48	19	287
44.	45	43	40	64	39	14	245
45.	42	34	43	60	41	15	235
46.	40	36	39	54	40	18	227
47.	30	37	41	57	36	17	218
48.	37	39	38	43	40	15	212
49.	43	43	42	61	36	18	243
50.	46	42	36	56	41	17	238
51.	49	37	45	62	38	20	251
52.	28	47	41	62	39	19	236
53.	34	44	43	47	37	17	222
54.	55	47	38	52	44	14	250
55.	47	32	36	57	42	15	229
56.	20	34	37	47	41	16	195
57.	54	39	42	64	46	21	266
58.	46	40	44	49	43	18	240
59.	29	24	34	44	42	17	190
60.	44	47	42	58	43	20	254
61.	49	45	34	46	45	16	235
62.	59	39	48	70	47	20	283
63.	51	43	43	68	41	23	269
64.	29	36	35	35	33	12	180
65.	30	31	34	30	42	11	177
66.	38	41	38	54	37	18	226
67.	43	40	40	47	30	17	217
68.	41	33	40	50	33	13	211
69.	38	26	42	43	37	19	205
70.	45	47	40	66	50	17	265

APPENDIX H

PRE-SATS TEST FOR EXPERIMENTAL GROUP

Sub-ject	Sub-Test 1 13 Q.	Sub-Test 2 12 Q.	Sub-Test 3 14 Q.	Sub-Test 4 17 Q.	Sub-Test 5 11 Q.	Sub-Test 6 5 Q.	Sub-Test T 72 Q.
1.	54	44	49	68	43	20	278
2.	27	26	34	25	33	9	154
3.	25	31	34	31	30	12	163
4.	43	41	41	55	36	16	232
5.	38	35	46	54	37	15	225
6.	45	37	41	54	39	18	234
7.	35	27	47	58	41	18	226
8.	28	40	43	52	38	17	218
9.	36	40	34	46	37	14	207
10.	40	36	50	49	40	20	235
11.	39	47	43	64	33	21	247
12.	36	35	39	42	42	18	212
13.	43	34	40	50	38	16	222
14.	51	44	46	58	48	18	265
15.	42	28	42	49	43	14	218
16.	35	39	40	40	27	12	193
17.	23	34	38	38	40	13	186
18.	36	34	39	42	41	15	207
19.	44	48	37	41	38	16	224
20.	42	28	25	42	38	15	190
21.	52	27	45	72	42	22	260
22.	40	33	40	58	39	19	229
23.	53	47	40	58	45	18	261
24.	37	31	45	51	36	17	217
25.	46	47	36	45	43	18	235
26.	31	34	45	44	38	12	204
27.	39	36	39	43	29	13	199

APPENDIX I

POST-SATS TEST FOR EXPERIMENTAL GROUP

Subject	Sub-Test 1 13 Q.	Sub-Test 2 12 Q.	Sub-Test 3 14 Q.	Sub-Test 4 17 Q.	Sub-Test 5 11 Q.	Sub-Test 6 5 Q.	Sub-Test T 72 Q.
1.	54	44	49	68	43	20	278
2.	27	26	34	25	33	9	154
3.	25	31	34	31	30	12	163
4.	43	41	41	55	36	16	232
5.	38	35	46	54	37	15	225
6.	45	37	41	54	39	18	234
7.	35	27	47	58	41	18	226
8.	28	40	43	52	38	17	218
9.	36	40	34	46	37	14	207
10.	40	36	50	49	40	20	235
11.	39	47	43	64	33	21	247
12.	36	35	39	42	42	18	212
13.	43	34	40	50	38	16	222
14.	51	44	46	58	48	18	265
15.	42	28	42	49	43	14	218
16.	35	39	40	40	27	12	193
17.	23	34	38	38	40	13	186
18.	36	34	39	42	41	15	207
19.	44	48	37	41	38	16	224
20.	42	28	25	42	38	15	190
21.	52	27	45	72	42	22	260
22.	40	33	40	58	39	19	229
23.	53	47	40	58	45	18	261
24.	37	31	45	51	36	17	217
25.	46	47	36	45	43	18	235
26.	31	34	45	44	38	12	204
27.	39	36	39	43	29	13	199

APPENDIX J

PRE-PROCESS TEST FOR IPS GROUP

Sub-ject	SUB-TESTS 1. 9 Q.	2. 5 Q.	3. 13 Q.	4. 12 Q.	5. 25 Q.	6. 10 Q.	7. 14 Q.	8. 8 Q.	Total 96 Q.
28.	4	4	9	12	16	3	4	3	57
29.	7	5	9	10	20	8	6	6	71
30.	8	4	11	12	19	4	5	4	57
31.	6	4	10	11	19	8	8	5	71
32.	6	3	9	11	11	7	6	3	56
33.	7	5	11	12	20	6	8	7	76
34.	6	2	8	11	15	1	6	5	54
35.	5	4	10	7	17	5	7	5	60
36.	5	4	13	9	16	6	2	1	56
37.	5	3	9	10	19	7	9	5	67
38.	7	5	10	12	19	7	5	5	70
39.	5	3	5	9	13	1	6	4	46
40.	6	5	10	12	22	7	10	6	78
41.	6	3	12	11	16	6	5	5	64
42.	8	4	10	12	22	8	9	3	76
43.	9	5	11	12	23	8	6	4	78
44.	7	5	11	11	18	4	7	2	65
45.	7	3	12	9	18	6	7	6	68
46.	5	3	11	11	22	7	8	6	73
47.	8	4	12	12	17	9	6	4	72
48.	9	5	12	10	18	7	9	5	75
49.	8	4	11	11	21	6	10	6	77
50.	6	4	10	11	20	6	8	7	72
51.	8	5	10	11	25	9	12	5	75
52.	9	2	10	12	18	4	6	5	66
53.	7	4	12	12	23	8	10	6	80
54.	8	2	9	11	13	8	9	4	64
55.	6	5	10	10	17	6	8	6	68
56.	4	3	8	9	19	4	8	2	57
57.	6	3	9	11	19	10	9	5	72
58.	8	3	11	12	19	7	7	6	73
59.	5	5	12	9	14	7	8	7	67
60.	6	5	9	12	20	3	10	5	70
61.	5	4	8	11	16	7	6	6	63
62.	5	4	7	10	17	4	7	7	61
63.	8	4	9	11	18	7	10	5	73
64.	6	3	8	8	17	5	3	4	54
65.	9	4	10	11	17	6	10	6	73
66.	5	4	9	9	19	5	7	2	60
67.	8	4	13	10	23	7	5	7	77
68.	7	4	9	11	21	3	6	3	64
69.	6	4	9	8	17	5	8	4	61
70.	5	4	10	11	25	6	5	3	64

APPENDIX K

POST-PROCESS TEST FOR IPS GROUP

Subject	SUB-TESTS 1. 9 Q.	2. 5 Q.	3. 13 Q.	4. 12 Q.	5. 25 Q.	6. 10 Q.	7. 14 Q.	8. 8 Q.	Total 96 Q.
28.	4	4	8	10	20	5	4	6	61
29.	8	2	12	10	21	7	8	4	72
30.	8	4	12	10	21	6	4	4	59
31.	8	5	9	11	24	9	10	5	81
32.	6	4	10	11	15	8	3	5	62
33.	7	4	12	12	23	8	10	5	81
34.	5	5	12	10	18	6	2	1	59
35.	6	5	12	12	23	7	8	4	77
36.	5	5	9	11	16	5	2	1	54
37.	7	4	8	11	22	9	10	6	77
38.	7	4	9	12	20	6	5	6	69
39.	5	3	10	10	15	5	7	5	60
40.	8	4	10	12	12	4	4	2	56
41.	7	4	11	11	17	5	3	6	64
42.	8	5	10	12	21	8	12	7	83
43.	9	5	11	10	24	7	13	6	85
44.	6	4	11	11	19	7	9	3	70
45.	6	5	9	11	18	4	7	5	65
46.	5	4	10	9	24	9	9	7	77
47.	8	5	11	10	22	9	9	6	80
48.	8	5	12	11	21	9	11	5	82
49.	7	5	12	11	24	8	9	4	80
50.	7	4	9	11	22	6	10	7	76
51.	8	5	13	12	24	9	11	5	86
52.	6	4	10	11	18	5	7	5	66
53.	8	5	13	12	20	8	10	7	83
54.	4	2	10	12	9	5	8	3	53
55.	6	4	10	12	20	4	6	6	68
56.	7	2	9	10	21	3	9	3	64
57.	6	5	10	11	22	8	10	4	76
58.	8	5	12	12	21	6	7	8	79
59.	2	5	12	9	17	5	8	6	64
60.	6	4	12	12	19	6	8	5	72
61.	8	5	13	12	21	8	8	7	82
62.	6	4	10	11	23	7	11	8	80
63.	6	5	11	10	19	5	10	5	71
64.	5	5	9	11	18	5	7	4	64
65.	8	4	10	12	23	7	9	6	79
66.	5	4	10	9	22	9	9	6	74
67.	9	5	12	10	22	9	5	1	73
68.	7	4	12	12	22	6	10	7	80
69.	6	5	10	10	18	5	7	5	66
70.	6	5	10	11	24	8	9	6	79

APPENDIX L

PRE-PROCESS TEST FOR EXPERIMENTAL GROUP

Subject	SUB-TESTS 1. 9 Q.	2. 5 Q.	3. 13 Q.	4. 12 Q.	5. 25 Q.	6. 10 Q.	7. 14 Q.	8. 8 Q.	Total 96 Q.
1.	9	5	10	11	23	6	11	7	82
2.	7	4	10	11	18	6	6	4	66
3.	6	4	9	11	15	6	6	7	64
4.	7	4	9	10	18	8	8	6	70
5.	7	5	8	11	23	6	10	7	77
6.	4	4	9	11	18	5	6	6	63
7.	9	3	11	12	20	7	10	5	77
8.	6	4	6	11	20	6	8	5	66
9.	7	5	9	11	16	5	10	4	67
10.	5	4	10	11	17	3	5	3	58
11.	4	5	8	9	14	6	5	1	53
12.	6	4	10	12	19	7	11	6	75
13.	6	5	6	12	21	6	6	5	67
14.	3	4	9	10	19	4	6	5	60
15.	5	3	12	10	16	5	6	5	62
16.	9	4	11	9	20	8	6	4	71
17.	6	4	11	10	13	8	5	6	63
18.	5	4	9	11	22	6	7	4	68
19.	7	3	9	10	21	8	8	4	68
20.	8	3	7	10	19	6	9	3	55
21.	6	4	11	10	18	6	6	3	62
22.	6	4	7	11	20	7	7	2	64
23.	9	5	11	11	24	8	12	7	87
24.	4	4	9	11	21	6	7	6	68
25.	8	5	11	12	19	5	6	7	73
26.	4	9	11	11	18	6	5	3	67
27.	6	2	9	10	19	8	7	5	66

APPENDIX M

POST-PROCESS TEST FOR EXPERIMENTAL GROUP

Subject	SUB-TESTS 1. 9 Q.	2. 5 Q.	3. 13 Q.	4. 12 Q.	5. 25 Q.	6. 10 Q.	7. 14 Q.	8. 8 Q.	Total 96 Q.
1.	9	5	9	11	22	8	12	5	81
2.	7	5	13	11	20	8	7	6	77
3.	6	5	11	10	16	7	8	4	67
4.	6	5	12	12	19	7	11	4	76
5.	7	5	8	12	24	5	12	7	80
6.	7	4	7	12	18	6	9	7	70
7.	6	3	13	11	20	7	12	6	78
8.	7	5	8	11	24	8	8	4	75
9.	6	5	10	10	17	3	8	4	63
10.	4	3	9	10	15	2	7	4	54
11.	5	3	6	12	18	5	5	3	57
12.	7	4	13	9	18	6	11	7	75
13.	7	5	10	11	22	6	11	6	78
14.	6	5	9	12	18	7	8	6	71
15.	5	5	13	11	18	5	6	5	68
16.	8	4	12	10	21	5	9	5	74
17.	4	5	10	11	19	5	6	4	64
18.	9	4	9	12	23	8	7	4	76
19.	7	2	9	11	18	9	9	3	68
20.	7	5	11	10	25	8	8	4	78
21.	8	4	11	11	14	7	6	3	64
22.	6	5	9	11	20	7	10	3	71
23.	7	4	11	11	25	8	8	6	78
24.	6	5	11	10	20	9	6	6	73
25.	8	5	10	11	19	5	8	4	70
26.	4	4	12	9	19	5	9	5	67
27.	6	5	11	9	21	5	13	5	75

APPENDIX N

PRE AND POST TOUS TEST FOR IPS GROUP

Subject	Pre-TOUS Test 1. 18 Q.	Pre-TOUS Test 2. 18 Q.	Pre-TOUS Test 3. 24 Q.	Pre-TOUS Test Total 60 Q.	Post-TOUS Test 1. 18 Q.	Post-TOUS Test 2. 18 Q.	Post-TOUS Test 3. 24 Q.	Post-TOUS Test Total 60 Q.
28.	10	7	11	28	11	6	15	32
29.	7	4	8	19	9	3	7	19
30.	7	8	12	27	10	3	12	25
31.	9	6	11	26	13	8	10	31
32.	9	6	13	28	10	8	12	30
33.	12	2	8	22	13	9	15	37
34.	6	7	6	19	8	8	10	26
35.	11	8	8	27	11	11	5	27
36.	11	7	12	30	11	9	11	31
37.	9	7	8	24	14	7	9	30
38.	10	10	11	31	10	5	9	24
39.	11	6	4	21	8	3	9	20
40.	10	5	12	27	10	10	12	32
41.	10	5	11	26	13	9	12	34
42.	13	7	12	32	14	8	6	28
43.	7	8	11	26	8	9	6	21
44.	7	5	9	21	11	4	12	27
45.	7	7	8	22	7	8	6	21
46.	7	8	5	20	7	5	8	20
47.	8	7	10	25	11	7	7	25
48.	14	6	10	30	15	4	13	32
49.	12	11	12	35	12	10	12	34
50.	14	12	16	42	15	12	16	45
51.	10	11	16	37	14	10	13	37
52.	12	8	8	28	2	11	5	18
53.	13	11	17	41	12	10	14	36
54.	8	8	10	26	9	7	15	31
55.	6	4	15	25	8	4	14	26
56.	11	4	15	30	10	9	13	32
57.	14	9	13	36	15	9	14	38
58.	14	6	10	30	13	9	9	31
59.	11	7	13	31	11	7	14	32
60.	11	13	13	37	12	13	10	35
61.	11	9	12	32	9	5	11	25
62.	10	9	13	32	11	7	5	23
63.	9	2	13	24	10	11	9	30
64.	10	3	13	26	10	6	17	33
65.	10	10	16	36	12	10	11	33
66.	6	10	13	29	10	10	8	28
67.	13	12	3	28	12	8	15	35
68.	7	7	6	20	7	8	10	25
69.	11	9	16	36	6	5	11	22
70.	10	9	18	37	12	5	14	31

APPENDIX O

PRE AND POST TOUS TEST FOR EXPERIMENTAL GROUP

Subject	Pre-TOUS Test 1. 18 Q.	Pre-TOUS Test 2. 18 Q.	Pre-TOUS Test 3. 24 Q.	Pre-TOUS Test Total 60 Q.	Post-TOUS Test 1. 18 Q.	Post-TOUS Test 2. 18 Q.	Post-TOUS Test 3. 24 Q.	Post-TOUS Test Total 60 Q.
1.	14	8	15	37	14	9	14	37
2.	7	8	9	24	7	3	5	15
3.	10	6	5	21	9	7	10	26
4.	10	6	9	25	8	8	14	30
5.	15	9	15	39	15	8	17	40
6.	11	10	13	34	12	9	14	35
7.	11	10	15	36	11	12	16	39
8.	10	7	7	24	10	12	15	37
9.	8	7	3	18	10	6	12	28
10.	10	10	14	34	12	10	14	36
11.	7	4	9	20	12	5	9	26
12.	6	4	11	21	8	6	13	27
13.	8	12	5	25	11	13	13	37
14.	12	11	12	35	14	7	13	34
15.	7	11	8	26	6	7	14	27
16.	9	10	9	28	14	8	13	35
17.	7	6	11	24	7	5	10	22
18.	11	9	11	31	8	4	11	23
19.	7	7	13	27	10	7	13	30
20.	11	10	6	27	13	8	3	24
21.	7	10	13	30	9	9	11	29
22.	13	8	15	36	9	8	9	26
23.	16	10	18	44	14	11	19	44
24.	8	3	7	18	8	3	9	20
25.	13	9	14	36	14	9	12	35
26.	9	10	15	34	9	12	13	34
27.	11	9	9	29	13	9	11	33

APPENDIX P

SUB-TEST HEADINGS FOR SATS, TOUS AND TEST OF SCIENCE PROCESSES

SATS 1 - Text materials
SATS 2 - Course content
SATS 3 - Student interest
SATS 4 - Student needs
SATS 5 - Laboratory work
SATS 6 - Student involvement
TOUS 1 - The scientific enterprise
TOUS 2 - The scientists
TOUS 3 - The aims and methods of science
PROCESSES 1 - Observing
PROCESSES 2 - Comparing
PROCESSES 3 - Classifying
PROCESSES 4 - Quantifying
PROCESSES 5 - Measuring
PROCESSES 6 - Experimenting
PROCESSES 7 - Inferring
PROCESSES 8 - Predicting

APPENDIX Q

LABORATORY ACTIVITIES FOR EXPERIMENTAL GROUP

EXPERIMENTS, DEMONSTRATIONS AND RELATED PROBLEMS

1. Electrolysis of water - Calculate ratio of gases produced.
2. Law of Constant Proportions - mechanical models.
3. Law of Multiple proportions - mechanical models.
4. Electrolysis - Determination of the mass of copper deposited by the passage of a known quantity of electricity.
5. "Black Box" experiments.
6. Problem - Calculate the mass of each element deposited by passing a given quantity of electricity through various solutions and salts.
7. Cathode rays and Thomson e/m experiment.
8. The Measurement of Elementary Charge (Millikan's experiment).
9. Photoelectric Effect (Electroscope Demonstration).
10. Photoelectric Effect (Phototube Experiment).
11. Spectroscopy
    a. Incandescent lamp
    b. Flames of various salts
    c. Absorption by dyes
    d. Fluorescent lamp
    e. Balmer tube
12. Radioactivity (Effect of radioactive substances on film).

APPENDIX R

ASSIGNMENT ON SCIENTISTS FOR EXPERIMENTAL GROUP

The following individuals were involved in some way in Man's development of an atomic model of matter. Prepare a profile of the individuals of your choice. Select at least one from each column. Try and identify with the person you have chosen looking for evidence of human qualities such as warmth of personality, approachibility, humour and humility. You are also to look for evidence of some of the desirable attitudes of a scientist such as curiosity, rationality, willingness to suspend judgement, open-mindedness, objectivity and intellectual honesty. You should find out the key contributions that the individual has made to scientific knowledge or theory. Important experiments should be demonstrated or explained wherever possible. For example the researcher studying Michael Faraday should plan an experiment or experiments to demonstrate some of Faraday's work relating to an understanding of the electrical nature of matter. The student doing research on Ernest Rutherford should be able to explain graphically some of Rutherford's important experiments.

COLUMN A:

1. Democritus	5th century B.C.
2. Lucretius	1st century B.C.
3. Michael Faraday	1791-1867
4. Antoine Lavoisier	1743-1794
5. Henry Cavendish	1731-1810
6. James C. Maxwell	1831-1879
7. Jons Berzelius	1779-1848
8. Joseph Proust	1754-1826
9. Isaac Newton	1642-1727
10. John Dalton	1766-1844
11. Dmitri Mendeleev	1834-1907
12. Antoine Becquerel	1852-1908
13. Marie S. Curie	1867-1934
14. Pierre Curie	1859-1906
15. Henry Moseley	1834-1915
16. Wilhelm K. Roentgen	1845-1923
17. Joseph J. Thomson	1856-1940
18. William Crookes	1832-1919
19. Max Planck	1858-1947
20. Robert A. Millikan	1868-1953
21. Charles T. R. Wilson	1869-1959
22. Arthur H. Compton	1892-1962
23. James Chadwick	1891-

APPENDIX R (continued)

24.James Franck	1882-1964
25.Gustav Hertz	1887-

COLUMN B:

1.Ernest Rutherford	1871-1937
2.Francis W. Aston	1877-1945
3.Frederick Soddy	1877-1956
4.Albert Einstein	1879-1955
5.Niels Bohr	1885-1962
6.Erwin Schrodinger	1887-1961
7.Louis de Broglie	1892-
8.George Thomson	1892-
9.Wolfgang Pauli	1900-1958
10.Werner K. Heisenberg	1901-
11.Enrico Fermi	1901-1954
12.Linus Pauling	1901-
13.Paul A. Dirac	1902-
14.George Gamow	1904-
15.Robert Oppenheimer	1904-
16.Emilio Segre	1905-
17.Edwin McMillan	1907-
18.Hideki Yukawa	1907-
19.Glenn Seaborg	1912-
20.Chen-Ning Yang	1922-
21.Tsung-Dao Lee	1926-
22.Donald A. Glaser	1926-

APPENDIX S

IPS COURSE - OUTLINE FOR CHAPTERS 6, 7 AND 8

<u>Chapter</u> <u>6</u>: Compounds and Elements

The first experiment, the decomposition of potassium chlorate, demonstrates that certain pure substances which are compounds can be broken down into simpler substances. The next group of experiments illustrate the law of constant proportions (decomposition and synthesis of water and synthesis of zinc chloride). The remaining experiments demonstrate some of the discoveries which were useful in the identification of the substances as elements. Flame test of salts are used to identify the metallic element in the salt.

<u>Chapter</u> <u>7</u>: Radioactivity

This chapter is a historical survey of the discovery of radioactivity and includes an experiment similar to Becquerel's discovery of radioactivity in uranium compounds. A second experiment involves the use of a Wilson cloud chamber to track radioactive particles. The geiger counter is also used to detect and measure radioactivity.

<u>Chapter</u> <u>8</u>: The Atomic Model of Matter

The first experiment is a black box containing three washers which are arranged on three knitting needles. The students must determine the arrangement of the washers inside by tilting, careful listening and shaking of the box. The model must be tested without opening the box.

APPENDIX S (continued)

The next experiment uses fasteners and rings to illustrate the law of constant proportions. By combining the fasteners and rings in different combinations the law of multiple proportions is also introduced. This law of multiple proportions is demonstrated by displacing the copper in two copper chloride compounds with aluminum in solution.

APPENDIX T

PROJECT PHYSICS COURSE OUTLINE FOR CHAPTERS 17, 18, 19 AND 20

Chapter 17: The Chemical Basis of Atomic Theory

The contributions of the early Greek Atomists, Leucippus and Democritus, introduces the students to atomic theory. Dalton's atomic theory and its ability to account for the laws of conservation of mass, definite and multiple proportions precedes an introduction to atomic mass and the combining capacity of the elements. The development of the periodic table is included acknowledging particularly the contributions of Newlands and Mendeleev. Examination of Faraday's discoveries and their importance in indicating the electrical nature of matter completes the chapter.

Chapter 18: Electrons and Quanta

This chapter describes the experiments and theories which confirmed the idea, suggested by the periodicity of elements, that atoms themselves have a structure. The experiments of Crookes and Thomson with cathode rays and Millikan's measurement of the charge of an electron are introduced. The discovery of the photo-electric effect by Hertz, Einstein's theory of the photo-electric effect and Max Planck's quantum theory exemplify the revolutionary ideas of physics in the early twentieth century. The impact of Wilhelm K. Rontgen's discovery of x-rays on science generally and its contribution to medical diagnosis completes the chapter.

APPENDIX T (continued)

Chapter 19: The Rutherford-Bohr Model of the Atom

The study of the absorption and emission spectra of elements, particularly that of hydrogen, led to a more sophisticated model of the atom. The experiments of Rutherford refined Thomson's theory of the structure of the atom. Bohr's contribution to atomic theory and the supporting evidence from hydrogen spectra and the Franck-Hertz experiment, which proved the existence of distinct energy states in matter, provided a further development in atomic theory. The periodic table is explained using Bohr's theory and the weaknesses of the theory are also revealed.

Chapter 20: Some Ideas From Modern Physical Theories

An attempt is made in this chapter to give the reader a feeling for some of the great developments in physics which influenced man's understanding of the atom and Einstein's relativity theories are introduced. The dualism of nature, the particle-like behavior of waves and the wave-like properties of matter completes the chapter and the unit.

APPENDIX U

FILMS AND FILM STRIPS

FILMS:

THE MILLIKAN EXPERIMENT (PSSC)

THE FRANCK-HERTZ EXPERIMENT (PSSC)

THE RUTHERFORD EXPERIMENT (PSSC)

THE PHOTO-ELECTRIC EFFECT (PSSC)

THE INTERNATIONAL ATOM (N.F.B.)

AN INTERVIEW WITH LINUS PAULING (N.F.B.)

FILM STRIPS:

THE ATOMIC THEORY

STRUCTURE OF THE ATOM

THE PERIODIC TABLE

COMPOSITION OF ATOMS

ELECTRON ARRANGEMENT AND CHEMICAL BONDS

STRUCTURE OF MATTER

ATOMIC WEIGHTS

APPENDIX V

SUMMARY OF DAILY ACTIVITIES

OF THE EXPERIMENTAL GROUP

The following is an outline of the activities of the experimental group, which is based largely on the suggestions found in the Project Physics Course, Teacher Resource Book 5: Models of the Atom.

Chapter 17 - Chemical Basis of Atomic Theory

Day I (a) The students were given selected short profiles of recent Nobel prize-winners in science. They were asked to read them and discuss them in small groups.

(b) A general discussion of those more recent scientists and their work served as the 'launching pad' for a quick journey back in time to the early Greek atomists and a brief teacher introduction reviewed developments regarding the nature of matter up to and including Dalton's atomic theory.

(c) Students were referred to the school library and outside libraries for books, journals and other resources which gave some biographical information on scientists who had contributed to an understanding of the nature of matter.

Day 2 The library was the meeting place for the second day's instructional period. The librarians had previously set out scientific journals, books and all available film strips. Each student was required to seek out information on ten scientists, that were considered by the student, to have contributed most to the development of an atomic model

Day 3 (a) A quick review of the previous day's assignments enabled a preliminary list of scientists to be drawn up. The inclusion of a scientist had to be defended by a sponsoring student. The teacher's choices were made at this time.

(b) Teacher presentation included the following:

1. Early atomic theories
2. Laws of chemical combination
3. Atomic masses
4. Combining capacities of the elements

Day 4 (a) The students were handed the assignment instructions shown in Appendix R. The students were asked to hand in the assignment to the teacher to be graded. The students were also reminded that they would be required to give background information on the scientists and their work informally in class. They would also be required to answer similar questions in a lab station setting and illustrate or demonstrate experiments to groups of their classmates.

(b) Introduction to the Periodic Table of the Elements

-Historical presentation by teacher

-Contributions of Newlands and Mendeleev.

Day 5 (a) The Periodic Table was presented as a device which reduced the complexities of chemistry to more meaningful and useful information on the basis of classification of the elements. Overhead transparencies were used extensively to illustrate the features of the periodic table which helped explain physical and chemical properties of the elements. Reference was made to the periodic table throughout the instructional period.

(b) The project on scientists provided an opportunity for individual and group discussion

(c) Some of the filmstrips listed in Appendix T were viewed.

Days 6 and 7 Lab stations and individual presentations of research findings related to scientists

The experiments and the individual presentations were scheduled at the same time. There were nine lab stations and one or two students, representing scientists, were located at each one of those stations. In most cases the students were responsible for an experiment as well as portraying his role as a well-known scientist. The students, representing Michael Faraday, were involved in planning the experiment and illustrating the quantitative relationship between electricity and matter. The following experiments were part of the laboratory work in which all students were expected to participate by moving from one station to another.

A. Mechanical Models of chemical compounds illustrating the Law of Multiple Proportions

B. Electrolysis of water and calculation of the ratio of hydrogen to oxygen produced.

C. Electrolysis - Determination of the mass of copper deposited by the passage of a known quantity of electricity.

D. Problems relating to experiment C - How much of each element would be deposited by 1 Faraday of electricity.

E. "Black Box" experiments. Students try to discover the contents of a box and how items in a box are arranged without opening the box.

Chapter 18 - Electrons and Quanta

Day 8 (a) Review of Chapter 17.

(b) Lecture and demonstration of cathode rays.

(c) Discussion of the Thomson e/m experiments in understanding the nature of matter.

Day 9 (a) Discussion of elementary particles and Millikan experiment led by teacher.

(b) Viewing of the first fifteen minutes of film "Millikan Experiment" and discussion of the film.

Day 10 (a) Teacher led discussion of the photoelectric effect and its importance.

(b) Demonstration of the photoelectric effect.

Day 11 (a) Film presentation of the "Photoelectric Effect".

(b) Discussion of Einstein's Theory of the photoelectric effect.

Days 12 and 13 Lab stations - The following experiments were set up and demonstrated by one or two students who had done some research and initial preparation on one of those experiments. Individual verbal presentations took place at the same time.

A. Cathode rays and Thomson e/m experiment

B. The measurement of elementary charge (Millikan's experiment).

C. Photoelectric effect (electroscope demonstration).

D. Photoelectric effect (phototube experiment).

E. Spectroscopy experiments using spectrometer.

(1) incandescent lamp

(2) flames of various salts

(3) absorption of dyes

(4) fluorescent lamp

(5) Balmer tubes

(6) radioactivity (effect of radioactive substances on film).

Day 14 (a) Students' presentation on the discovery of x-rays and the many technological and diagnostic applications of x-rays.

(b) Teacher presentation of Thomson's atomic model.

<u>Chapter</u> <u>19</u> - The Rutherford-Bohr Model of the Atom

Day 15 (a) Viewing of film strips on the structure of matter

(b) Discussion of the Rutherford gold foil experiment

and (c) Rutherford's nuclear model of the atom.

Day 16 Viewing and discussion of the film "The Rutherford Atom".

Day 17 Teacher presentation : Bohr model of the hydrogen atom

(a) regularities in the hydrogen spectrum

(b) the postulates

(c) successes

(d) size of the hydrogen atom

Day 18 (a) Film presentation of "The Franck-Hertz experiment".

(b) Discussion of the film and stationary states of atoms.

Day 19 Teacher presentation:

(a) Failures of the Bohr model.

(b) Periodic table in terms of the Bohr model.

Days 20 and 21 Film presentation and discussion of "An Interview with Linus Pauling".

Chapter 20 Some Ideas from Modern Physical Theories

Day 22 Teacher presentation: Discussion on relativity theory and wave and quantum theories.

Day 23 and 24 Lab stations for final student presentations on scientists including demonstrations, illustrations, reading materials, role playing or any acceptable student-initiated mode of presentation.

Day 25 Teacher presentation and discussion.

(a) Mathematical and visualizable atoms with historical references.

(b) Uncertainty principle and probability interpretation of the structure of the atom.

Day 26 Final testing.

Day 27 Student reaction to experimental course. A discussion of its strength and weakness.