AN EXPERIMENTAL COMPARISON OF INSTRUCTIONAL APPROACHES BASED ON INQUIRY SESSIONS AND REGULAR LABORATORY ACTIVITIES FOR THE DEVELOPMENT OF SCIENTIFIC REASONING AND ATTITUDES TOWARD SCIENCE

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Jacob Hiebert

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Background to the Study

The rate at which scientific knowledge has increased has had a direct influence on curriculum construction. As a result of this, new approaches to curriculum construction and new solutions for the classroom situation had to be found. It was recognized by curriculum committees that to incorporate additional knowledge into existing fact oriented courses was impossible. Instead some alternative solution had to be found.

One possible solution lay in the shift of emphasis from the presenting of factual information to the teaching of understanding. This resulted in the development of science courses which attempted to teach students how to research scientific problems and how to use this knowledge to solve other problems. Instead of emphasizing facts, students were to learn skills necessary for scientific reasoning in order to deal with new situations.

During the past decade, Manitoba schools have been affected by the scientific knowledge explosion, and serious attempts have been made to improve programs in order to achieve the stated objective. The search by teachers and curriculum directors has resulted in numerous changes for the schools of this province.

In many of the high schools the following courses have replaced more traditional programs: Physical Science Study Committee (PSSC) physics, Chem Study chemistry, Biological Science Curriculum Study (BSCS) biology, and Introductory Physical Science (IPS). These programs presented a more up-to-date body of scientific knowledge with a strong emphasis on understanding rather than memorization. Even though textbooks still contained a large body of factual material, the emphasis was on stressing a process, which leads to a body of facts.

The BSCS biology program came into being as a result of dissatisfaction with existing courses. Traditional biology programs were primarily descriptive in nature, with a strong emphasis on labeling diagrams and memorizing facts. This method served its purpose in the past, but with the tremendous increase in knowledge it became impossible to use the traditional method in a meaningful way. The first stage in an attempt to resolve this problem was the organizing of the BSCS Steering Committee by the American Institute of Biological Sciences (AIBS), a professional society representing 85,000 biologists.[1]

This steering committee was to formulate a basic policy with the intent of improving secondary school

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[1]Don E. Meyer and Virginia M. Dryden (eds.), Biological Science: An Inquiry Into Life (New York: Harcourt, Brace & World, Inc., 1963), p. xvii.

biological education. Because of the present rate of scientific advance, the committee decided against the traditional selective approach in presenting biological material. The selective approach, the arbitrary selection of material from a vast body of information, was rejected because it would be meaningful only to a limited number of students. The committee decided to shift the emphasis to an investigative process.

This change in emphasis was made to help students understand what science really is. According to the editors of the BSCS program science is,

> . . . not a modern magic but a variety of ways of finding out verifiable information and building up concepts and principles that adequately explain what we know of nature's ways.[2]

To achieve its objective, BSCS biology seeks to emphasize investigation and inquiry in the presentation of subject material. Bentley Glass, chairman of the BSCS committee in 1962, expressed the sentiment of the committee by stating:

> We are agreed that the boy or girl in school cannot comprehend the nature of science by learning facts about nature. Instead, real participation in scientific enquiry and as full a participation as possible should be provided.[3]

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[2]Don E. Meyer and Virginia M. Dryden (eds.), Biological Science: Student Laboratory Guide (New York: Harcourt, Brace & World, Inc., 1963), p. ix.

[3]Bentley Glass, "Renascent Biology: A Report on the AIBS Biological Science Curriculum Study," The School Review, Vol. 70 (Spring, 1962), p. 18.

The 1962 Annual Report of the BSCS made the following claim about the program:

> BSCS high school biology put a greater stress on laboratory work than do traditional texts. Teachers using these materials reported spending more than double the class time in the laboratory than they had previously with traditional materials. Furthermore, the traditional illustrative types of laboratory exercise is de-emphasized and stress is given to investigative exercises which introduce the student to the inquiring processes of science.[4]

The primary aim in BSCS biology is to expose students to experiences in which observations must be made, experimentation takes place, hypotheses are formed, and given information is verified. In order to provide the opportunities to investigate and inquire, the course was structured as a laboratory-centered method of instruction. These laboratory experiences were to develop in students the skills necessary for scientific reasoning essential for meaningful inquiry.

Accepting the BSCS philosophy and objectives as outlined for the yellow version biology program,[5] the question of whether these objectives are really achieved still seems uncertain according to the literature reviewed. Laboratory activities as outlined in the manual accompanying the text may not really provide the experiences necessary to develop scientific reasoning skills. The purpose

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[4]"About BSCS Biology," BSCS Newsletter, Annual Report, XVII (1962), 8.

[5]The yellow version is one of three programs developed by the BSCS committee.

of this study was to investigate another method of presenting laboratory work in order to determine whether it is more effective in developing scientific reasoning skills.

The alternative method investigated in this study involved the use of discussion techniques instead of following the outline given in the yellow version of the laboratory manual. Laboratory exercises were re-structured in order to present the material as problem situations to be analyzed by the students.

Statement of the Problem

The purpose of the study was to compare experimentally the effectiveness of two different approaches to laboratory work.

This study compared the development of scientific reasoning skills in Treatment A, an instructional method using the outline given in the laboratory manual, with Treatment B, an instructional method using inquiry sessions (discussion techniques). More specifically, the questions of major interest were:

1. Is Treatment B as effective as Treatment A in developing scientific reasoning skills?

2. If a significant difference exists between the treatments, which one is more effective?

3. Is the attitude towards science in general different in the two treatments?

4. Does the treatment influence a student's

attitude towards the laboratory activity?

Two areas investigated in addition to the major interests were:

1. Is there a difference in the level of scientific reasoning skills between the sexes?

2. Is there a difference in the level of scientific reasoning skills between students taking only one science (BSCS biology) and students taking more than one science subject?

Hypotheses Tested

The following null hypotheses were tested in this study:

Ho_1: There is no statistically significant difference in the scientific reasoning ability as measured by the Sequential Test of Educational Progress (STEP)[6] for science between students in Treatment A, the control group using the laboratory manual, and students in Treatment B, the experimental group using the inquiry session.

Ho_2: There is no statistically significant difference in the scientific reasoning ability as measured by the STEP for science between the sexes.

Ho_3: There is no statistically significant difference in the scientific reasoning ability as measured by the STEP for science between students taking one science (BSCS biology) and students taking more than one science subject.

Ho_4: There is no statistically significant difference in attitude towards science as measured by the Student Attitude Toward

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[6]See Appendix B

Science (SATS)[7] test between students in Treatment A, the control group, and students in Treatment B, the experimental group.

Ho_5: There is no statistically significant difference in attitude towards laboratory work as measured by the SATS sub-test 5 between students in Treatment A, the control group, and students in Treatment B, the experimental group.

Significance of the Study

The introduction of the BSCS biology program in the schools of Manitoba has resulted in a greater emphasis on developing inquiry skills in students. The part of this course that proposes to teach students to think scientifically and critically is the laboratory program.

The BSCS philosophy implies that students actively involved in their laboratory program are being trained to become investigating, inquiring "scientists." This objective, the teaching of inquiry skills, was not questioned in this study. The purpose of this study was to evaluate a series of laboratory exercises in order to determine their effectiveness in achieving the stated objective.

The present trend in education seems to be towards more flexibility in science course content and teaching methods.[8] In view of this trend it is important that a

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[7]See Appendix C.

[8]The Core Committee on the Reorganization of the Secondary Schools, Interim Report of the Committee, A Proposal For the Reorganization of the Secondary Schools of Manitoba (Province of Manitoba, November, 1970), p. 3.

study be undertaken to evaluate the effectiveness of courses in order to make value decisions.

Theoretical Assumptions

According to the STEP test manual the skills necessary for scientific reasoning are the following:

1. Ability to identify and define scientific problems
2. Ability to suggest and screen hypotheses
3. Ability to select valid procedures
4. Ability to interpret data and draw conclusions
5. Ability to evaluate critically claims or statements made by others
6. Ability to reason quantitatively and symbolically.[9]

A basic assumption in this study was that the categories of scientific reasoning outlined in the STEP test manual were also the skills the test actually measured, and that the test therefore measures the ability to carry on scientific reasoning. It was assumed that an inquiry session, based on McREL's major factors in inquiry, develops scientific reasoning skills. This assumption was based on similarities between the McREL factors in inquiry and the abilities the STEP test is designed to measure.

The Mid-Continent Regional Educational Laboratory

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[9] STEP Manual for Interpreting Scores (Los Angeles: Educational Testing Service, 1957), p. 7.

(McREL) study of inquiry lists the following as major factors in inquiry:

1. Formulating a problem
2. Formulating hypotheses
3. Designing a study
4. Executing the plan of investigation
5. Interpreting the data or findings
6. Synthesizing knowledge gained from investigation.[10]

It was assumed that the SATS test measuring attitudes towards science was valid.

Definitions

Certain terms are being used in a specific sense in this study; an explanation seems desirable.

Biology. This refers to the yellow version of BSCS biology used at the grade 12 level.

Laboratory manual. This refers to the collection of laboratory exercises accompanying the BSCS, yellow version, textbook.

Inquiry session. This refers to an investigative approach to the study of a problem, following the method

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[10] R. M. Bingman, ed., Inquiry Objectives in the Teaching of Biology (Kansas City: Mid-Continent Regional Educational Laboratory, 1969), p. 14.

described by Schwab in his "Invitations to Enquiry"[11] and the method used in the BSCS Inquiry Slide Series.[12] The background information of a problem is given and data is provided as necessary. The inquiry session began by raising a problem to which students were invited to respond. These responses were dealt with by asking diagnostic questions in order to help students see the appropriateness of their answers. The BSCS inquiry slides are similar to Schwab's inquiry problems except that the slides are used to present the problem. According to the Sampler Handbook accompanying the slide series,

> . . . students become involved in observing, comparing, classifying, questioning, hypothesizing, designing investigations, evaluating and analyzing data, interpreting, inferring, and applying knowledge to new situations.[13]

Treatment A. This refers to the method as outlined in the laboratory manual accompanying the yellow version of BSCS text. It includes the following activities:

1. A pre-lab, which involved a brief discussion of the activities in the exercise to draw attention to significant procedures and techniques

2. A laboratory activity in which students followed the prescribed procedure in the exercise and answered the

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[11] Joseph Schwab, Biology Teachers' Handbook (New York: John Wiley and Sons, Inc., 1963), p. 49.

[12] Sampler Handbook BSCS Inquiry Slides (New York: Harcourt, Brace & World, Inc., 1969).

[13] Ibid., p. 6.

questions. Assistance was given when requested

3. A post-lab, which involved a discussion of the results and a summary of possible data.

Treatment B. This refers to the method using the inquiry sessions. The laboratory manual was not used by the students during the discussion period. The same laboratory exercise covered in Treatment A was re-structured to form a problem to be discussed and analyzed. The teacher was a discussion leader giving some kind of focus and direction, but at the same time permitting the freedom necessary for honest inquiry. Inquiry sessions involved the formulation of hypotheses, evaluation of data to determine its significance, designing of experiments and forming conclusions from data.[14]

Students taking one science. This refers to the students in the study taking only grade 12 BSCS biology as a science in addition to four non-science subjects.

Students taking additional science subjects. This refers to those students taking grade 12 BSCS biology plus chemistry and/or physics in their program of studies.

STEP. This refers to the Sequential Test of Educational Progress in Science, form 2A, developed by Educational Testing Service, Los Angeles, California.

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[14]See Appendix D.

SCAT. This refers to the School and College Ability Test, form 2A, developed by Educational Testing Service, Los Angeles, California.

SATS. This refers to the total score on the Students Attitude Toward Science test developed by R. L. Hedley in the course of research at the College of Education, Michigan State University, East Lansing, Michigan, in 1966.

Design of the Study

This study involved 113 students in four grade 12 biology classes at Vincent Massey Collegiate, Fort Garry, Manitoba. The four classes were combined to form two groups: a control group and an experimental group. The socio-economic status, according to a subjective evaluation, of the community served by the school is dominantly middle to upper-middle class. In this regard the students in the study may not be considered a representative sample.

The school operated on a ten-day teaching cycle with six fifty-minute periods each day. Each class was assigned to nine periods of biology per teaching cycle. The experimental treatment was conducted over a period of 3 months.

Laboratory periods were conducted during each teaching cycle to correlate with the material covered in the textbook. For this reason no specific periods in the teaching cycle were assigned to laboratory work. Students in Treatment A, the control group, worked in pairs during the laboratory activities. Since Treatment B, the experimental group, was a discussion group, no pairing of students was necessary. Students were permitted to discuss ideas with other members in the class.

Students were given the SCAT, STEP and SATS tests prior to placement in either of the treatment groups.

The SCAT test was given as a measure of the student's capacity for academic pursuit and formed the basis for a comparison of the control and experimental groups.

The STEP and SATS tests were administered again following the treatment. The results obtained from these two tests before the treatment formed the pre-test scores and the results obtained after the treatment were considered the post-test scores. In view of the time period between the pre-test and post-test it was considered acceptable to use the same form in each case. The difference between the pre-test and post-test scores was considered an indication of the effect of the treatment.

As stated earlier, the two groups were taught in the following manner: Treatment A followed the outline as given in the laboratory manual and Treatment B was involved in specially prepared inquiry sessions.

Treatment of Data

The primary interest of this study was to determine the effects of two different methods of handling laboratory work on the development of scientific reasoning ability.

A second consideration was to study the changes in attitude towards science as a result of the treatment received.

SCAT scores were used as indicators of student academic ability in order to compare students in Treatment A and students in Treatment B prior to the treatment. The four classes involved in the study were combined to form two groups on the basis of the SCAT scores. Combining class sections one and two to form one group, and sections three and four to form the second group, resulted in the formation of two groups with a small difference in the SCAT mean scores.

The STEP pre-test scores were used as indicators of prior knowledge of scientific processes. The difference in the pre-test and post-test results was considered an indicator of the effect of the treatment used.

The SATS test scores from the pre-test were used as indicators of student attitude towards science prior to the treatment, and the change on the post-test was considered to be a result of the treatment.

The following 10 variables were considered in the analysis:

1. SCAT Verbal scores
2. SCAT Quantitative scores
3. STEP pre-test scores
4. STEP post-test scores
5. SATS Total pre-test scores
6. SATS Total post-test scores

7. SATS Sub-test 3 pre-test scores
8. SATS Sub-test 3 post-test scores
9. SATS Sub-test 5 pre-test scores
10. SATS Sub-test 5 post-test scores.

Numerous comparisons of mean scores were made in the study to determine if any trends resulted from the treatments. The statistical treatment included an analysis of covariance to determine the significance of the difference in scores between the following:

1. Student scores in Treatment A and Treatment B
2. Boys and girls scores
3. Scores obtained by students taking one science and students taking additional science subjects.

The Verbal and Quantitative SCAT scores and the STEP pre-test scores were used as covariates in comparing STEP post-test results. The SATS pre-test scores were used as the Covariates for the SATS post-test results.

The SCAT Verbal scores were also used to split the groups of students in the treatments into three ability levels. The "t" test was used to compare pre-test with post-test scores in the three levels and the two treatment results in each level to determine the statistical significance of each difference.

Delimitations

The study was limited to one school involving only grade 12 biology students. Four classes with a total of

113 students formed the sample.

As one teacher was involved in the study the role of the teacher in inquiry teaching was not considered as a variable.

A series of 10 consecutive experiments, extending over a three month period, was used in the study.

Limitations

The students involved in the study were assigned to specific classes on the basis of course selection. This was the consequence of an administrative condition which made it impossible to randomly select students for the study.

Consideration in this investigation was limited to comparisons involving only science courses, and effects of various combinations of non-science subjects were not considered.

No attempt was made to investigate the student's background experiences in the home, society, church and work to determine their influences on the results obtained.

The results of the study may have been affected by the use of the same form of the STEP and SATS for both the pre-test and post-test. Any practice effect due to using the same form would impose a limitation on the study.

A subjective evaluation of the subjects in the study suggested that the sample was not representative with respect to the socio-economic background. A fairly large number of the students in the sample were from middle and upper-middle class homes.

The results obtained in each of the treatments may have been influenced by teacher preference for a method, and so the involvment of only one teacher becomes a limitation. Any variations in teaching the course content, beyond the experimental work, were not considered in this study.

No consideration was given to differences in efficiency in handling multiple-choice test questions. Any difference that may have existed was considered to be insignificant.

CHAPTER II

REVIEW OF LITERATURE

Numerous articles and books have been written on the topic of inquiry. Since there is a great deal of information on this topic, this chapter will be limited to three specific areas. The first section will be limited to research and articles dealing with the components and definitions of inquiry. The second section will deal with the use of inquiry in the classroom. The third area will include a review of research comparing the inquiry method of teaching with conventional methods.

Description of Inquiry

In 1964, Turner did an analysis of scientific inquiry as used in the BSCS laboratory program in order to determine the meaning of inquiry, as used by the authors of the program.[1] In his investigation he included a study of the meaning of scientific inquiry as used by the BSCS representatives and the extent to which the BSCS laboratory exercises reflected the elements of inquiry. Turner became concerned about the claims in the writings of BSCS representatives with respect to scientific inquiry and states

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[1]G. C. Turner, "An Analysis of Scientific Enquiry as Used in a BSCS Laboratory Program." (unpublished Ed.D. dissertation, Arizona State University, 1965).

his problem briefly as follows:

> The lack of a clear definition of what comprises scientific enquiry, and yet the confidence with which the BSCS states the laboratory work conveys an understanding of enquiry, makes the foregoing suspicion of major importance and worthy of intensive investigation.[2]

In order to determine the elements of scientific inquiry as used by the BSCS representatives, Turner analyzed 167 books, pamphlets, newsletters, circulars, and journals containing materials published by the BSCS relating to their program. From this material he selected 78 descriptive statements as elements of scientific inquiry. These statements were developed into a check-list which Turner used as an operational definition for the analysis of a number of laboratory exercises in the yellow version manual.

The 78 statements were categorized under the following major sections:

A. Problems are derived through critical and creative thinking

B. Various intellectual and technical factors influence the formulation of a problem

C. Extensive reading and discussion are needed to obtain background for an investigation

D. The way the problem is stated determines direction the research will take

E. Structure of an hypothesis determines its usefulness

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[2] Ibid., p. 6.

F. Design of an investigation delimits the information obtainable

G. Refinements in design must be developed as needed

H. Appropriate sampling techniques must be selected for the research design

I. The role of experimental control must be understood

J. Technical knowledge must be obtained for carrying out an investigation

K. Data must be carefully selected

L. Data must be organized for greater usefulness

M. Interpretations are based on the way evidence is "ordered"

N. Interpretations of data are guided by theoretical factors

O. Conclusions are personal formulations

P. Conclusions must be verifiable to be acceptable

Q. Conclusions must be presented in an acceptable manner.[3]

The preceding outline is not the expected form of a definition for scientific inquiry. It does suggest a problem of definition. This problem is the difficulty in presenting a clear, simple definition. It was recognized by Bentley Glass when he said, ". . . one must learn . . .

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[3]Ibid., p. 17.

how varied and refractory to definition are the methods of science."[4]

After a study of the literature relating to scientific inquiry Turner came to the following conclusion:

> Thus any attempt at definition or at listing steps in a sequence under the rubric of scientific enquiry would be unrealistic. Rather the elements gleaned from this investigation are presented as examples of the kinds of things one does when engaging in scientific enquiry according to the writers of the BSCS materials.[5]

At another point Turner says,

> Thus, original, individualized modes of attack restricted only by the ingenuity and imagination of the inquirer seem to mark the spirit and to some extent the forms of scientific enquiry.[6]

The check-list of activities reflective of scientific inquiry was used to analyze 10 laboratory exercises selected from the yellow version manual. In these exercises the elements of scientific inquiry were touched upon, however many of the components of the elements were not found in any of the exercises examined. Turner lists the more serious omissions as follows:

1. The problem is always given or inferred and students are told what to do

2. Exercises give very little background information

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[4]Bentley Glass, "Background," <u>BSCS Newsletter</u>, 12 (February, 1962), 5.

[5]Turner, op. cit., p. 43.

[6]Ibid., p. 53.

3. Seldom are students required to form a clear statement about the problem

4. Experimental design is usually developed

5. Experimental design is not considered as one among others, is not defended or its limitation not discussed

6. The possibility of other variables is not given proper consideration

7. Technical problems which may arise are not considered

8. Data collection is prescribed leaving no choice

9. Introductory comments guide the investigation

10. Assumptions underlying interpretations are not required

11. Relationships from among observations are not applied to new situations

12. Students are not required to make alternate conclusions nor account for data that may not support conslusions.

The preceding omissions led Turner to the following conclusion:

> This omission of components and the necessity of using inference to locate elements suggests that these laboratory exercises may not be presenting the picture of scientific enquiry intended. The following may be implied: (a) Students may carry out these laboratory exercises with only a vague awareness of the processes in which they are engaged. (b) Students may participate in these laboratory activities without acquiring the

depth of understanding expected.[7]

Addison E. Lee in his article, "Main Points of the McREL Document" defines inquiry as,

> . . . a set of activities directed toward solving an open number of related problems in which the student has as his principle focus a productive enterprise leading to increased understanding and application.[8]

The activities referred to in the definition are further defined in the article as "factors in inquiry" and include (i) problem formulation, (ii) formulation of hypotheses, (iii) designing investigations, (iv) executing the plan of investigation, (v) interpreting data or findings, and (vi) synthesizing knowledge gained from investigations.[9]

Inquiry teaching, according to Lee, will develop more independent inquirers who will ask questions about themselves and their environment in the process of learning.

Suchman defines inquiry as, ". . . the active pursuit of meaning involving thought processes that change experience to bits of knowledge."[10] This pursuit includes observing, theorizing, experimenting and theory testing. These activities require a climate of freedom to pursue the

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[7]Ibid., p. 97.

[8]Addison E. Lee, "Main Points of the McREL BSCS Document," American Biology Teacher, November, 1970, p. 475.

[9]Ibid.

[10]J. Richard Suchman, Developing Inquiry (Chicago: Science Research Associates, 1968), p. 1.

meanings the students want to pursue. Freedom is also necessary since there is no single, ideal approach to inquiry. Inquiry is, according to Suchman, ". . . a purposeful activity, a search for greater meaning into some event, object or condition that raises questions in the inquirer's mind."[11]

Suchman divides inquiry into four types of action; searching, data processing, discovery and verification. Searching involves the selection of information relating to the problem from a larger body of observations. The data selected must be processed, which consists of reducing information to principles and relationships. Discovery refers to the "assimilation of perceived data within the framework of a conceptual system."[12] Verification is the testing of the conceptual system by examining all the data to determine whether the system is supported by the data.

A study of the literature makes it very clear that there is really no comprehensive, simple definition for the inquiry method of instruction. Operational definitions have been suggested but they also have limitations since inquiry is an individualized process. There is no rigid sequence that is followed by true inquirers, but patterns may still be constructed to help teachers in the training process.

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[11]J. R. Suchman, Inquiry Development Program (Chicago: Science Research Associates, Inc., 1966), p. 15.

[12]J. R. Suchman, The Elementary School Training Program in Scientific Inquiry , (research project, University of Illinois, 1963), p. 11.

In summary, it can be said that inquiry involves activities directed towards solving a problem or finding meaning in events. The sequence of these activities may not be completely predictable.

Using Inquiry

Suchman has made a very significant contribution to the use of inquiry in elementary classrooms. In 1966 Science Research Associates published a program developed by him for the teaching of physical science. In 1968 a similar program was published for the teaching of earth science. The primary aim in both Inquiry Development Programs was to, ". . . help the naturally inquisitive child . . . become an inquiring adult--a self-confident, reasonable person who can and will investigate the world for his own satisfaction."[13]

In these new programs the teacher's role was very different from ordinary classroom lessons. According to Suchman, his role was:

1. To establish and maintain the procedures of operation
2. Make new information available, and
3. Guide the development of inquiry skills and strategies.

Time and energy are required to make the inquiry method

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[13] Suchman, Inquiry Development Program in Physical Science, 1966, p. 3.

sussessful.

The following materials were basic in Suchman's program:

1. A problem book which focused attention on specific problems with sufficient data to start the investigation

2. Problem-episode films which presented a wide range of processes without verbal explanations

3. Experimental kits in order to experimentally investigate certain topics

4. An idea book which gave additional ideas to draw upon in the search for viable theories, and

5. Resource books of a descriptive and exploratory nature.

The inquiry sessions in Suchman's program usually began with a problem-episode film or demonstration presenting a discrepant event to stimulate thinking. The initial questions involved the clarifying of the problem which was presented. This was followed by attempts to construct a theory to account for the event. After formulating a hypothesis, data was collected to test the theory.

In an article discussing the teacher's role in inquiry teaching of students, Massialas makes the following statement:

> Their teachers, instead of acting as dispensers of ready made conclusions, are teaching them to think for themselves and to use the methods of disciplined inquiry to explore concepts in various domains of

knowledge and to study the world about them.[14] The teacher's role is to create a climate in the classroom that encourages student participation and freedom to express divergent points of view in order to test them.

Teachers stressing the process of inquiry will perform the following roles, according to Massialas:

1. The teacher plans activities and organizes the sequences of materials to be used

2. The teacher introduces new materials to make it a "discovery episode," or provocative situation

3. The teacher raises questions, redirects questions addressed to him, assists in probing to find support for arguments and encourages the exchange of ideas

4. The teacher performs routine management in a classroom which should include assistance to students executing inquiries of their own

5. The teacher rewards students by encouraging or praising them

6. The teacher is a value investigator. He refrains from taking a firm position during the introductory phase of discussions involving values, and thus he gives students the opportunity to inquiry and to develop value judgments that are publicly defensible.[15]

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[14] Byron G. Massialas, "Teaching and Learning Through Inquiry," Today's Education, May, 1969.

[15] Ibid.

Learning through inquiry changes students attitudes towards knowledge. They begin to recognize that facts accepted today are subject to change in the light of new information. In this way students are being prepared for the continuous revision of knowledge.

Massialas believes the inquiry and discovery method is not limited to superior students.

> Not only superior students but also those who have lower-than-average IQ scores prove to be capable of performing such intellectual operations as defining a problem, hypothesizing, drawing logical inferences, gathering relevant data, and generalizing.[16]

J. L. Carter in his article, "The Authoritarian versus the Inquiry Approach," emphasizes the role of teachers in developing a philosophy of inquiry in students. He says the primary function of the teacher is not the imparting of factual knowledge, but the developing of thinking in students. Carter's position is seen in the following statement:

> The true value of science cannot be imparted by indoctrinating students and requiring them to memorize a text, and we cannot hope to produce a rational, thinking person by such methods.[17]

Paul DeHart Hurd presented a new challenge to the teaching of inquiry in his article "Inquiry Objectives for the Teaching of Biology in the 1970s."[18] He feels too much

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[16] Ibid.

[17] J. L. Carter, "The Authoritarian versus the Inquiry Approach," School Science and Mathematics, 1967, p. 688.

[18] P. D. Hurd, "Inquiry Objectives for the Teaching

much emphasis has been placed on the means by which scientists find answers to questions. Most of these problems are too far removed from the student and therefore unrealistic. Inquiry should develop in students the skills necessary to deal with problems they face. Students must develop skills necessary in the application of knowledge. This can be accomplished by dealing with real-world problems where the answers are usually not as clean and neat as the laboratory activities.

In order to deal with the biological problems of real-life students must develop the skills necessary for choosing actions, sorting, ordering, applying, and evaluating information. These are the inquiry skills and thinking processes essential to deal with problems of contemporary living.

A problem encountered in inquiry teaching, according to Hanson in his article "Alternate Theory Formation by Students,"[19] relates to teacher response to alternate theories submitted by students. Teachers using inquiry have a tendency to reject other possible theories arising from a discussion in order to direct inquiry to a specific concept or theory. This type of inquiry, in which freedom is limited, is dishonest. Teachers using inquiry must

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of Biology in the 1970s," American Biology Teacher, XXXII (December, 1970), 553-54.

[19] R. K. Hanson, "Alternate Theory Formation by Students" (paper presented at the National Association for Research in Science Teaching, March, 1970, Minneapolis, Minn.).

recognize that data-to-theory relationships obvious to them are not as obvious to the students. Students may have other logical explanations that must be considered.

A second problem mentioned by Hanson relates to the objectives of inquiry teaching. He suggests inquiry teaching is not the best method for presenting established theories or knowledge. He believes the primary objective of inquiry teaching should be the preparation of students for research.

Esler[20] suggests that inquiry as a method of teaching has received only limited acceptance in public schools because of the uncertainty and general lack of understanding that surrounds the inquiry concept. Simple definitions of the concept have only resulted in greater difficulty for the inquiry-teacher instead of resolving the problem.

After raising the problem of defining inquiry, Esler illustrates how to structure an inquiry lesson. The teacher must have a single purpose and a clearly defined scientific principle at which he expects the students to arrive before he begins the lesson. The inquiry session may be introduced in one of a number of ways. The methods suggested include using a discrepant event, an anecdote with or without demonstration, presentation of data, or using pictorial stimulation. After introducing the problem,

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[20] William K. Esler, "Structuring Inquiry for Classroom Use," School Science and Mathematics, May, 1970, pp. 454-58.

one of three techniques may be used to deal with the inquiry activity. The teacher may ask questions to stimulate thinking and answers from the students, as well as directing the discussion towards the desired goal. Another technique involves the students in asking the questions and the teacher responds with a yes or no answer. A third technique involves the use of experimentation in situations where the investigator has no prior knowledge of the outcome.

Most of the articles dealing with inquiry as a method of teaching were strongly in favor of using the inquiry approach to instruction. The next two articles in this review present a different point of view.

Harry Wong presents his position in the article, "Inquiry Training in a Biology and Research Program."[21] He claims the inquiry method of instruction does not teach students to think, since every child is born with the ability to think. Inquiry teaching is rather a process of helping students develop a technique of learning, and the development of a laboratory-centered program does very little to achieve the objectives of the inquiry-teacher. Due to the highly structured laboratory exercises in the existing programs, he believes, we can at best hope to produce trained technicians.

Wong suggests the best approach to biology is to

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[21] Harry K. Wong, "Inquiry Training in a Biology and Research Program," School Science and Mathematics, October, 1965, pp. 593-96.

present it within the framework of the "Great Idea." There are certain main "Ideas" in every discipline that a student must first understand and then he can move to the unknown. The organized facts, concepts, and principles forming the "Great Idea" help a student see relationships between parts and give meaning to knowledge. Presenting materials in this context prepares the student to carry on inquiry in an actual research program.

Wong seems to suggest that the only meaningful inquiry, is inquiry arising out of a classroom investigation. The student must want to research a problem emerging from the classroom discussion, instead of being assigned a problem in a laboratory manual.

Newton[22] suggests the role of the teacher as being a guide and advisor is a "fad" in education, and any criticism of this role is given no consideration. Criticism in the article is directed at those who promote inductive teaching of science. This method of teaching, he says, is intellectually dishonest for the following reasons:

1. Teenagers need the security of authority which is found in a structured and organized lesson

2. It doesn't give students an honest preparation for college life. A basic body of facts is still required for college life

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[22]David E. Newton, "The Dishonesty of Inquiry Teaching," School Science and Mathematics, October, 1965, pp. 807-10.

3. It does not honestly reflect the nature of science since science is not all process

4. Inquiry teaching has not been shown to be effective and efficient as a technique of teaching.[23]

Newton does not suggest that inquiry teaching should be abandoned, but he does say that traditional methods are being neglected and unfairly abused. This has happened because teachers were swept up in an educational "fad."

Review of Research

Suchman directed a study of inquiry teaching in 1961. The study involved twelve teachers and extended over a period of 24 weeks. All of the teachers involved were given an eight-week summer training program at the University of Illinois in the summer of 1960. Each teacher was assigned to a grade six class for the inquiry-teaching session. All "non-inquiry" lessons were conducted by a second teacher. Each inquiry class was given one or two inquiry sessions per week for the 24 weeks. Control groups were selected to compare with the inquiry groups in intelligence and general academic ability.[24]

Problem-episode films, tape recordings of previous inquiry sessions, discussion of the inquiry process, and

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[23] Ibid., p. 807.

[24] J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry (Project of the Illinois Studies in Inquiry Training, College of Education, University of Illinois, Urbana, Illinois, 1962).

examination of searching and data processing were part of the inquiry experience. The control groups were given the same films as the inquiry group but instead of discussion they were taught the principles by expository and didactic methods. Demonstrations, reading assignments, and regular laboratory experiences were part of the control groups' activities.

Suchman arrived at the following conclusions from the results of the study:

1. Inquiry training is accompanied by conceptual growth equal, if not superior, to traditional expository methods of teaching

2. The trial and error searching of inquiry is more time consuming than the expository method

3. Students in the inquiry group were much more fluent in asking questions than students in the traditional method

4. Students in the inquiry group expressed a greater degree of motivation in their work than the traditional group

5. There was more freedom to find data in the inquiry group than in the traditional group.

The article "The Triple 'i' Program"[25] describes a study in training for inquiry teaching, directed by Leonard

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[25]B. C. Leonard and F. J. Gies, "Improving Instruction Through Inquiry: The Triple 'i' Program," <u>School and Community</u>, February, 1970, pp. 8-9.

and Gies. Thirty teachers were involved in a 32-week in-service course consisting of workshops, inclass activities, and independent study. The program was a cooperative venture of the Center for Educational Improvement at the University of Missouri, Mid-Continent Research Education Laboratory and the Springfield, Missouri public schools.

The purpose of the in-service training was to change teacher behavior in order to change the learning process to one of inquiry and self-directed activities. A secondary purpose of the in-service was to develop packages of inquiry material to be used in the classroom to stimulate inquiry learning. A third objective was the development of an in-service teaching program.

It was recognized that numerous variables influence the learning situation, and most of them are difficult to control. Among the different factors, the teacher was considered the single most determining one. Because it is the one that is accessible and receptive to modification, it is important that in-service be organized to change teacher behavior. Teachers must be trained to utilize programs which focus on the needs of pupils in their struggle to become autonomous individuals.

An article by James Meyer,[26] "The Influence of the Invitations to Enquiry" discusses the results of a study

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[26]James H. Meyer, "The Influence of the Invitations to Enquiry," American Biology Teacher, October, 1969, pp. 451-53.

involving the use of the "Invitations to Enquiry." Forty-six first year high school students were divided into two heterogeneous classes. The two groups were found to be similar in their vocabulary comprehension, mathematics comprehension and IQ scores. Both classes were given the same treatment except for the use of the "Invitations to Enquiry."[27]

The experimental group was presented with one "invitation" each week for the entire school year for a total of 31 "invitations." No attempt was made to correlate the "invitations" with the topics studied in the yellow version of BSCS biology.

The following tests were used as pre-tests and post-tests to assess the two treatments: Test on Understanding Science, The Watson-Glaser Critical Thinking Appraisal, and the BSCS Comprehensive Final Examination.

The results from this study indicated no significant difference in the two groups in understanding of science, critical thinking ability or biological achievement as a result of the treatment.

Thomas and Snider compared Guided Discovery with Didactic methods of instruction with 8th grade pupils.[28]

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[27]Joseph J. Schwab, Biology Teachers' Handbook (New York: John Wiley and Sons, Inc., 1963), pp. 45-221

[28]Barbara Thomas and Bill Snider, "The Effects of Instructional Method upon the Acquisition of Inquiry Skills," Journal of Research in Science Teaching, VI (1969), 377-86.

Instruments were selected to measure achievement of factual-conceptual content, use of critical thinking skills, and use of problem solving skills. The instruments employed to measure inquiry skills were unrelated to the subject matter used in developing the skills. This study favored the Didactic method for the factual-conceptual achievement results and the Guided Discovery for the acquisition of inquiry skills. An interaction was found between method and intelligence. The low intelligence level in the Didactic treatment scored higher on the TAB Inventory of Science Processes than the Guided Discovery treatment. The opposite was true for the high intelligence level. The authors suggest that activities may have been too difficult to provide meaningful discovery for the low ability group and therefore they did not experience the Guided Discovery method of instruction.

Evans and Balzer[29] categorized the verbal and non-verbal behaviors of biology teachers in 40 class periods. BSCS and non-BSCS teachers were equally represented in the study. Teacher behaviors were coded as teacher-centered content development, student-centered content development. Less than 50% of the activities were found to fit into the two areas studied and only 2.78% were student-centered development activities. This meant teachers spent approx-

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[29]LeVon Balzer, "Teacher Behaviors and Student Inquiry in Biology," American Biology Teacher, January, 1970, pp. 26-8.

imately five seconds per class on student-centered scientific-process behaviors.

Balzer discusses two problems he sees in the use of inquiry. In a structured inquiry activity there is a tendency to present a series of questions that lead to guessing. The type of question asked is often one that requires prior knowledge in order to give an "acceptable" answer. A second problem relates to methods of presenting problems. Students are usually not given opportunity to observe natural phenomena in order to formulate problems and hypotheses. Background information and problems are usually presented, thus denying the student a very important experience of inquiry.

According to Balzer, the teacher may often function as a distractor from student inquiry. The teacher's role is that of a discussion leader to keep the topic in focus. Questions arising out of the inquiry must be handled with care to avoid releasing information that makes further inquiry unnecessary; nevertheless, all questions and submitted data must be honored and discussed.

In a doctoral dissertation L. K. Lisonbee[30] compared the effects of the inquiry oriented, experimental BSCS biology and traditional biology upon student achievement.

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[30]Lorenzo K. Lisonbee, "The Comparative Effects of BSCS and Traditional Biology Upon Student Achievement" (unpublished Ed.D. dissertation, Arizona State University, 1963.

The Nelson Biology Test and the BSCS Achievement Test-Comprehensive Final were used to measure achievement. The subjects for the study were selected by random sampling from a population of 3,500 tenth-grade biology students. The two treatments were stratified by low, middle and high ability sub-groups. The difference between the treatments on the Nelson Biology Test was non-significant. The only significant difference between treatments, on the BSCS Achievement Test, was found in the middle ability sub-group.

A study involving 202 college chemistry laboratory students, comparing the use of commercially prepared laboratory exercises with the inquiry method, was done by V. H. Richardson.[31] Thirteen chemistry experiments were selected for the experiment. A laboratory final examination was used as a pre-test and post-test. In this study the inquiry groups achieved statistically significantly higher scores than the students using the regular exercises.

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[31]Verlin H. Richardson, "A Study of the Inquiry-Discovery Method of Instruction in College Chemistry Laboratory" (unpublished Ph.D. dissertation, University of Oklahoma, 1969.

CHAPTER III

EXPERMENTAL DESIGN

The purpose of this chapter is to outline the nature of the experimental study involving laboratory work in BSCS Biology 300. This outline includes a discussion of the sample, course description and treatment, data collection, discription of instruments, and methods of data analysis.

Population and Sample

The sample consisted of 113 students taking BSCS yellow version 300 Biology in Vincent Massey Collegiate, one of two senior high schools in Fort Garry School Division Number 5. The school enrolment in September 1971 was 1030, and 155 of these students selected 300 BSCS Biology as one of their courses. Students in this school were assigned to one of the various sections in the course by means of a computer. This administrative condition made it impossible to regroup students for this study, and therefore intact groups were used. The biology students were assigned to five sections with reasonably equal numbers in each section. Since a large number of the students in section five were grade 11 students taking 300 BSCS Biology, this section was not included in the experimental study.

Nature and Sources of Data

The grade 12 level of biology deals with physiological and biological systems, genetics and evolution, and the appropriate levels of biochemistry in each case. These textbook topics were discussed within the framework of BSCS philosophy of presenting science as investigation and inquiry. Presentation of the textbook topics involved lecturing, discussion and question periods, answering chapter questions and discussing them, and viewing some related films. A conscious attempt was made to treat all four sections in the study alike, except during the laboratory activities.

Each one of the four sections received nine class periods during a 10 day teaching cycle. Each period was of 50 minutes duration. Laboratory exercises were done whenever it was appropriate, generally using one period for one laboratory exercise. In most cases the inquiry session involved less time than the regular laboratory activity. No attempt was made to keep the two types of laboratory activities within the same time period.

During the month of November, 1970 a series of tests were administered to the four sections selected for the experimental study. The following tests were given:

1. School and College Ability Test (SCAT)

2. Sequential Tests of Educational Progress (STEP) in Science

3. Student Attitude Toward Science (SATS)

The SCAT and STEP were each given in two sessions since the tests required more than the 50 minute period. These tests are constructed to provide for this eventuality.

The SCAT was used as a measure of the level of student ability in order to compare the control and experimental groups. On the basis of these scores the four sections were grouped into two groups, one to be assigned the control treatment, and the other the experimental treatment. Two sections were combined in each of the two treatment groups. This combining of sections was not a random selection. The sections were combined on the basis of the smallest difference in the average SCAT scores for the two resulting groups. It was found that combining sections one and two to form one group, and three and four to form the second group, resulted in the smallest difference between the SCAT means of the two groups. Sections one and two formed group A, and sections three and four group B.

An examination of the two resulting groups was made to determine the distribution of students taking chemistry and/or physics. The above combinations were found to produce the most uniform distribution of students with respect to taking additional science courses.

The matter of assigning the control and experimental treatments to the groups was decided by tossing a coin. This resulted in group A forming the control, and group B the experimental treatment. The total of 113 students was divided into two groups, with 59 in group A and 54 in group B.

The series of laboratory exercises used in this study was introduced during the third week of December 1970, and completed during the third week of March 1971. Upon completion of the treatment, the STEP and SATS tests were administered to determine the post-test scores. A factual, multiple-choice test on laboratory work was also given to measure retention of factual information.

Ten laboratory exercises were selected from the laboratory manual accompanying the BSCS yellow version biology text. These exercises were re-structured for the experimental group to form inquiry sessions instead of activity periods. In designing the inquiry sessions great care was exercised not to change the content of the laboratory exercise. The basic difference in the two treatments was found in the method of presenting information. In the inquiry session emphasis was placed on students clarifying the problem, forming hypotheses, suggesting experimental design, evaluating data and forming conclusions. These sessions were considered a discussion period and students were not required to submit a written report.

Two criterion tests were administered as pre-tests and post-tests to determine what, if any, change in scientific reasoning ability and attitudes towards the science in question were developed as a result of treatments A and B.

Characteristic of the STEP

The STEP was selected to test the level of scientific reasoning ability. This test was developed under the direction of Educational Testing Service, Los Angeles, California. In the process of test construction the committee decided to prepare a list of skills considered necessary in scientific reasoning to be used as a guide in question selection for the STEP test. The list is summarized briefly as follows:

1. Ability to identify and define scientific problems

2. Ability to suggest and screen hypotheses

3. Ability to select valid procedures

4. Ability to interpret data and draw conclusions

5. Ability to evaluate critically claims or statements made by others

6. Ability to reason quantitatively and symbolically.[1]

The test consists of sets of items. Each set has a brief description of a situation with a number of questions relating to the situation. In each question there are four choices from which the student must select one answer. Test booklets contain 60 multiple-choice questions which are divided into two equal parts. This division makes it possible to administer the STEP in two 35 minute

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[1] See Appendix B for details about the STEP.

periods.

The raw STEP score is obtained by counting the number of correct responses out of the 60 questions. This score is converted to a three-digit "converted" score which is used in the statistical analysis.

A validity study of the STEP was done by Mayer in the Newark Central High School in 1957, involving 271 seventh-grade students. The coefficient of correlation between the STEP (science) and science grades obtained in this study was .66 with a standard error of .04. A follow-up to this study, using school marks at the end of the 8th-grade, for 118 of the original students resulted in a correlation of .74. The publisher states that, "content validity is best insured by relying on well-qualified persons in constructing the tests, as was done for the STEP series. It can be judged in large measure by reviewing the tests."[2]

The reliability measure was the result of an internal analysis based on a single administration of the test. Therefore this measure is an estimate of internal consistency. Kuder-Richardson Formula 20 was used to estimate reliability and standard error, of 100 cases selected at random from approximately 4,000 tests. The reliability estimate for the STEP 2A (science) from this study was .81.

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[2]Cooperative Test Division, STEP Technical Report (Los Angeles: Educational Testing Service, 1957), p. 9.

A correlation study involving the STEP and SCAT produced the following results: STEP and SCAT Verbal correlation of .72, STEP and SCAT Quantitative correlation of .69, and STEP and SCAT Total correlation of .76.

The STEP is a measure of "power" rather than speed of performance and, therefore, sufficient time has been allowed to permit completion of the test by the students.

Characteristic of the SATS

The SATS test was chosen to measure the attitudes before and after the experimental treatment of the groups. This instrument was constructed by R. L. Hedley in the course of research.[3] The test investigates six separate areas of attitudes towards a science course as follows:

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.

Seventy-two statements make up the test, to which the students were asked to respond on a five point scale. The letters A to E were used on the answer sheet, with C representing a neutral reaction to a statement, A as strongly agree, and E as strongly disagree. Values of one

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[3]Robert Lloyd Hedley, "Student Attitude and Achievement in Science Courses in Manitoba Secondary Schools" (unpublished Doctor's dissertation, Michigan State University, 1966).

to five were assigned to each question when marking the instrument. The assigning of values is based on the Likert method of summated ratings. For certain questions A was given a value of one with values increasing by one to E, while in other questions A was equal to five with values decreasing by one to E. Students writing the test were not aware of the sub-tests or the values assigned to the letters selected as their answers.

In the test construction each of the sub-test scores was correlated with the total test scores. A correlation of .704 was obtained for the SATS Sub-test 3 and the SATS Total. The correlation for the SATS Sub-test 5 and the SATS Total was .474.

The correlation statistics obtained for the SATS and the Test on Understanding of Science (TOUS) Total scores were not significant at the 5% level.

In developing the SATS Hedley did not determine the validity or reliability of the test. The first edition was given to 51 students, who were interviewed to determine which questions were ambiguous. On the basis of this evaluation the test was revised to eliminate the ambiguous statements.

Since this study was primarily directed at student interest in course content and attitude towards the laboratory work, only two sub-tests, interest in course content and attitude towards the laboratory work, were considered in the statistical analysis in addition to the total scores.

Characteristic of the SCAT

The SCAT test was selected as a means of measuring the capacity of a student to undertake the next higher level of school work in order to compare the control and experimental groups. In view of the nature of this study, it was felt that a measure of a student's readiness to cover new work was a better comparison than intelligence scores.

The SCAT was developed by Educational Testing Service, Los Angeles, California. An Advisory Committee recommended that "school-learned abilities" were a better predictor of how well a student will succeed in school work than IQ. A list of nine "school-learned abilities" was used as a guide in constructing the experimental tests. Those items with a high correlation with the list were finally selected to construct the test.

This test consisted of four parts which can be administered in two 30 minute periods. Parts I and III are used to give a Verbal (SCAT-V) score, and Parts II and IV a Quantitative (SCAT-Q) score. The total test has 110 items.

A number of studies have been done to determine the predictive validity of the SCAT. A study involving three schools compared first term eleventh grade SCAT scores with final marks obtained in grade twelve. A correlation of .56 was obtained.

Reliability for the SCAT was determined by using Kuder-Richardson Formula 20 on 100 case samples drawn from approximately 3,000 students. The following reliabilities were found: SCAT Verbal .92, SCAT Quantitative .90, and SCAT Total .95.

SCAT scores have been correlated with a number of well established tests. The College Entrance Examination Board Scholastic Aptitude Test (SAT) and SCAT were correlated for 291 freshman entering the College of William and Mary with the following results: SAT Verbal with SCAT Verbal was .79. SAT Mathematical with SCAT Quantitative was .74. Goldman administered the SCAT and Wechsler Adult Intelligence Scale (WAIS) to 11th and 12th grade students in five public schools and found a correlation of .84 for total scores. Swem involved 252 students in a study correlating grade nine Otis IQ scores and grade 12 SCAT scores and obtained a correlation of .72.

Factual Laboratory Test

A multiple-choice, factual test was constructed for this study and administered to both groups to assess the retention of facts by the two groups. This test was based entirely on the 10 laboratory exercises used in the study. The laboratory manual was used in the test construction. This test was given without prior warning to prevent more ambitious students from preparing for the test, since it was to be a measure of information retained from laboratory experiences.

Statistical Treatment

For each of the students in the study the following information was transferred to punch cards for computer analysis:

1. Factor level number
2. Student number
3. Post-STEP score
4. Post-SATS Sub-test 3 (Interest in content) score
5. Post-SATS Sub-test 5 (Attitude towards lab) score
6. Post-SATS Total score
7. Pre-STEP score
8. Pre-SATS Sub-test 3 score
9. Pre-SATS Sub-test 5 score
10. Pre-SATS Total score
11. SCAT Verbal score
12. SCAT Quantitative score.

Discussions with Dr. J. P. Stevens, a statistician, resulted in an A x B x C (2 x 2 x 2) factorial design and an analysis of covariance. Factor A was a comparison of the two treatments, factor B was a comparison of boys and girls scores, and factor C was a comparison of students taking only biology, as a science, with students taking chemistry and/or physics in addition to biology.

In the first analysis the Pre-STEP, SCAT-V and SCAT-Q scores were used as covariates with the Post-STEP scores as the dependent variable. In the second analysis the Pre-SATS Sub-test 3 was used as a covariate with the

Post-SATS Sub-test 3 as the dependent variable. For the third analysis the Pre-SATS Sub-test 5 was the covariate with the Post-SATS Sub-test 5 the dependent variable. For the fourth analysis the Pre-SATS Total was the covariate with the Post-SATS Total as the dependent variable.

This analysis produced the following information:

1. The means and standard deviations for the 10 variables for groups A and B

2. A correlation matrix for the total group

3. An analysis of covariance to test the significance of the differences between the two groups in each of the three factors A, B, and C.

The results from the preceding investigation suggested a further analysis. SCAT-V scores were used to split each treatment group into low, middle, and high ability levels. A comparison of the Pre-STEP and Post-STEP means was made for each of the three levels. Treatment means within each level were also compared.

The "t" test was used to determine the statistical significance of the difference in mean scores.

CHAPTER IV

ANALYSIS OF DATA

The purpose of this chapter is to examine the data collected in this study, and to evaluate statistically the significance of the difference between the two treatments. The following areas will be examined to evaluate the significance of the treatments:

1. A correlation matrix for the 10 variables listed on page 50, for the total group

2. The means and standard deviations and the differences in means for various groups

3. A comparison of course marks and laboratory marks

4. The analysis of covariance for the Post-STEP, Post-SATS Sub-test 3, Post-SATS Sub-test 5, and Post-SATS Total scores.

Study of the Correlation Matrix

A number of correlations in Table 1 deserve some attention. The correlation between the Pre-STEP and Post-STEP in this study was .806. Since this correlation was the result of repeating the test it can be considered a measure of reliability, and agreed very well with the reliability given for the STEP Science 2A in the manual (see above, p. 45).

The STEP Technical Manual listed the correlations between the STEP and SCAT as follows: A correlation of .72 between the STEP and SCAT-V, and a correlation of .69 between the STEP and SCAT-Q. Correlations obtained in this study were considerably lower than those given in the manual. A correlation of .533 to .597 was obtained for the STEP and SCAT-V and .307 to .348 for the STEP and SCAT-Q.

Correlations between the STEP and the SATS Sub-tests were fairly low, ranging from .039 to .325. This suggests that a strong positive attitude towards science, as measured by the SATS test, is not an indication that a student will score high on the STEP. The correlation between the STEP and SATS Total was higher than for the two sub-tests considered in the study.

It was interesting to find a lower correlation between the nine variables and the SCAT-Q than for the variables and the SCAT-V. Upon examination of the tests the writer felt that the SCAT-Q and STEP had more in common than the other combinations. According to the results obtained the SCAT-V is a better predictor of STEP scores than the SCAT-Q scores.

Examination of Means and Standard Deviations

The standard deviations for the total group are listed in Table 2. It is significant that the pre-test and post-test standard deviations differ very little except in the case of the SATS Total scores. In all the other

Table 1

Correlation Matrix for the Ten Variables in the Total Group

	Pre-STEP	Post-STEP	Pre-SATS 3	Post-SATS 3	Pre-SATS 5	Post-SATS 5	Pre-SATS-T	Post-SATS-T	SCAT-V	SCAT-Q
Pre-STEP	1.000	.806	.325	.301	.018	.063	.187	.309	.533	.348
Post-STEP		1.000	.308	.265	.039	.112	.226	.311	.597	.307
Pre-SATS 3			1.000	.608	.143	.254	.648	.562	.191	.047
Post-SATS 3				1.000	.119	.262	.614	.695	.221	.002
Pre-SATS 5					1.000	.440	.412	.293	.048	.123
Post-SATS 5						1.000	.410	.655	.176	.005
Pre-SATS-T							1.000	.731	.231	.123
Post-SATS-T								1.000	.298	.071
SCAT-V									1.000	.331
SCAT-Q										1.000

cases the pre-test and post-test means differ by less than one. The amount of spread has changed very little from pre-test to post-test for the total group.

Table 3 lists the means for each of the two groups within the three levels: treatment, sex, and the number of science subjects taken by students. An examination of the means for the two treatments indicates very little difference exists between the two groups except in the case of the Pre-STEP. Treatment A raised the Post-STEP mean by 3.9 while Treatment B increased the mean by 6. It is interesting to note a slightly higher SCAT-V mean for Treatment A. Since studies have indicated a reasonably high correlation between SCAT scores and intelligence test scores, a bias, if any, was in favor of Treatment A. In view of this it was interesting to find a greater increase for Treatment B on the Pre-STEP to Post-STEP means.

Fourteen of the 72 questions in the SATS test form the SATS Sub-test 3. This test is a measure of student attitude towards science in general. The test can therefore be applied to any particular science course. Since a value of three represents a neutral position for each question, 42 would indicate a neutral attitude on the sub-test. The difference between pre-test and post-test means for both treatments is very small for the SATS Sub-test 3. There is a slight improvement in attitude from pre-test to post-test, but all the results are still slightly negative since they are below 42.

Table 2

Standard Deviation for the Total Group

Variable	Standard deviation
Pre-STEP test	10.71
Post-STEP test	10.87
Pre-SATS sub-test 3	6.11
Post-SATS sub-test 3	6.21
Pre-SATS sub-test 5	5.04
Post-SATS sub-test 5	4.39
Pre-SATS total	22.96
Post-SATS total	26.01
SCAT Verbal	12.23
SCAT Quantitative	11.62

Eleven out of 72 questions in the SATS test form the SATS Sub-test 5. This test was a measure of student attitudes towards laboratory activities. A neutral was indicated by a value of 33. The change from pre-test to post-test on this sub-test was relatively small for both treatments. Even though the change was small, it was interesting to find a negative change for Treatment A and a positive change for Treatment B. All the means for the SATS Sub-test 5 were above the neutral value of 33, which suggests a favorable response towards laboratory activities.

Grouping students on the basis of sex, irrespective of treatment, resulted in fairly large differences between the two groups for seven of the ten variables. On the basis of SCAT-V means, which correlated highly with intelligence test scores, there was little difference in ability between the two sexes. Examining the STEP means suggested boys scored much higher than girls but the increase from pre-test to post-test was similar in the two sexes.

Grouping students on the basis of the number of science subjects taken, irrespective of treatment, produced higher means for the students taking more than one science. Only a small difference existed for the SCAT-V means while the STEP means differed significantly.

The results in Table 3 suggested that boys scored higher than girls and students taking additional science courses scored higher than students taking one science on the STEP test even though SCAT-V scores differed only

Table 3

Observed Combined Means for Treatments, Sex and Number of Sciences Taken

Variable	Group A	Group B	Boys	Girls	Two or more sciences	One science
Pre-STEP	291.0	288.0	296.3	285.5	293.2	285.7
Post-STEP	294.9	294.0	301.8	290.0	298.9	289.7
Pre-SATS sub-test 3	40.88	40.69	43.00	39.43	42.78	38.61
Post-SATS sub-test 3	41.54	41.26	42.93	40.47	43.37	39.26
Pre-SATS sub-test 5	38.08	37.74	37.98	37.89	38.36	37.44
Post-SATS sub-test 5	37.85	38.13	38.07	37.93	38.39	37.54
Pre-SATS total	236.5	236.2	241.8	233.0	245.9	225.9
Post-SATS total	236.2	234.3	240.1	232.3	243.0	226.9
SCAT-V	297.3	296.1	296.5	296.9	297.0	296.5
SCAT-Q	311.9	312.0	316.7	309.0	317.0	306.4
Number of students	59	54	43	70	59	54

slightly.

From the computer analysis data it was possible to study various additional group means to determine trends. This type of information is presented in Tables 4 to 7. Table 4.1 represents the data obtained for the STEP and SCAT for boys in the two treatments. Recognizing that differences were very small in terms of percentages, it was interesting to find both STEP and SCAT means were higher for Treatment A, but the difference from Pre-STEP to Post-STEP was greater for Treatment B. The results were slightly in favor of Treatment B.

The information given for boys in Table 4.1 is given for girls in Table 4.2. There was basically no difference between the two treatments for girls.

Table 5.1 is a comparison of STEP means for boys taking more than one science in the two treatments. SCAT means for the two treatments differed by approximately one, suggesting the two groups were similar in abilities. Comparing the Pre-STEP and Post-STEP means indicated a greater difference existed for Treatment B. Table 5.2 indicates an even greater difference for boys taking only one science. The SCAT means were considerably higher for Treatment A, while the difference from Pre-STEP to Post-STEP means was significantly greater for Treatment B. Any difference as the result of the treatment was in favor of Treatment B.

Table 6.1 is a comparison of STEP means for girls taking more than one science in the two treatments. SCAT

Table 4.1

Comparison of STEP Means and Standard Deviations for Boys in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	297.79	294.37
Pre-STEP standard deviation	10.59	15.35
Post-STEP mean	302.12	301.31
Post-STEP standard deviation	14.38	13.16
Mean difference	4.33	6.94
SCAT Verbal	297.13	295.63
SCAT Quantitative	318.00	314.95
Number of students	24	19

Table 4.2

Comparison of STEP Means and Standard Deviations for Girls in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	284.11	284.60
Pre-STEP standard deviation	8.41	8.69
Post-STEP mean	290.00	290.50
Post-STEP standard deviation	10.16	9.29
Mean difference	5.89	5.90
SCAT Verbal	297.48	296.28
SCAT Quantitative	307.65	310.35
Number of students	35	35

Table 5.1

Comparison of STEP Means and Standard Deviations for Boys Taking Additional Science Courses in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	298.41	296.36
Pre-STEP standard deviation	10.08	18.61
Post-STEP mean	304.12	303.64
Post-STEP standard deviation	9.88	15.08
Mean difference	5.71	7.28
SCAT Verbal	295.71	296.79
SCAT Quantitative	318.82	319.79
Number of students	17	14

Table 5.2

Comparison of STEP Means and Standard Deviations for Boys Taking One Science Course in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	296.29	288.80
Pre-STEP standard deviation	11.83	6.23
Post-STEP mean	297.29	294.80
Post-STEP standard deviation	15.01	7.80
Mean difference	1.00	6.00
SCAT Verbal	300.57	292.40
SCAT Quantitative	316.00	301.40
Number of students	7	5

means were higher for Treatment B but the Pre-STEP mean was higher for Treatment A. The difference between the Pre-STEP and Post-STEP means was greater again for Treatment B. Table 6.2 indicates no difference for the two treatments for girls taking only one science. The difference from Pre-STEP to Post-STEP was 4.29 for both treatments.

The information given in Tables 4, 5 and 6 is only suggestive of a trend since differences between means were fairly small and statistically non-significant. It was still of interest for this study, that improvement from Pre-STEP to Post-STEP was greater for Treatment B in all but one comparison.

A comparison of SATS Sub-test 3 means is listed in Table 7.1 for students taking additional science subjects in the two treatments. This test is a measure of student interest in the science course under study. Treatment B produced a slightly stronger positive reaction on both pre-test and post-test, as well as a greater increase from Pre-SATS Sub-test 3 to Post-SATS Sub-test 3.

The means for the SATS Sub-test 3 in Table 7.2 are all below the neutral position of 42. This suggested that students taking a minimum number of science courses did not react favorably to the science course being taken. For Treatment B there was also a decrease in mean score from pre-test to post-test, while Treatment A increased their score.

Table 6.1

Comparison of STEP Means and Standard Deviations for Girls Taking Additional Science Courses in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	289.14	287.71
Pre-STEP standard deviation	10.16	7.50
Post-STEP mean	291.71	294.93
Post-STEP standard deviation	10.23	8.27
Mean difference	2.57	7.22
SCAT Verbal	295.93	299.71
SCAT Quantitative	312.57	316.43
Number of students	14	14

Table 6.2

Comparison of STEP Means and Standard Deviations for Girls Taking One Science Course in the Two Treatments

	Treatment A	Treatment B
Pre-STEP mean	284.57	282.52
Pre-STEP standard deviation	7.24	9.49
Post-STEP mean	288.86	286.81
Post-STEP standard deviation	10.12	9.97
Mean difference	4.29	4.29
SCAT Verbal	298.52	294.00
SCAT Quantitative	304.38	306.29
Number of students	21	21

Table 7.1

Comparison of SATS Sub-test Three Means and Standard Deviations for Students Taking Additional Science Courses in the Two Treatments

	Treatment A	Treatment B
Pre-SATS sub-test 3 mean	42.39	43.22
Pre-SATS sub-test 3 S.D.	6.40	5.46
Post-SATS sub-test 3 mean	42.42	44.43
Post-SATS sub-test 3 S.D.	5.22	7.34
Mean difference	.03	1.21
SCAT Verbal	295.81	298.25
SCAT Quantitative	316.00	318.11
Number of students	31	28

Table 7.2

Comparison of SATS Sub-test Three Means and Standard Deviations for Students Taking One Science Course in the Two Treatments

	Treatment A	Treatment B
Pre-SATS sub-test 3 mean	39.22	37.96
Pre-SATS sub-test 3 S.D.	6.10	6.22
Post-SATS sub-test 3 mean	40.58	37.85
Post-SATS sub-test 3 S.D.	5.74	6.04
Mean difference	1.36	- .11
SCAT Verbal	299.04	293.81
SCAT Quantitative	307.29	305.35
Number of students	28	26

A comparison of SATS Sub-test 5 means is given in Table 8.1 for students taking additional science courses in the two treatments. This test was a measure of student interest in the laboratory activity. All of the means were above 33 and therefore indicated a positive response to the laboratory work. It is significant that there was a negative difference from pre-test to post-test for Treatment A and a positive difference for Treatment B. Opposite results were found for students taking only one science subject according to the results in Table 8.2. Results given in Tables 8.1 and 8.2 suggested that science oriented students preferred the inquiry session and students taking only one science preferred the structured laboratory activity.

Course work, excluding the laboratory activities, was evaluated on the basis of term tests and a three hour examination in March. The results obtained from this evaluation are given in Table 9. This table provides the mean scores for each treatment as well as the means for three levels of the SCAT-V scores. The comparison of marks obtained in course work was made to assist in the interpretation of results from the factual laboratory test.

A factual laboratory test was constructed to evaluate student retention of factual information encountered in the laboratory activities. This test was based entirely on the work covered in the laboratory manual for the study. The test was written without prior notice in order to avoid preparation for the test, since it was to be a measure of

Table 8.1

Comparison of SATS Sub-test Five Means and Standard Deviations for Students Taking Additional Science Courses in the Two Treatments

	Treatment A	Treatment B
Pre-SATS sub-test 5 mean	38.64	38.04
Pre-SATS sub-test 5 S.D.	5.51	3.69
Post-SATS sub-test 5 mean	37.42	39.47
Post-SATS sub-test 5 S.D.	4.55	4.98
Mean difference	-1.22	1.43
SCAT Verbal	295.81	298.25
SCAT Quantitative	316.00	318.11
Number of students	31	28

Table 8.2

Comparison of SATS Sub-test Five Means and Standard Deviations for Students Taking One Science Course in the Two Treatments

	Treatment A	Treatment B
Pre-SATS sub-test 5 mean	37.47	37.42
Pre-SATS sub-test 5 S.D.	5.61	4.54
Post-SATS sub-test 5 mean	38.34	36.69
Post-SATS sub-test 5 S.D.	3.60	3.76
Mean difference	.87	- .73
SCAT Verbal	299.04	293.81
SCAT Quantitative	307.29	305.35
Number of students	28	26

retention. Results from this test are given in Table 9. Even though the test was based on material used in Treatment A, Treatment B means compared favorably with Treatment A means. On the basis of this test, handling the laboratory materials in the 10 laboratory exercises did not influence the acquisition of factual knowledge.

Analysis of Covariance

A study of the STEP means suggested that Treatment B gained as much, and in most cases more, than Treatment A from Pre-STEP to Post-STEP. This difference was examined by a statistical analysis of covariance to determine the significance.

The analysis of covariance for the Post-STEP is given in Table 10. The Pre-STEP, SCAT-V and SCAT-Q scores were used as covariates. A probability at the 5% level was accepted as significant.

The probability for a difference between Treatment A and Treatment B was .2234. Since this was much higher than the accepted level the hypothesis of no significant difference between the two treatments could not be rejected.

The difference between boys and girls produced a probability of .002. This was significant at the 1% level and therefore the hypothesis of no significant difference between the sexes could be rejected.

The difference between the students taking one science and the students taking more than one science produced

Table 9

Comparison of Course Marks and Laboratory Marks for Three Levels of SCAT Verbal Scores in the Two Treatments

	Treatment A		Treatment B	
	Course mark mean	Laboratory mark mean	Course mark mean	Laboratory mark mean
Total group	61.18	13.19	59.96	13.07
SCAT-V 267-291	50.80	11.33	53.00	11.47
SCAT-V 292-302	61.23	12.28	60.22	13.06
SCAT-V 303-327	71.60	15.95	67.47	14.88
Number of students	59	59	54	54

a probability of .032, which was significant at the 5% level. Thus the hypothesis of no significant difference between students taking one science and students taking more than one science could be rejected.

Probabilities for the interactions between treatments, sex, and the number of science subjects are all above the 5% level and therefore could not be rejected.

The analysis of covariance for the Post-SATS Subtest 3 is given in Table 11. An examination of this data indicated that none of the differences were statistically significant at the 5% level. The interaction between treatments and the number of science subjects taken could be considered significant at the 10% level. Since this is above the accepted level the hypothesis of no interaction could not be rejected. Figure 1 gives a visual representation of the relationship between treatments and the number of science subjects taken.

The analysis of covariance for the Post-SATS Subtest 5 is given in Table 12. Only one of the probabilities was significant at the 5% level. The interaction between treatments and the number of science subjects taken produced a probability of .0124. This interaction is given in Figure 2. A study of this figure suggested the following two conclusions. Students taking additional science courses in Treatment A decreased their score from pre-test to post-test while the students in Treatment B increased their score, and those taking only one science in Treatment A

Table 10

Analysis of Covariance for the Post-STEP with the Pre-STEP, SCAT Verbal and SCAT Quantitative as Covariates

Source	df	MS	F	P
A. Between treatments	1	56.6875	1.5006	.2234
B. Between pupil sex	1	381.8711	10.1086	.0020**
C. Between number of science courses taken	1	178.6445	4.7290	.0320*
A x B Interaction	1	.2344	.0062	.9374
A x C Interaction	1	2.7148	.0719	.7892
B x C Interaction	1	54.2500	1.4361	.2336
A x B x C Interaction	1	61.2109	1.6203	.2060
Error	102			

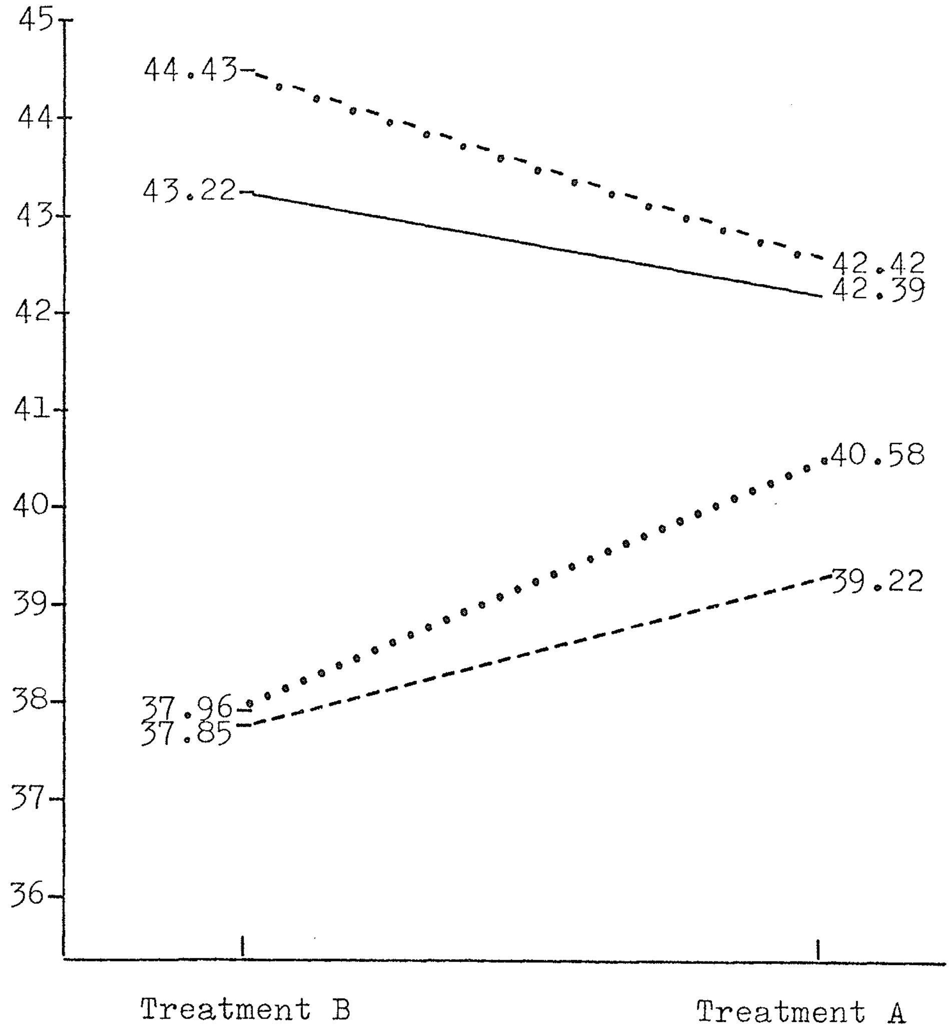
* Statistic significant at the 5% level

** Statistic significant at the 1% level

Table 11

Analysis of Covariance for the Post-SATS Sub-test Three with the Pre-SATS Sub-test Three as the Covariate

Source	df	MS	F	P
A. Between treatments	1	.7371	.0300	.8630
B. Between pupil sex	1	1.4175	.0576	.8109
C. Between number of science courses taken	1	61.9924	2.5192	.1155
A x B Interaction	1	17.9268	.7285	.3954
A x C Interaction	1	67.4590	2.7413	.1008
B x C Interaction	1	.0076	.0003	.9861
A x B x C Interaction	1	.0276	.0011	.9734
Error	104			



______ Pre-test scores of students taking additional science courses

-.-.-. Post-test scores of students taking additional science courses

------ Pre-test scores of students taking one science

...... Post-test scores of students taking one science

Lines joining 44.43, the value for Treatment B and 42.42, the value for Treatment A, and the other joined values, indicate the scores were arrived at using the same test.

Figure 1

Interaction Between Treatments and the Number of Science Courses Taken Based on SATS Sub-test Three increased their score from pre-test to post-test while students in Treatment B decreased their score. This interaction suggested that science oriented students preferred the inquiry session while students taking a minimum of science subjects preferred a more rigidly structured laboratory session.

Table 13 lists the data for the analysis of covariance for the Post-SATS Total. The interaction between treatments and the number of science subjects taken produced the only statistically significant probability. This interaction is illustrated in Figure 3. The interaction for students taking more than one science was not very pronounced. Students taking only one science produced opposite results in the two treatments, supporting the conclusions suggested by Figure 2.

Treatment Differences in Three Ability Levels

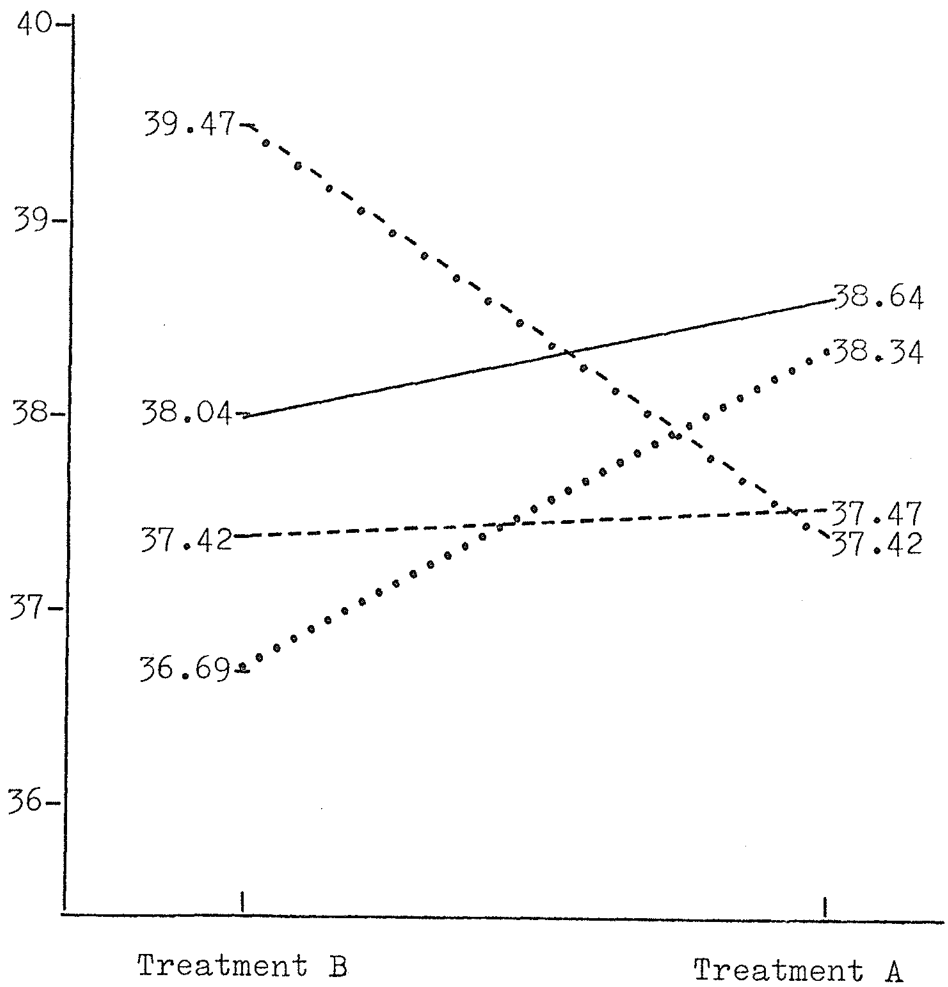
The results from an analysis of covariance indicated no statistically significant difference between Post-STEP means for the two treatments in the study. Since the hypothesis of no significant difference could not be rejected, an additional analysis was done. Students in both treatments were grouped into three levels on the basis of SCAT-V scores and the STEP means and standard deviations calculated for each level. The "t" test was used to determine the significance of the difference between the Pre-STEP and Post-STEP means for each treatment, at each of the three

Table 12

Analysis of Covariance for the Post-SATS Sub-test Five with the Pre-SATS Sub-test Five as the Covariate

Source	df	MS	F	P
A. Between treatments	1	4.8315	.3074	.5805
B. Between pupil sex	1	.4534	.0288	.8655
C. Between number of science courses taken	1	6.7266	.4280	.5145
A x B Interaction	1	5.1738	.3292	.5674
A x C Interaction	1	102.0078	6.4901	.0124*
B x C Interaction	1	36.7170	2.3361	.1295
A x B x C Interaction	1	.0850	.0054	.9416
Error	104			

* Statistic significant at the 5% level



——— Pre-test scores of students taking additional science courses
-.-.-. Post-test scores of students taking additional science courses
------ Pre-test scores of students taking one science
...... Post-test scores of students taking one science

Lines joining 39.47, the value for Treatment B and 37.42, the value for Treatment A, and the other joined values, indicate the scores were arrived at using the same test.

Figure 2

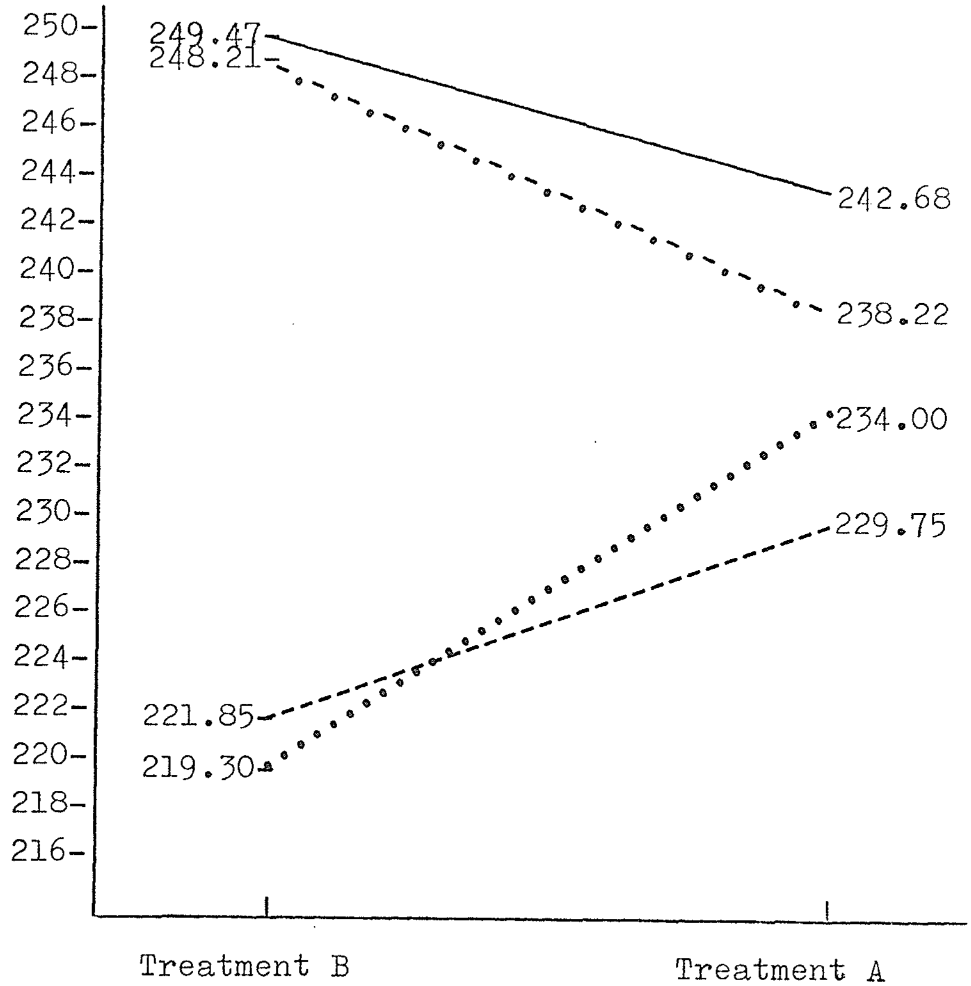
Interaction Between Treatments and the Number of Science Courses Taken Based on SATS Sub-test Five

Table 13

Analysis of Covariance for the Post-SATS Total with the Pre-SATS Total as the Covariate

Source	df			
A. Between treatments	1	73.2930	.2307	.6321
B. Between pupil sex	1	4.5078	.0142	.9055
C. Between number of science courses taken	1	10.4727	.0330	.8563
A x B Interaction	1	28.4336	.0895	.7655
A x C Interaction	1	1318.2500	4.1490	.0442*
B x C Interaction	1	485.1758	1.5270	.2194
A x B x C Interaction	1	12.5352	.0395	.8430
Error	104			

* Statistic significant at the 5% level



——— Pre-test scores of students taking additional science courses

-.-.-. Post-test scores of students taking additional science courses

------ Pre-test scores of students taking one science

...... Post-test scores of students taking one science

Lines joining 249.47, the value for Treatment B and 242.68, the value for Treatment A, and the other joined values, indicate the scores were arrived at using the same test.

Figure 3

Interaction Between Treatment and the Number of Science Courses Taken Based on SATS Total levels. Results from this analysis are given in Table 14.

A study of this table indicated a larger "t" value for Treatment B in each of the three levels. The Pre-STEP and Post-STEP means did not differ significantly for Treatment A in the lowest level while the difference for Treatment B was statistically significant at the 5% level. Both treatments produced statistically significant differences between pre-test and post-test means at the 5% level in the middle level. For the highest level the Pre-STEP and Post-STEP differences were statistically significant at the 1% level for Treatment A and at the .1% level for Treatment B. Tests were also done to determine the significance of the difference between Treatments A and B in each of the three levels. These differences were found to be statistically non-significant at the 5% level.

Table 14

Comparison of Mean Differences in Pre-STEP and Post-STEP for Three Levels of the SCAT Verbal in the Two Treatments

	Treatment A	Treatment B	$\tilde{z}$-value
SCAT-V 267-291			
Pre-STEP mean	285.19	280.95	
Pre-STEP S.D.	8.52	11.84	
Post-STEP mean	288.29	286.37	
Post-STEP S.D.	11.08	9.95	
Mean difference	3.10	5.42	.3642
Mean difference "t" value	1.693	3.870*	
Number of students	21	19	
SCAT-V 292-302			
Pre-STEP mean	290.44	286.94	
Pre-STEP S.D.	7.37	10.79	
Post-STEP mean	293.94	292.06	
Post-STEP S.D.	10.33	9.63	
Mean difference	3.50	7.12	.3377
Mean difference "t" value	2.330*	2.517*	
Number of students	18	18	
SCAT-V 303-327			
Pre-STEP mean	297.70	297.12	
Pre-STEP S.D.	12.38	10.96	
Post-STEP mean	302.80	304.65	
Post-STEP S.D.	10.91	11.23	
Mean difference	5.10	7.53	.3420
Mean difference "t" value	3.783**	8.398***	
Number of students	20	17	

* Statistic significant at the 5% level
** Statistic significant at the 1% level
*** Statistic significant at the .1% level
$\tilde{z}$-value greater than 1.96 is significant at the 5% level

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The main purpose of this study was to compare experimentally the effectiveness of two different methods of teaching laboratory work. The questions the study attempted to answer were:

1. Is the use of inquiry sessions, to deal with laboratory work, as effective in developing scientific reasoning skills as following the outline in the laboratory manual?

2. Is the difference, if any, between the two methods of teaching laboratory work statistically significant?

3. Is student attitude towards science influenced by the method used in teaching laboratory work?

A sample of 113 Fort Garry grade 12 students was selected for the study. Four class sections taking BSCS 300 Biology were selected and combined to form two groups on the basis of results obtained on the SCAT and Pre-STEP. Combining sections one and two to form one group, and three and four to form the second group, produced the smallest difference in mean scores possible on the two tests. Sections one and two formed the control group and three and four formed the experimental group.

The STEP (science) was selected to measure the student's level of scientific reasoning ability and was administered as a pre-test and post-test. The SATS test was chosen to measure the student's attitude and interest in science and laboratory work. This test was also given as a pre-test and post-test in order to measure any change in attitude as a result of the treatment.

Statistical techniques were used to determine the significance of the difference in scores obtained by the control and experimental groups for the STEP and SATS tests.

MAJOR FINDINGS

The hypotheses tested are reproduced in this chapter with the results of the statistical analyses. Three hypotheses were tested for the STEP test.

1. There is no statistically significant difference in the scientific reasoning ability, as measured by the STEP, between the two treatments.

The scores for the experimental group were higher than the scores obtained by the control group, but the difference was not significant at the 5% level. Therefore, the hypothesis could not be rejected.

2. There is no statistically significant difference in the scientific reasoning ability, as measured by the STEP, between the sexes.

The scores for the boys were significantly higher than the scores for the girls and were found to be statistically significant at the 1% level. Therefore, the hypothesis could be rejected.

3. There is no statistically significant difference in the scientific reasoning ability, as measured by the STEP, between students taking one science and those taking additional science subjects.

The scores obtained by the students taking additional science subjects were significantly higher than the scores obtained by students taking one science. The difference was found to be statistically significant at the 5% level. Therefore, the hypothesis could be rejected.

Statistical tests were done to determine the significance of interactions between treatments and sex, treatments and the number of science subjects taken, sex and the number of science subjects taken, and treatments sex and the number of science subject taken. None of the interactions proved to be statistically significant for the STEP at the 5% level.

Three hypotheses were tested for the SATS Sub-test 3.

1. There is no statistically significant difference in interest towards science, as measured by the SATS Sub-test 3, between the two treatments.

The difference between the treatment means was very small and statistically non-significant. Therefore, the hypothesis could not be rejected.

2. There is no statistically significant difference in interest towards science, as measured by the SATS Sub-test 3, between the sexes.

The boys obtained a higher score on the test but the difference was statistically non-significant. Therefore, the hypothesis could not be rejected.

> 3. There is no statistically significant difference in interest towards science, as measured by the SATS Sub-test 3, between students taking one science and those taking additional science subjects.

The students taking additional science subjects scored higher on the test than students taking only one science, but the difference was not statistically significant at the 5% level. Therefore, the hypothesis could not be rejected.

Three hypotheses were tested for the SATS Sub-test 5, a measure for interest in laboratory activities.

> 1. There is no statistically significant difference in interest towards laboratory activities, as measured by the SATS Sub-test 5, between the two treatments.

Students in the control group scored higher on the pre-test than the experimental group but their score decreased on the post-test, while the experimental group increased their score on the post-test. The difference between the two treatments was not statistically significant at the 5% level. Therefore, the hypothesis could not be rejected.

> 2. There is no statistically significant difference in interest towards laboratory activities, as measured by the SATS Sub-test 5, between the sexes.

Scores obtained by the two sexes differed by an insignificant fraction. Therefore, the hypothesis could not be rejected.

3. There is no statistically significant difference in interest towards laboratory activities, as measured by the SATS Sub-test 5, between students taking one science and those taking additional science subjects.

Students taking additional science subjects scored slightly higher but the difference was statistically nonsignificant. Therefore, the hypothesis could not be rejected.

A statistically significant interaction was obtained for the SATS Sub-test 5 between treatments and the number of science subjects taken. Students in the experimental group taking additional science subjects increased their score from pre-test to post-test, while the students taking only one science decreased their score from pre-test to post-test. The control group results were the opposite of the experimental group.

Three hypotheses were tested for the SATS Total scores.

1. There is no statistically significant difference in attitude towards science, as measured by the SATS Total, between the two treatments.

Scores in the two treatments did not differ significantly and, therefore the hypothesis could not be rejected.

2. There is no statistically significant difference in attitude towards science, as measured by the SATS Total, between the sexes.

Scores obtained by the boys were higher than for the girls but the difference was not statistically significant. The hypothesis could not be rejected.

3. There is no statistically significant differ-

> ence in attitude towards science, as measured by the SATS Total, between students taking one science and those taking additional science subjects.

Higher scores were obtained by students taking additional science subjects but the difference was not statistically significant. Therefore, the hypothesis could not be rejected.

A significant interaction was obtained for the SATS Total scores between treatments and the number of science subjects taken. This interaction was significant at the 5% level.

The "t" test was used to test for the significance of mean differences between Pre-STEP and Post-STEP for each of the two treatments in the three ability levels. The SCAT-V scores were used to establish the three ability levels. The lowest level included scores between 267 to 291, the middle level included scores between 292 and 302, and the highest level contained scores between 303 and 327. The "t" value for Treatment A was not statistically significant at the 5% level in the lowest ability level. Treatment B in the lowest level, and Treatments A and B in the middle level, resulted in mean differences that were statistically significant at the 5% level. Treatment A in the highest level was statistically significant at the 1% level, and Treatment B at the .1% level.

The significance of the mean difference between Treatments A and B was tested in each of the three levels and found to be statistically non-significant in each case.

CONCLUSIONS

Statistically significant differences in scientific reasoning ability, as measured by the STEP (science), were not found between the control and experimental groups in this study. Even though the differences between the two treatments were found to be statistically non-significant, it was of interest that the differences from pre-test to post-test as shown in Tables 3, 4, 5, and 6 were greater for the experimental groups in all cases except Table 6. These results suggested that the experimental treatment proved to be as effective, if not better, than the control treatment.

The comparison on the basis of the sexes proved to be statistically significant at the 1% level. On the basis of the SCAT-V means the difference between the sexes was .4, indicating the two groups did not differ in ability. The STEP means differed by more than 10 units, with the boys achieving the higher score. Even though the boys obtained a higher initial mean, the increase from pre-test to post-test was similar for both sexes. This suggested the boys did not really gain more from course work than girls, irrespective of treatment.

Students taking additional science subjects scored significantly higher on the STEP test than students taking only one science subject. Orientation towards science, it is believed, influences the number of science subjects selected, and the results obtained on the test. Therefore there would seem to be a direct relationship between the number of science subjects a student selects and scientific reasoning ability.

Attitudes towards the laboratory work for the three factors, treatment, sex, and the number of science subjects taken, did not differ significantly. An interesting interaction was found between treatments and the number of science subjects taken. Students in the experimental group, taking additional science subjects, responded more positively on the Pre-SATS Sub-test 5 than students taking only one science. The difference between the two groups in the experimental treatment increased on the post-test. Students taking additional science subjects increased their score while those taking one science decreased their score on the post-test. Results for the two groups in the control treatment were opposite to the experimental treatment, except that differences were smaller. These results suggested that science oriented students preferred the inquiry session, while the less science oriented students preferred a structured type of outline for laboratory work.

Splitting the groups of students in both treatments into three ability levels did not produce differences, between the treatments in each level, that were statistically significant. It was interesting to note that the "t" test value for the difference between the Pre-STEP and

Post-STEP means was greater for the experimental group in each of the three levels.

A problem recognized early in the study was the fact that a fairly large number of the students did not become verbally involved in the discussion sessions. It seemed that participation in discussion was limited to the more aggressive students in most cases. A conscious effort was made to draw pupils into the discussions during the inquiry sessions, but this proved less successful than a voluntary response. No attempt was made to determine whether verbally participating students differed from non-participating students on the tests.

Students in the experimental group were not required to complete written laboratory reports. This concession was made to provide time to follow the discussion rather than concentrate on recording answers. The anticipated results were achieved in most cases. In a few cases, no written reports provided an opportunity to waste time.

The handling of laboratory equipment is generally interesting and exciting at the high school level and therefore should be part of a science program. Students are keenly interested in working with microscopes and doing dissections. This sentiment occasionally surfaced in the inquiry group of students.

The real problem is probably not one of laboratory work versus inquiry sessions, but it is rather a matter of defining the objectives to be achieved during an activity.

Both of the methods discussed may be necessary to achieve the objectives of a science course. For students to learn to follow a prescribed set of directions and handle equipment, the BSCS yellow version manual may serve the purpose. Where discussion and exchange is important, students should be exposed to inquiry sessions.

Excitement about the inquiry session was high at the beginning of the study but did not remain at this level. This excitement with the method could probably have been maintained by alternating inquiry sessions and laboratory work. Such an arrangement would likely be more successful, since certain laboratory exercises are more suitable for inquiry sessions while others should be done in the laboratory. A subjective conclusion would, therefore, be that both inquiry sessions and laboratory work should be included in teaching the biology program.

RECOMMENDATIONS

Certain areas important in a study of this nature were not included and should be investigated.

It became evident that the teacher's role was more significant in the inquiry session than in the regular laboratory exercise. The success of an inquiry session, it was felt, depended to a very large degree on the enthusiasm of the teacher, and the ability to motivate the students. It is recommended that a further investigation be undertaken to include more than one teacher in the study.

It is also recommended that a further study be conducted using a less rigid format for the inquiry session. The format used for the inquiry sessions in this study paralleled very closely with the information given in the laboratory manual. Less concern about following the laboratory manual could provide opportunity for discovery in a larger area, which in turn could stimulate interest.

Extending the study over the entire laboratory program for a particular grade ought to be investigated. This study was limited to approximately one-third of the biology program. It is possible that extending the time to one year would increase the differences found in this study to the extent where they might be statistically significant.

A further investigation also should be undertaken into the use of other tests of behavioral changes that take place as a result of different treatments.

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APPENDIX A

DESCRIPTION OF SCAT

What does SCAT do?

The School and College Ability Tests (SCAT) aid in estimating the capacity of a student to undertake the academic work of the next higher level of schooling. They measure the two kinds of school-related abilities which are most important in the greatest number of school and college endeavors: verbal and quantitative.

How does SCAT do it?

Each test booklet in the SCAT series contains four parts or subtests. Two of these subtests, Part I and III, are measures of developed verbal ability. Parts II and IV measure developed ability in basic quantitative areas. The test items (questions) in all four parts are multiple-choice items; the student has to choose the best answer from among five choices presented.

Characteristics of SCAT

Part	Kind of Items	Number of Items	Time Allowed (minutes)
I	Sentence understanding	30	15
II	Numerical computation	25	20
III	Word meanings	30	10
IV	Numerical problem solving	25	25

Each of the tests in the series yields three scores: a Verbal score, based on Parts I and III; a Quantitative score, based on Parts II and IV; and a Total score, based on all four parts.

APPENDIX A (continued)

Forms of SCAT

Level	Alternate Tests	Appropriate Examinee Group
1	A, B	College freshmen and sophomores Grade 12
	C, D	College freshmen and sophomores already admitted
2	A, B	Grades 10, 11, and 12
3	A, B	Grades 8, 9, and 10
4	A, B	Grades 6, 7, and 8
5	A, B	Grades 4, 5, and 6

The tests at a given level are designed to be appropriate for "typical" students in the indicated range of grades. No grade designation appear on the test booklets or answer sheets, however, so a particularly advanced or retarded group may be given tests at the next higher or next lower level. In addition, since instructions for administering SCAT are the same for all levels, a test administrator may find it convenient to give one level of SCAT to some members of a test group and another level of SCAT to other members at the same time.[1]

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[1]Cooperative Test Division, SCAT Manual for Interpreting Scores (Los Angeles: Educational Testing Service, 1957), p. 5.

APPENDIX B

DESCRIPTION OF STEP SCIENCE

What does STEP SCIENCE measure?

The Sequential Tests of Educational Progress (STEP) in Science tests were designed to measure ability to use scientific knowledge to solve problems.

The committee planning the SCIENCE tests prepared the following list which they believed covered the most important types of scientific reasoning and they believed should be assessed by the STEP SCIENCE tests:

1. Ability to identify and define scientific problems. Included in this category is the ability to isolate a problem from a mass of given material and to formulate the problem in a way which allows for systematic solutions.

2. Ability to suggest or screen hypotheses. Subabilities included here are the abilities to suspend judgment, recognize cause-and-effect relationships, recognize the possibility of testing a hypothesis, recognize the logical consistency and plausibility of a hypothesis, and check it with relevant laws, facts, operations or experiments.

3. Ability to select valid procedures. This encompasses the design of experiments and the planning required for collection of appropriate data.

4. Ability to interpret data and draw conclusions. This includes the ability to formulate valid conclusions and to recognize or draw valid generalizations from data known or given.

5. Ability to evaluate critically claims or statements made by others. This encompasses the critical evaluation of advertisements, written materials, and audio-visual materials. Other abilities included are the abilities to detect superstition and fancy, recognize the pseudo-

APPENDIX B (continued)

scientific, and avoid unwarranted extrapolations and generalizations; to distinguish fact, hypothesis, and opinion; and to distinguish the relevant from the irrelevant.

6. Ability to reason quantitatively and symbolically. Included under this heading are abilities to understand and use numerical operations, symbolic relations, and information presented in graphs, charts, maps, and tables.

For each of the SCIENCE tests the approximate percentages of questions designed to probe each of the abilities are as follows:

Define problems	10%
Screen hypotheses	25%
Select procedures	17%
Draw conclusions	23%
Evaluate claims	12%
Reason quantitatively	13%

The percentages are not exactly the same for all of the tests, but the differences from one form to another generally are not great.

The scientific knowledge involved in the items in the tests comes from six fields. A list of the more important concepts and principles for each of these fields was prepared. A phase of one of the concepts that was considered appropriate for a particular grade level was selected and combined with one of the six abilities to be tested to form the basis for each item written for the tests. The distribution of the questions among the six subject-matter fields is as follows:

Biology	40%
Chemistry	16%
Physics	23%
Astronomy	8%
Geology	7%
Meteorology	6%

APPENDIX B (continued)

How does STEP SCIENCE measure it?

The SCIENCE tests are made up of sets of items. Each set is introduced by a brief description of a situation and is made up of from 3 to 10 questions related to that situation. This plan was used in order to make questions seem of more practical significance, and perhaps interest, to students and to make possible the development of questions which cut across the conventional dividing lines between the sciences, emphasizing the point that some of the same abilities are involved in the pursuit of all sciences.

The situation about which groups of questions were written were selected from the following:

1. Economic (conservation, industry, mining, fuels, agriculture).
2. Social (medicine and hygiene, communications).
3. Cultural (hobbies, mass-entertainment media).
4. Home (home equipment and repairs).

The number of situations in a test varies from 8 to 13. The situations are about equally divided among the four described, except that more questions at the college level are classified "economic" and more at the elementary are classified "home."

Each test booklet in the SCIENCE series contains 60 items of the multiple-choice type; the student has to choose the best answer from among four choices presented. The items are divided equally between two parts, so that a test may be given in one or two sessions, depending on class schedules or college schedules. A single score based on "number right" is obtained.

In order to provide for the wide range of ability found between the fourth grade and the college sophomore year, the series includes tests at four levels of difficulty.

APPENDIX B (continued)

In addition, so that the same level may be given to a student more than once and results will not be affected by his memory of the items, equivalent tests are provided at each level. The forms and groups for whom they are appropriate are listed below:

Forms of STEP SCIENCE

Level	Alternate Tests	Appropriate Examinee Group
1	A, B	College freshmen and sophomores
2	A, B	Grades 10, 11, and 12
3	A, B	Grades 7, 8, and 9
4	A, B	Grades 4, 5, and 6

The tests at a given level are designed to be appropriate for "typical" students in the indicated range of grades. However, no grade designations appear on the test booklets or answer sheets, and a particularly advanced or retarded group may be given tests at the next higher or next lower level. In addition, since instructions for administering STEP SCIENCE are the same for all levels, a test administrator may find it convenient to give one level of the test to some members of a group and another level to other members at the same time.[1]

[1] Cooperative Test Division, STEP Manual for Interpreting Scores - Science (Los Angeles: Educational Testing Service, 1957), pp. 7-8.

APPENDIX C

This test was developed by Dr. Robert Lloyd Hedley in the course of research at Michigan State University, East Lansing, Michigan, in 1966.

S A T S

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

F O R M   A - (Revised)

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 physical 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.

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.

APPENDIX D

INQUIRY SESSION OUTLINES

The inquiry sessions were based on laboratory exercises taken from the Laboratory Manual accompanying the yellow version BSCS text. The following exercises were selected for the study:

1. 19-3
2. 21-1
3. 22-1
4. 23-1
5. 24-1
6. 26-1
7. 29-1
8. 30-2
9. 30-5
10. 31-2.

The inquiry session outlines provided the basic pattern for a discussion period. The following pages contain the outlines used for the inquiry sessions.

Exercise 19-3 Inquiry Session

Objectives

1. Students should be able to explain how paramecia ingest food particles.
2. Students should be able to describe what happens to the food in the food vacuole and explain the pH changes during digestion.
3. Students should be able to describe the elimination of waste products in a paramecium.

Background Information

The picture you see on the overhead transparency represents a paramecium in a solution containing red yeast cells, blue cells, and black particles. The red color of the yeast cells is due to a dye which is pH sensitive.

The Problem

Examine the solution surrounding the paramecium very carefully, ignoring what happens inside the paramecium. Notice the variations in concentration for some of the materials in the solution.

Hypotheses

Explain why the concentrations of some of the materials vary throughout the solution. (Answers given are to be discussed and evaluated).

Experimental Design

Suggest possible ways to experimentally test your hypothesis. (After discussing the suggestions, information will be given about the actual experiment using stained yeast cells and paramecia).

The Second Problem

Carefully examine the paramecium cell. Study the food vacuole cycle and take note of the color change.

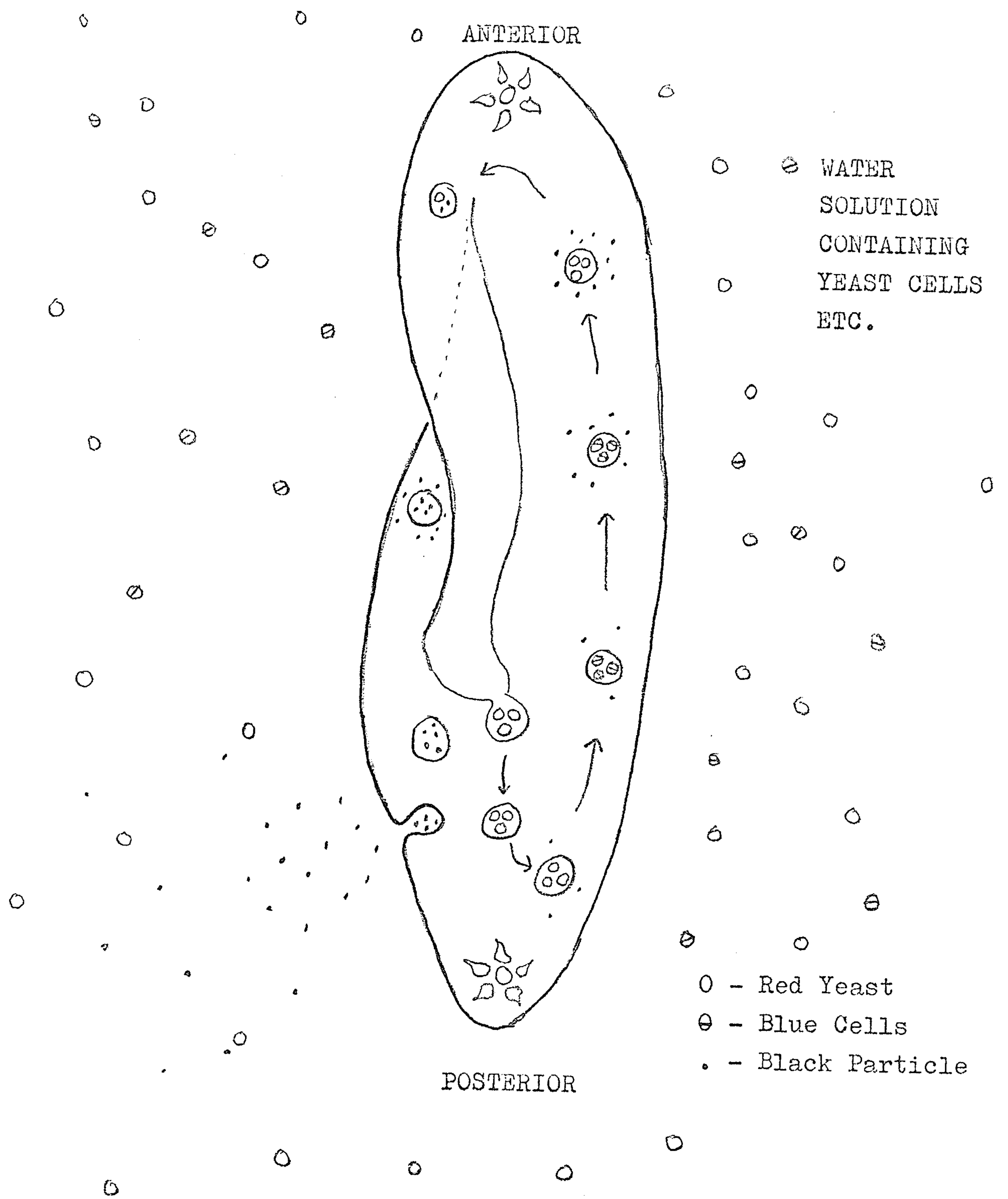
Hypotheses

Suggest reasons for the color change and explain why it may be necessary. (Answers given are to be discussed and evaluated).

Experimental Design

Suggest possible ways to experimentally test your hypothesis. (After discussing the suggestions, information will be given about the actual experiment illustrating the color change and pH concentration).

INGESTION AND DIGESTION IN PARAMECIUM



Exercise 21-1 Inquiry Session

Objectives

1. Students should know how chemicals are used to test common foodstuffs for starch, sugar, protein, and fat.
2. Students should be able to relate the chemical composition of foodstuffs with the location where they will be broken down in the human digestive system.
3. To give students an experience in critically evaluating the results obtained from a number of chemical tests for nutrients.

Background Information

In order to determine the presence of different nutrients in foodstuffs we must have some knowledge about the chemical tests which can give us this information. Research analysts have developed various tests to determine the presence of different elements and compounds. We have selected four tests to determine the presence of four nutrients: starch, glucose, protein, and fat. The tests are:

1. When testing with iodine, a blue-black color indicates the presence of starch.
2. When testing with Benedict's solution and heat, an orange-yellow color indicates the presence of glucose.
3. When testing with Biuret solution, a pink-violet color indicates the presence of protein.
4. When testing a food by rubbing it on paper, a permanent translucent spot indicates the presence of fat.

The Problem

Four different foods were analyzed using the tests outlined. Results from these tests are shown on the overhead transparency. (A transparency showing colored reactions was used to arrive at the following results).

	Whole Milk	Skim Milk	Banana	Bread
Iodine	-	-	+	+
Benedict's	+	+	+	+
Biuret	+	+	-	-
Paper Spot	+	-	-	-

Evaluation of Data

1. Which of the foodstuffs contain
   a) starch?
   b) glucose?
   c) protein?
   d) fat?
2. What seems to be the only difference between whole and skim milk?
3. According to these results there is no fat in skim milk and no protein in banana and bread. On the basis of what you know about cell structure in living tissue, can you accept these results as accurate?

A New Problem

1. If proteins are actually present in banana and bread, why do the tests give us a negative result?
2. What important lesson may be learned from this data?

Relating Digestion of Foods and Location of Enzyme Activity

The following chart, taken from exercise 21-1, is to be used to relate the chemical composition of foodstuffs with the location where enzymes break foods down in the human digestive system:

Overhead Transparency

Area	Gland	Foods Affected	End Products
Mouth	Salivary	Starch	Maltose
Stomach	Gastric	Protein	Proteoses and Peptones
Intestine	Pancreatic and	Fats	Fatty acids and Glycerol
	Intestinal	Starch	Maltose
		Proteins	
		Proteoses and Peptones	Amino Acids
		Maltose milk sugar and table sugar	Glucose and other simple sugars

Hypotheses

1. How would you, as a scientist, go about determining digestion sites?

Analysis of Data on Transparency

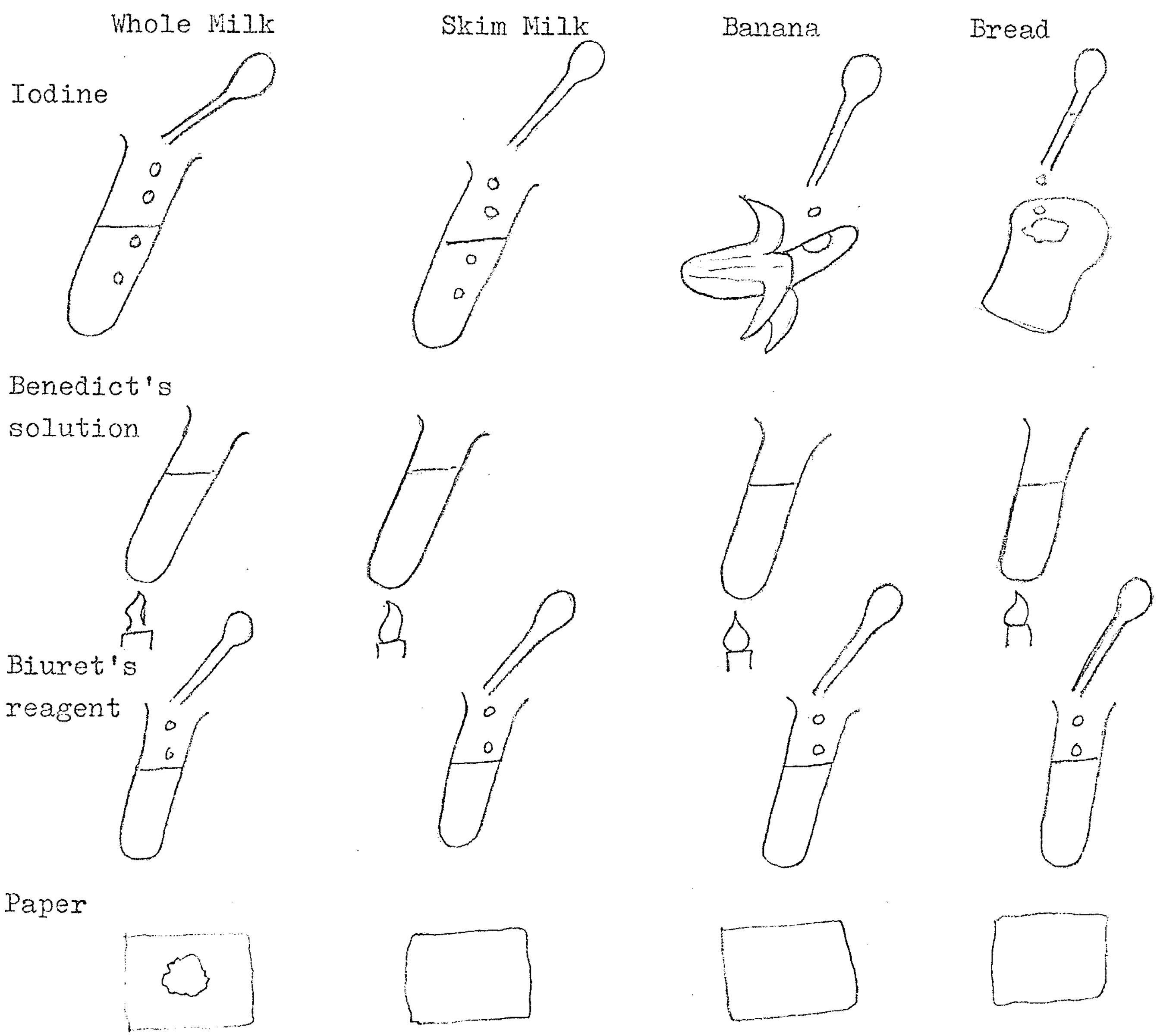
1. Where does digestion for each of the following foods begin:
   a) whole milk? b) skim milk? c) banana? d) bread?
2. Which foods are digested in both an acid and an alkaline pH?

TRANSPARENCY

Tests

1. Iodine and starch - blue-black color.
2. Benedict's solution and glucose - orange-yellow color;
3. Biuret solution and protein - violet color.
4. White paper and fat - permanent translucent spot.

(Reactions in color on overhead transparency to show a positive or negative reaction).



Exercise 22-1 Inquiry Session

Objectives

1. Students should be able to describe the effects of temperature changes on the rate of heartbeat in the daphnia.
2. Students should be able to describe the effects of drugs, in terms of tranquilizers and stimulants, on the rate of heartbeat.
3. Students should be able to relate the effects of temperature change and drug effects to variability of organisms. Not all organisms are affected in the same way by changing conditions.

Background Information

Since most students do not know what daphnia are like it is necessary to give some information. (A diagram of a daphnia is to be used and presented by means of an overhead projector). The daphnia is a fresh-water crustacean about 1/16 of an inch long. It moves through water using its feelers as oars. It has a transparent carapace surrounding most of its body. The action of the heart can be seen visually with the aid of a microscope, therefore, the effects of temperature change and drugs on the rate of heartbeat can readily be observed.

The Problem

How can we find the effects of specific temperature changes and drugs such as chlorpromazine, dexedrine and 5% ethyl alcohol on the rate of heartbeat in daphnia?

Hypotheses

Some of the drugs to be considered have been used to treat certain conditions in humans. Chlorpromazine has been used effectively in the treatment of mental problems and hyperactivity conditions. Dexedrine is often used to control mental depression. The effects of alcoholic beverages is due to the concentration of ethyl alcohol. In view of this information, what effect would you expect the three chemicals to have on the rate of heartbeat in daphnia? What effect, if any, should a temperature change have on the heartbeat?

Experimental Design

How would you go about testing the effects of drugs and temperature change on the rate of heartbeat in daphnia? (After discussing possible methods suggested, students were given a brief description of the method described in the laboratory manual).

Analysis of Data and Forming Conclusions

The following data from an earlier experiment is to be presented by means of an overhead transparency:

Daphnia	Rate of Heartbeat for Each Temperature						
Number	36°	31°	26°	21°	16°	11°	6°
1	406	388	352	310	282	198	162
2	382	372	306	258	252	198	174
3	120	350	336	282	252	198	162
4	282	150	138	294	210	102	66
5	408	376	360	324	264	192	150
6	439	426	402	258	215	143	108
7	102	336	438	330	258	192	120
8	444	396	360	330	246	196	-
9	342	312	300	270	240	186	138
10	-	360	348	300	288	216	180

Daphnia Number	Rate of Heartbeat for Each Drug Chlorpromazine	Dexedrine	5% Ethyl Alcohol
1	-	-	276 - 198
2	-	-	336 - 264
3	-	288 - 348	-
4	-	228 - 198	-
5	360 - 210	-	-
6	270 - 48	-	-
Average	____	____	____

1. Does a 5 degree temperature change affect all daphnia equally? What does this suggest?
2. Does a 5 degree temperature change have the same effect anywhere between 36 and 6 degrees?
3. Do drugs effect all daphnia equally? Why?
4. Classify the chemicals as tranquilizers and stimulants.
5. When the temperature data in the table is plotted on a graph, does it support your hypothesis explaining the relationship between heartbeat and temperature? (An overhead transparency is to be used to present a graph).
6. What are some factors to be considered before applying the information about chemicals to other organisms?

Exercise 23-1 Inquiry Session

Objectives

1. Students should be able to perform a simple experiment to measure the rate of carbon dioxide production in the human body.
2. Students should be able to relate the rate of carbon dioxide production to the rate of metabolism and oxygen requirement.
3. Students should be able to relate the rate of metabolism to such factors as level of activity, body size, rate of respiration, and food consumption.

Background Information

In order to understand the relationship between carbon dioxide produced and oxygen used in metabolism the student must have a knowledge of the unit of measurement used. The micromole is used as the unit to measure quantities of gas in this experiment. A micromole is a millionth of a gram molecular weight of a substance. The gram molecular weight of oxygen is 32 and carbon dioxide is 44, therefore one micromole of oxygen, 32 millionths of a gram, is equivalent to one micromole of carbon dioxide, 44 millionths of a gram.

Phenolphthalein is an indicator of pH in this experiment. Sodium hydroxide is a base and combines with carbonic acid to form sodium bicarbonate and water. This reaction can be used to measure the amount of carbon dioxide dissolved in water in the form of carbonic acid. The following reactions are involved:

$$CO_2 + H_2O = H_2CO_3$$

$$H_2CO_3 + NaOH = NaHCO_3 + H_2O$$

The Problem

In this session we want to look at the problem of human respiration. More specifically, we want to examine the rate of metabolism in our bodies. The area of metabolism we are concerned about is the oxidation of glucose. We want to investigate the rate at which this oxidation process takes place.

Experimental Design

Suggest a method we could use to measure the rate of metabolism in terms of glucose oxidation in man.

Experiment to Measure Metabolism

The experiment used in the laboratory manual for this exercise is to be outlined and illustrated with an overhead transparency.

Analysis of Data and Forming Conclusions

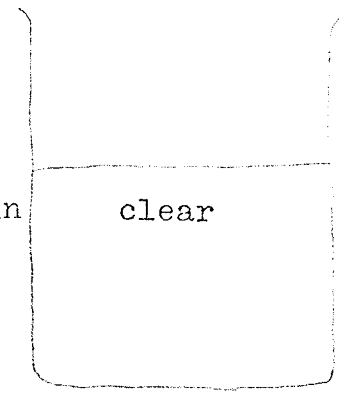
Data from an experiment is to be presented on an overhead transparency for discussion.

Questions for discussion:

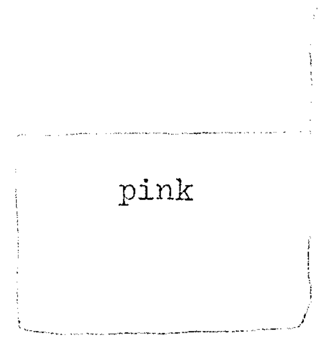
1. What are some conclusions you would make on the basis of this data?
2. Formulate an hypothesis suggesting a reason for the differences in metabolic activities.
3. How could you test your hypothesis?
4. Suggest a relationship which might exist between the rate of respiration and food requirements.
5. Could the hypothesis in question four be tested? How?

TRANSPARENCY

1.
100 ml.
water and a
few drops of
phenolphthalein

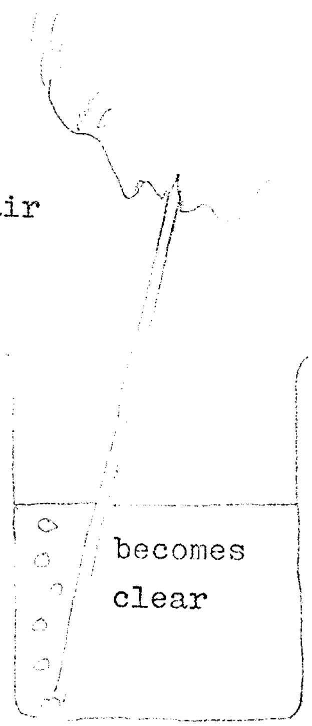


2.
added a few
ml. of NaoH



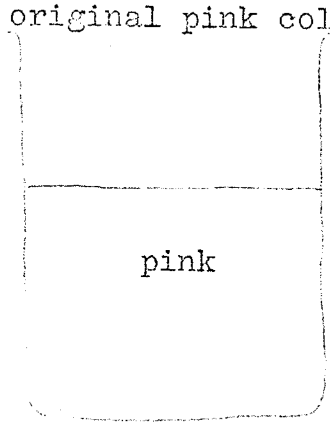
What does this color change suggest about phenolphthalein?

3.
Exhale air
for one
minute.



Why does the pink color disappear?
What has happened to the pH of the solution?
What compound is formed as a result of breathing through the solution?

4.
Added a number of ml. of 0.04% Na OH to change solution back to original pink color.



How many micromoles of CO_2 were exhaled in one minute?

TRANSPARENCY

Micromoles of carbon dioxide exhaled in one minute for each of ten students.

Student	Micromoles exhaled at rest	Micromoles exhale after exercising			
		20 steps	40 steps	60 steps	weight
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					

Exercise 24-1 Inquiry Session

Objectives

1. Students should be able to explain the homeostatic function of the kidney, using specific nutrients to illustrate their answers.
2. Students should be able to explain the effects of certain diets on the presence of wastes in urine.
3. To give students information about tests used in a urinalysis to determine the presence or absence of urea, chloride ions, glucose, and pentose.

Background Information

One aspect of the problem investigating human kidney functions requires a knowledge of tests used in determining the presence of certain products in urine. The products we are interested in are: urea, sodium chloride, glucose, and pentose. The following tests can be used to detect their presence:

1. The test for urea. Glacial acetic acid and a few drops of xanthydrol in a methyl alcohol solution are added to a urine sample. The formation of large, loose clumps indicates the presence of urea. The concentration of the clumps can be used as a measure of the amount of urea in the sample.
2. The test for chloride ions. A few drops of silver nitrate are added to a urine sample. A cloudy, white precipitate indicates the presence of chloride ions.
3. The test for glucose. A piece of glucose tes-tape is immersed in a urine sample. The color change from yellow to different shades of green

indicates the presence and concentration of glucose. Color charts are provided with the tes-tape in order to interpret results.

4. The test for pentose. Bial's reagent is added to a urine sample and gently warmed. A few drops of 1% ferric chloride is added to the warm solution. A deep green color appears if pentose is present.

(If students have not been given a structural knowledge of the nephron this background would have to be given also).

The Problem

In this discussion we are interested in learning something about the effects of certain diets on the composition of urine. The diets we are interested in are: a high protein, low salt, high glucose, and high pentose diets. A number of students have volunteered to restrict their diets in order to make a study of the effects this will have on urine concentration. (The results from such a study are presented by means of an overhead projector).

Forming Hypotheses

An overhead transparency of the human circulatory system is to be used for the formation of hypotheses in the following questions:

1. What effect would you expect a high protein diet to have on the concentration in the blood leaving,
   a) the small intestine?
   b) the liver?
   c) the kidney?
   d) the lungs?

2. What effect would you expect a low salt diet to have on absorption in the small intestine? Why?
3. How would a low salt diet affect the presence of sodium chloride in urine?
4. What effect would you expect a high glucose diet to have on the concentration of blood,
   a) in the portal vein?
   b) in the hepatic vein?
   c) in the renal artery?
   d) in the renal vein?
5. What effect would you expect a high pentose diet to have on urine concentration?
6. What would you expect to find if you compared samples of blood from a high protein and a high glucose diet?

Experimental Design

If you were asked to organize an experiment to determine the effects of diet on the concentration of wastes in urine, what would you consider to be necessary data to make reasonably valid conclusions?

Analysis of Data and Forming Conclusions

The chart in the manual, containing information about absorption in the kidney, is to be presented by means of an overhead transparency.

Questions for discussion:

1. Notice the differences in the percentages reabsorbed. What does this seem to indicate about the role of the kidney?
2. How would the percentages in the final column change for the protein, salt, and glucose diets if the hypotheses formed are correct?

Exercise 26-1 Inquiry Session

Objectives

1. Students should be able to describe the role of the sympathetic and parasympathetic nerves and the effects they produce in the same muscle tissue.
2. Students should be able to give reasons why it is important that the same type of nerves produce opposite effects in the heart and the stomach muscles.
3. Students should be able to relate Loewi's work with hearts with the discovery of the role of the autonomic nervous system.

Background Information

Our study will involve two kinds of muscle tissue: the cardiac muscle of the heart and the smooth muscle of the stomach. Both types of muscles are controlled by the autonomic nervous system. This is a system over which we have no conscious control. The autonomic nervous system is divided into two parts--the parasympathetic and the sympathetic--which have opposite effects from each other. Both systems are joined to the heart and the stomach in order to regulate their activities.

The Problem

We are told that there are two nerves entering the heart muscle. One of the nerves belongs to the sympathetic system and the other belongs to the parasympathetic system. These nerves are attached to the heart muscle at different points. One nerve impulse accelerates the rate of heartbeat and the other nerve slows it down. Our problem is to determine how these nerve impulses produce these opposite effects on the cardiac muscle tissue.

Hypotheses

What factors can you suggest that may account for the nerves having opposite effects on the heart muscle?

Experimental Evidence

After discussing the suggested hypotheses information about muscle response and nerve impulses will be given.

Using the frog heart it can be shown that a stimulus from the sympathetic nervous system will cause all the cardiac muscle tissue to contract, including the area where the parasympathetic nerve is attached. When the parasympathetic nerve is stimulated it also affects the tissue where the sympathetic nerve is attached. This implies that the point of attachment is not the significant difference between the two systems.

A study of nerve impulses has shown that the impulse travelling through a neuron from point A to point B is the same for all neurons. This impulse consists of a depolarized area moving along the neuron. This suggests that the difference is not in the type of impulse in the two systems.

Additional Hypotheses

In the light of the additional information are there any other hypotheses that could explain the difference in the two systems?

Additional Experimental Evidence

An explanation of Loewi's experiment is to be given. Loewi used two frogs' hearts with nerves removed from one of the hearts. The two hearts were joined by a tube so that the salt solution from one heart could be pumped into the second heart. The sympathetic and parasympathetic nerves were retained in one heart but not in the other. When the nerve was stimulated in the first heart, the effect produced also appeared in the seconded heart a few moments later. The only connection between the two hearts was the salt solution. (Illustrated with a diagram).

Further Hypotheses

What does Loewi's experiment suggest about the function of the nervous system?

The presence of hormones in the salt solution is to be explained at this time.

A Second Problem

Stimulating the sympathetic nervous system increases the heartbeat but decreases stomach activity.

Hypotheses

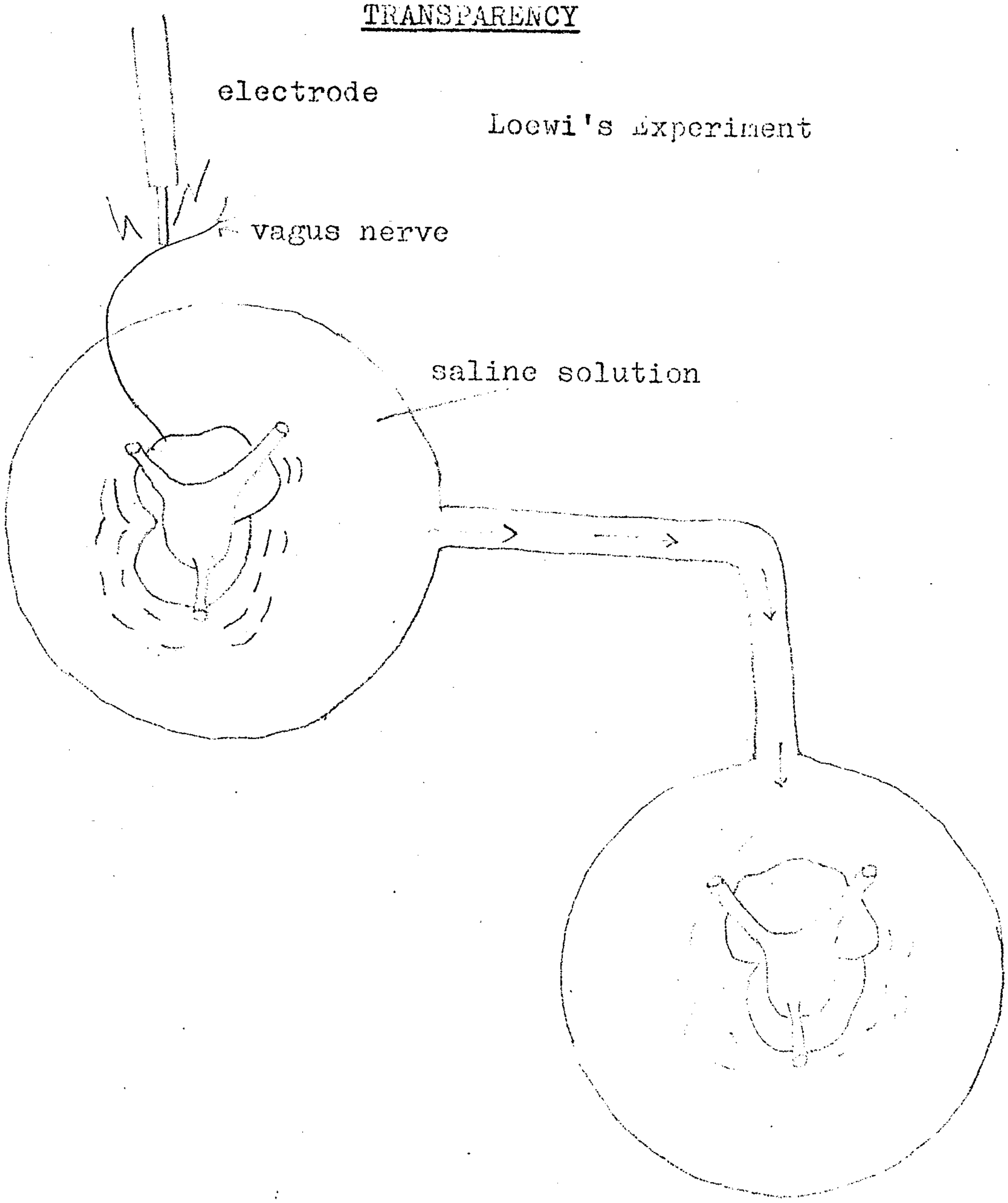
Suggest an explanation for the different effects produced by the two nervous systems.

Conclusions

1. Is it necessary to have two types of nerves connected to the same organ?
2. Why is it necessary to have two types of nerves producing opposite effects in the heart and the stomach?

TRANSPARENCY

Loewi's Experiment



Exercise 29-1 Inquiry Session

Objectives

1. Students should know that the ability to regenerate is dependent on the level of specialization achieved by a cell.
2. Students should know what effects certain cuts have on the regeneration process in planaria.

Background Information

Many animals have an amazing ability to regenerate, or replace parts of the body. Even in higher forms of animal life there are some very interesting phenomena. A lizard, called the glass snake, has a tail twice the length of its body. When an enemy seizes the lizard's tail, the animal pulls its body away from the tail and crawls to safety. The tail remains and continues to wriggle, keeping the enemy's attention. The lizard regrows the tail. Salamanders can replace their legs while the frog, which is also an amphibian, cannot replace its limbs. Crayfish can replace their eyes and appendages. Even man has a measure of regenerative ability. Sections removed from the liver have been known to grow back. The healing of cuts and repairing of bone and muscle tissue is a form of regeneration. Starfish regrow from small parts if a section of the central disc is included.

Asexual reproduction is a form of regeneration in which new organisms grow out of the parent tissue. This is the case in hydra and yeast. In plants like strawberries new plants grow from runners, and African violets grow from leaves.

The highest degree of regeneration is found in the invertebrates. The process takes place fairly rapidly and can easily be investigated in the laboratory. We want to study the process as it takes place in the planarian. In order to make this study we must have some knowledge about the basic body plan of the organism. (An overhead transparency is to be used to illustrate the basic structure of the nervous system). Notice the basic pattern of the nervous system.

The Problem

It is possible to do an experiment with planaria to show regeneration for a number of different cuts of the body. (Examples of different cuts is to be shown by means of the overhead projector). In two to three days buds form where the cuts were made and in about fourteen days the regeneration process is complete. No pigment develops during the bud stage. The five cuts shown on the transparency will produce eight new planaria, similar to the original except for size.

Hypotheses

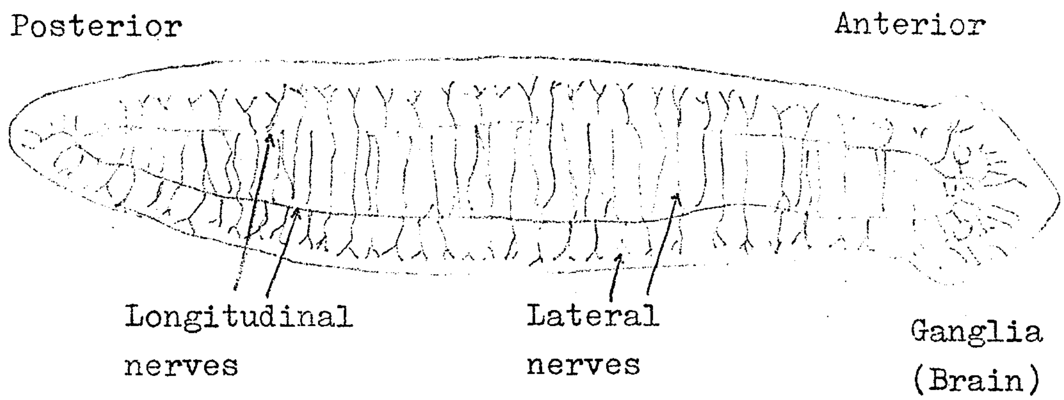
Considering the results obtained from the five cuts, does it make any difference where you cut the planarian for regeneration to take place?

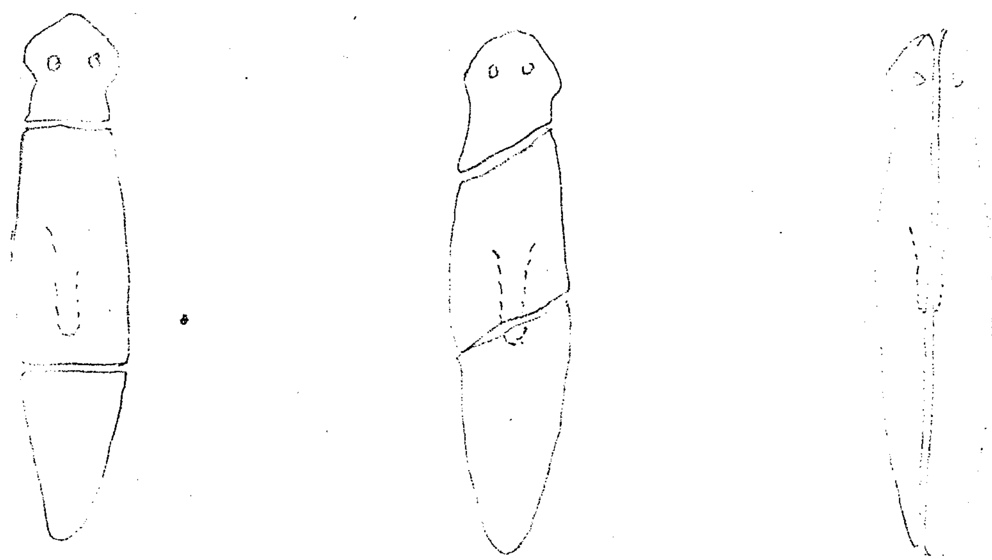
Experimental Design and Discussion of Results

1. Is it possible to make a cut to produce a planarian with two heads? How?
2. Could we produce two anterior heads?
3. How could you produce two heads, one anterior and one posterior?

4. Why do you think regeneration is possible to this extent in the planarian and not in the earthworm?
5. Why do oblique cuts not produce structures at right angles to the cuts? (This is a research problem still to be solved).
6. Suggest why the regenerating bud tissue is colorless.

TRANSPARENCY





Types of cuts in which each piece produces a new planarian.

Exercise 30-2 Inquiry Session

Objectives

1. To show students the importance of using large samples in research involving populations.
2. Students should know the meaning of the Product Rule and be able to use it in solving genetic problems where it applies.
3. Students should be able to use the terms, chance, randomness, and probability correctly in relation to genetics.
4. Students should be able to use the binomial expansion to find probabilities for different combinations of boys and girls in families.

Background Information

In this study we want to make a study of randomness, chance, and probability. In order to do this we will have to define each of these terms. Chance refers to situations where the causes affecting the outcome of an event cannot be determined because they are too numerous and individually very weak. We ignore the causes and treat the situation as if all events have an equal opportunity to be selected. The outcome of chance selection can be mathematically predicted under certain conditions. Such predictions are given values between 0 and 1 and are called the probabilities. Randomness means making a completely impartial choice. If there are factors influencing your choice it is no more a random selection.

A completely random selection in a situation involving two events should result in the selection of equal numbers from the two possibilities. In actual situations this may not always give us a one to one ratio. This difference between the expected and the actual results is called the deviation.

The chromosomes in the body cells can be grouped into pairs and therefore the genes on these chromosomes form pairs. It is a pair of genes on a pair of chromosomes that contain the information for a trait. To simplify the story we say that genes may be dominant or recessive. When a dominant gene pairs with a recessive gene, the recessive gene will not express itself. When two dominant genes, or two recessive genes, appear together they form a homozyous pair. When a dominant and recessive gene form a pair we say they are heterozygous.

The Problem

In order to make a study of randomness, chance, and probability, we will use data obtained by throwing dice. In our first problem only one die was used and the numbers were considered to be odd or even. This limits the results to two possibilities. The data to be used is the result of 100 throws, in groups of 10 throws, made by each of ten students. This provides us with a total of 1000 throws of the die.

Hypotheses

Predict what effect, if any, population size should have on the percentage deviation from the expected distribution.

Analysis of Data and Conclusions

Data is to be presented by means of an overhead transparency and discussed.

1. Examine the percentage deviations for the ten, one-hundred, and one-thousand throws. What conclusion can you make?
2. What are the implications for any research involving populations?
3. Why are the deviations of the larger groups less than the smaller groups?

A Second Problem

In the first problem only one event could happen at one time. In our second problem we want to look at situations where two events appear together. Each of the events may be odd or even and therefore four combinations are possible. In order to distinguish the two events from each other, one die was red and the other was green. The two dice were thrown together and the results recorded as one of the following: green even red even, green even red odd, green odd red even, or green odd red odd. Results were recorded for ten students, each throwing the dice forty times.

Hypotheses

What kind of a distribution would you expect to get from forty throws of the two dice?

If the probability of odd or even for one die is 1 out of 2, or 1/2, what would you expect the probability to be for both dice being even, or odd, or even and odd?

Analysis of Data and Conclusions

Results from data described in the problem are to be presented by means of an overhead projector.

1. Compare the distribution of forty throws with the total of four-hundred throws. What happens to the relative frequencies of the four combinations?
2. Is the green die independent of the red die?
3. What is the probabilty for the green die being odd, or the red die being odd?
4. What is the probability for the green die being odd and the red die being odd at the same time?
5. What is the relation of the individual probabilities for each die to the probability for the combination?
6. State the Product Rule of probability.

A Third Problem

In this problem each die will represent a pair of chromosomes. The even numbers represent one chromosome of a pair and the odd numbers the other. The two dice represent a chromosome pair in which one has come from each parent. Since each parent can contribute only one chromosome from each pair to the offspring, it is a matter of chance which one is passed on. It is a matter of chance which chromosome is given to the egg or sperm by the parent. The probabilty of a gamete receiving a specific chromosome from a pair is 1/2.

In most cases there is no difference between a chromosome coming from the sperm and egg. Thus the green even red odd and green odd red even combinations provide the same information.

Further Discussion and Conclusions

1. In what way does the additional information alter our distribution?
2. What chromosome combinations must the parents have to get a 1:2:1 distribution?
3. What happens to the phenotypic ratio of 1:2:1 when one gene is dominant over the other gene of a pair?
4. What happens to the distribution when one parent is homozygous and the other is heterozygous?
5. Is there a human trait that is distributed according to this ratio?
6. How can we use the product rule to find the probability for each of the following situations:
   a) two children, both boys?
   b) two children, one boy and one girl in this order?
   c) three children, all boys?
   d) three children, one boy and two girls in any order?

Exercise 30-5 Inquiry Session

Objectives

1. Students should know the meanings of the following terms as applied in genetics: chromosomes, genes, traits, gametes, dominant gene, recessive gene, heterozygous, and homozygous.
2. Students should be able to do simple genetics problems involving genotypes of parents and the types of offspring expected.
3. To show students the important relationship between the information carried by a gene and the influence of the environment on the expression of the gene.

Background Information

In order to understand the discussion in genetics you must have a clear understanding of a number of terms relating to this topic. We will examine a number of these terms and attempt to define them. The first term we should define is the chromosome. During the process of cell division DNA material in the nucleus becomes concentrated in a number of rod-like structures that can be seen with a microscope. These structures are called chromosomes. In meiosis the chromosomes arrange in pairs on the spindle in order to separate when the cell divides to form the egg or sperm. This separation reduces the chromosome number in the egg or sperm, called gametes, to one-half the original number. The arrangement of a pair of chromosomes on the spindle is a random selection. Each chromosome carries a section of DNA which represents the genes.

A corresponding section of DNA on a pair of chromosomes provides the information for a trait. Since a trait is the result of a pair of genes on a pair of chromosomes, different strengths of genes produces different results. One gene may be dominant over the other gene in a pair and therefore the recessive gene will not be expressed. The information carried by the recessive gene is still carried by the chromosome and can be passed on to the next generation.

Since genes can be either dominant or recessive, pairs may be alike forming a homozygous pair, or unlike forming a heterozygous pair. (The blackboard will be used in the definition of terms).

The Problem

In this session we want to examine the relationship between heredity and environment. More specificlly, we want to determine whether the expression of a gene is affected by the conditions in which it develops. To do this we will use the results from 120 tobacco seeds whose parents were heterozygous for the chlorophyll trait. This means each seed carries a gene which cannot produce chlorophyll. A combination of this gene produces albinism. The gene for chlorophyll is dominant over the gene for albinism.

Hypotheses

We want to make some predictions concerning the results from 120 seeds grown under specific conditions.

Let us use a capital "A" to represent the dominant gene producing chlorophyll and a small "a" to represent the recessive gene for albinism.

1. What would you expect the gene pair of the parents mentioned in the problem to be like?
2. What is their genotype?
3. What kind of gametes would each of the parents produce?
4. Form a hypothesis concerning the results you would expect from 120 seeds planted in a light environment. (Each hypothesis is to be discussed).

Analysis of Data and Conclusions

The 120 seeds were divided into two groups and planted in separate containers. One container was exposed to light and the other one was kept in complete darkness.

1. What results would you expect to find for the two treatments?

The data from an actual experiment is to be presented at this time giving the following information:

Plants exposed to light: green plants equal 47
albino plants equal 13.

Plants in complete darkness: green plants equal 0
albino plants equal 60.

2. How does the ratio of green:albino for the plants kept in the light compare with the predicted ratio?
3. How would you explain the results for the plants kept in complete darkness?
4. What would you expect if the plants kept in the dark were placed in the light? (Results from such a treatment is to be given at this time).
5. What can you conclude about the relative importance of heredity and environment from this experiment?

Exercise 31-2 Inquiry Session

Objectives

1. Students should be able to explain why certain traits appear much more frequently in males than in females.
2. Students should be able to do simple genetics problems involving sex-linked traits.

Background Information

Genetics is a very interesting area of study and a field in which there are still many questions to be answered. Some questions we thought we could answer at one point and we are not so sure today. The condition known as hemophilia is one such area. Research is being conducted at the Winnipeg General Hospital under the direction of Dr. Israels to learn more about hemophilia. This research has changed some previously held ideas about the disease and raised some doubt about its heredity. Within the last few years this research developed an anti-hemophilic globulin to control bleeding. This seemed to be the answer to the bleeding problem even to the extent where it was considered that operations were possible for hemophilics. This was considered a real break-through, only to discover later that the patient can build up anti-bodies making the serum ineffective for some time after the first treatment. This was an unexpected problem.

Questions are also being raised about the hereditary pattern of hemophilia. The accepted theory has been that the hemophilic father passes the gene to his daughters who become carriers of the condition. The father cannot pass the condition on to his sons.

There are some traits that are expressed differently in the two sexes. In some way such conditions must relate to the pair of chromosomes determining sex. A female has two microscopically identical chromosomes on which the sex genes are located, while the pair are not identical in the male. In the formation of gametes the chromosome pairs separate. Fertilization restores the chromosome pairs. The pair of chromosomes determining sex in the female are symbolized by XX and the pair in the male by XY. With this background we want to study a problem involving heredity in the fruit fly.

The Problem

Fruit flies have four pairs of chromosomes in each cell and one pair contains the genes determining sex. Using the same symbols used in man, we will indicate a female as XX and a male as XY.

The following crosses were made using pure strains of red-eyed and white-eyed drosophila:

a) white-eyed males crossed with red-eyed females.
b) white-eyed females crossed with red-eyed males.

Hypotheses

We don't know at this point which gene is dominant so we will consider both possibilities.

1. What results would you expect for both crosses if white is dominant?
2. What results would you expect for both crosses if red is dominant?

Analysis of Data and Conclusions

In our first cross using a white-eyed male and a red-eyed female all of the offspring had red eyes.

1. Which hypothesis does this support?

In our second cross using a white-eyed female and a red-eyed male half of the offspring were red-eyed and half were white-eyed.

2. Which hypothesis does this support?
3. How can you explain the fact that the two crosses did not produce the same results?
4. Does it help to know that all the white-eyed flies in the second cross were males?
5. What conclusions can we make from the results of the two crosses and the fact that the white-eyed flies are males?

APPENDIX E

Laboratory Evaluation

Select the one best answer in each of the following questions:

1. When red yeast cells, dyed with congo red, are ingested by paramecia there are color changes within the vacuoles. Select the correct sequence of color changes beginning with the ingested cell.
   a) red, black, blue.
   b) black, red, blue.
   c) blue, red, black.
   d) red, blue, red.
2. The color change of food being digested in the paramecium vacuole is due to
   a) enzyme activity.
   b) breakdown of food particles.
   c) change in the acidity.
   d) digested particles diffusing out of the vacuole.
3. Undigested food residue in the paramecium is discarded
   a) by diffusing through the cell membrane.
   b) through a specialized opening.
   c) into the cytoplasm.
   d) through the oral groove.
4. When testing foods containing protein
   a) biuret changes from blue to violet-pink in color.
   b) Bial's reagent changes to a pink color.
   c) Benedict's solution turns red.
   d) tes-tape changes to a green color.
5. Tests used to determine foodstuffs in the laboratory
   a) gave conclusive evidence that skim milk has no fat.
   b) indicated no starch in bananas.
   c) are reliable and commonly used.
   d) gave us some questionable results.

6. Protein digestion
   a) must start in the stomach in order to take place at all.
   b) need not start in the stomach.
   c) is completed in the stomach.
   d) is completed in the large intestine.
7. In the process of digestion, in man, some foods studied are
   a) treated in both an acid and basic pH.
   b) completely digested in the mouth.
   c) digested only in the stomach.
   d) are digested only because of the addition of saliva.
8. Using daphnia, which chemicals have a tranquilizing effect?
   a) dexedrine and alcohol.
   b) dexedrine and chlorpromazine.
   c) alcohol and chlorpromazine.
   d) alcohol, dexedrine and chlorpromazine.
9. Using different temperatures
   a) it was found that a series of increases of 5 degrees C., produced equal increases in a daphnia's heartbeat.
   b) only affects the heartbeat of daphnia differently at higher temperatures.
   c) seemed to indicate daphnia had a higher tolerance level for higher than lower temperatures.
   d) produced different changes in heartbeat in different daphnia.
10. Adding phenolphthalein to tap water
   a) produces a slight pink color.
   b) causes no color change.
   c) makes the water acid.
   d) raises the pH to above 7.
11. Blowing air through a straw into the water and indicator
   a) caused a pink color to appear.
   b) lowered the pH of the solution.
   c) made it more basic.
   d) added OH^- ions.

12. Adding sodium hydroxide after blowing air through a water solution
    a) neutralized the hydroxide ions.
    b) caused the pink color to disappear.
    c) is added to make it more acidic.
    d) is added to raise the pH.
13. In the respiration experiment
    a) we found no relationship between body weight and CO_2 exhaled.
    b) we found a close relationship between the increase in CO_2 exhaled after exercising for different students.
    c) most of the class members exhaled similar amounts of CO_2.
    d) we measured the amount of oxygen taken in for metabolism.
14. Which statement is <u>not</u> correct?
    a) Measuring CO_2 exhaled is an indirect measure of the rate of metabolism.
    b) CO_2 is a waste product of metabolism.
    c) The rates of metabolism are basically similar for all people.
    d) The rate of activity affects the amount of CO_2 exhaled.
15. Which atatement is correct about the function of nephrons?
    a) Increasing water intake decreases the amount of urine.
    b) Decreasing protein food will increase the percentage of urea absorbed back into the blood.
    c) A low salt diet increases chloride ions in urine.
    d) Glucose in urine is always due to excess sugar in the diet.
16. The test for urea involves adding
    a) glacial acetic acid and xanthydrol.
    b) biuret and xanthydrol.
    c) Bial's reagent and ferric chloride.
    d) silver nitrate.

17. Blood samples from two individuals on different diets
    a) should be different because of the intake of different diets.
    b) should be basically similar due to the homeostatic role of the nephron.
    c) should give an indication of the type of diet each was given.
    d) will be different if one of the diets is protein.
18. Which statement is correct?
    a) Adrenaline speeds up muscle activity in the stomach.
    b) Acetylcholine speeds up muscle activity in the heart.
    c) Adrenaline slows down the rate of breathing.
    d) Acetylcholine slows down activity in the heart.
19. Which statement is <u>not</u> true?
    a) Regeneration buds have no pigmentation at first.
    b) Regeneration always produces perfect replacements.
    c) There are limitations to the planarian's ability to regenerate.
    d) Planaria can be cut to form two heads and two tails.
20. In genetics the word "chance" means
    a) a situation where the causes affecting the outcome are not significant.
    b) that in two situations one is dependent on the other.
    c) there are few factors influencing the selection.
    d) a situation where the choices are equal in number.
21. "Randomness" is a term
    a) meaning a situation where the choices are equal in number.
    b) which does not involve chance.
    c) in which the probabilities are always equal.
    d) meaning a choice governed by chance.

22. If the results of ten throws of a die is 6:4, the deviation is

a) one.

b) two.

c) four.

d) six.

23. If the probability of each of two events is 1/2, the probability of a certain combination of the two events is

a) one-half.

b) one.

c) one-eighth.

d) one-quarter.

24. If the probabilities of two events are respectively 1/3 and 1/4, the probability of the same events occuring together is

a) 2/7.

b) 2/12.

c) 1/12.

d) 1/7.

25. What is the probability of a family of three being two boys and one girl in any order?

a) 3/8.

b) 1/8.

c) 1/6.

d) 1/4.

26. The tobacco seeds used in the experiment to study environment and heredity were

a) half heterozygous.

b) not the same genotype.

c) all homozygous.

d) all heterozygous.

27. The trait which develops depends

a) only on genotype.

b) only on phenotype.

c) on recessive genes.

d) on other factors besides genotype.

28. A pure red-eyed male fly is crossed with a pure white-eyed female. This produces

    a) only red-eyed flies.

    b) half red and half white-eyed flies.

    c) only white-eyed flies.

    d) 3/4 red-eyed and 1/4 white-eyed flies.

29. A pure red-eyed female crossed with a pure white-eyed male results in

    a) 1/2 white and 1/2 red-eyed flies.

    b) only white-eyed flies.

    c) only red-eyed flies.

    d) 3/4 re-eyed and 1/4 white-eyed flies.

30. A gene pair represented by $X^R X^r$ indicates a

    a) heterozygous genotype.

    b) heterozygous phenotype.

    c) homozygous genotype.

    d) homozygous phenotype.

APPENDIX F

CONVERTED SCAT SCORES FOR CONTROL GROUP

Subject	Verbal score	Quant. score	Total score	Subject	Verbal score	Quant. score	Total score
1	303	302	302	31	296	302	299
2	315	311	311	32	293	325	306
3	289	311	298	33	310	315	311
4	312	315	312	34	287	277	284
5	305	321	312	35	290	293	292
6	285	325	300	36	297	321	307
7	310	321	314	37	295	311	302
8	310	317	312	38	323	323	320
9	307	317	311	39	287	323	301
10	297	321	307	40	288	315	299
11	292	321	304	41	283	313	295
12	280	300	289	42	301	284	295
13	301	321	310	43	298	321	308
14	303	309	306	44	286	304	293
15	301	306	303	45	315	302	306
16	319	302	307	46	291	302	296
17	315	338	324	47	296	323	307
18	293	293	294	48	285	313	296
19	285	308	294	49	292	338	309
20	276	308	289	50	267	300	282
21	296	323	307	51	286	311	296
22	282	300	290	52	300	295	298
23	307	313	309	53	307	292	313
24	295	302	298	54	310	331	318
25	288	311	297	55	282	313	295
26	310	291	300	56	296	302	299
27	319	331	322	57	301	325	312
28	315	309	310	58	327	343	330
29	288	319	300	59	268	309	286
30	288	308	296				

APPENDIX G

CONVERTED SCAT SCORES FOR EXPERIMENTAL GROUP

Subject	Verbal score	Quant. score	Total score	Subject	Verbal score	Quant. score	Total score
1	279	311	292	28	298	315	306
2	293	319	304	29	290	309	298
3	296	309	302	30	289	308	299
4	285	295	289	31	307	304	305
5	310	319	313	32	297	291	295
6	298	308	302	33	305	304	304
7	305	300	302	34	275	289	282
8	291	302	296	35	296	331	310
9	305	331	316	36	268	289	278
10	310	328	317	37	298	315	306
11	312	331	320	38	272	315	290
12	279	309	291	39	292	298	295
13	315	304	307	40	301	298	300
14	296	334	311	41	290	302	295
15	288	291	290	42	305	338	318
16	305	319	311	43	301	297	300
17	287	313	297	44	312	311	310
18	303	334	316	45	305	321	312
19	300	315	306	46	293	308	300
20	289	309	297	47	300	288	295
21	300	313	306	48	290	308	297
22	297	297	297	49	307	317	311
23	298	325	310	50	285	315	297
24	291	315	301	51	280	325	297
25	303	315	308	52	290	311	299
26	295	309	301	53	287	325	302
27	305	334	317	54	319	325	320

APPENDIX H

CONVERTED STEP SCORES FOR CONTROL GROUP

Subject	Pre-test score	Post-test score	Subject	Pre-test score	Post-test score
1	297	300	31	273	281
2	289	292	32	297	303
3	300	310	33	319	326
4	290	307	34	276	277
5	292	308	35	274	287
6	284	300	36	297	310
7	297	297	37	287	287
8	289	295	38	290	297
9	289	295	39	295	303
10	295	310	40	279	294
11	295	308	41	282	274
12	292	290	42	284	292
13	289	297	43	295	300
14	298	294	44	287	294
15	300	298	45	294	300
16	282	286	46	276	282
17	305	305	47	297	294
18	289	287	48	284	277
19	274	274	49	292	287
20	271	276	50	290	303
21	294	300	51	290	290
22	284	281	52	286	284
23	287	302	53	310	315
24	276	273	54	311	311
25	287	277	55	292	303
26	292	298	56	287	286
27	322	320	57	295	294
28	282	289	58	319	319
29	302	294	59	281	287
30	289	281			

APPENDIX I

CONVERTED STEP SCORES FOR EXPERIMENTAL GROUP

Subject	Pre-test score	Post-test score	Subject	Pre-test score	Post-test score
1	277	282	28	286	287
2	294	311	29	281	289
3	286	292	30	287	287
4	255	276	31	295	295
5	297	302	32	289	290
6	279	287	33	302	308
7	286	290	34	271	265
8	290	300	35	317	297
9	307	322	36	287	286
10	290	298	37	276	287
11	281	297	38	297	298
12	277	282	39	271	273
13	294	303	40	292	300
14	292	282	41	279	286
15	281	286	42	286	297
16	298	308	43	271	282
17	282	286	44	305	313
18	313	322	45	303	310
19	295	303	46	284	295
20	284	284	47	292	305
21	276	281	48	274	279
22	294	298	49	298	303
23	287	297	50	284	295
24	279	287	51	279	286
25	282	287	52	263	276
26	284	290	53	311	311
27	292	298	54	322	326

APPENDIX J

SATS SCORES FOR CONTROL GROUP

Subject	Pre-test sub-test 3 score	Pre-test sub-test 5 score	Pre-test total score	Post-test sub-test 3 score	Post-test sub-test 5 score	Post-test total score
1	35	36	209	36	35	204
2	32	39	204	38	38	226
3	45	40	259	42	41	262
4	33	32	231	40	40	246
5	51	38	251	47	46	275
6	42	32	245	44	26	191
7	40	34	240	48	39	253
8	30	37	224	33	35	220
9	32	32	248	38	39	227
10	37	42	250	41	44	265
11	43	46	264	43	36	225
12	38	34	221	42	35	219
13	42	38	233	47	42	265
14	43	39	225	47	40	251
15	44	38	257	47	38	259
16	32	31	190	37	42	218
17	51	37	281	50	42	283
18	40	40	206	42	39	260
19	41	41	220	36	31	210
20	32	39	209	35	44	213
21	48	38	257	53	36	267
22	34	32	215	36	36	203
23	50	30	256	37	42	255
24	42	43	254	43	44	239
25	41	34	248	49	35	238
26	45	38	254	45	42	273
27	42	37	242	38	38	254
28	41	32	216	42	32	210
29	38	34	228	36	28	211

APPENDIX J (continued)

Subject	Pre-test sub-test 3 score	Pre-test sub-test 5 score	Pre-test total score	Post-test sub-test 3 score	Post-test sub-test 5 score	Post-test total score
30	36	29	196	36	34	186
31	40	43	268	41	35	235
32	36	32	195	43	35	225
33	55	43	276	47	40	257
34	36	31	224	48	35	228
35	50	44	284	44	41	243
36	36	56	245	33	47	249
37	49	47	234	42	37	223
38	36	47	258	37	41	260
39	33	43	205	36	36	214
40	38	34	224	39	35	229
41	33	39	237	35	39	235
42	47	47	273	52	42	277
43	43	34	224	39	35	219
44	45	37	238	42	39	253
45	47	39	262	49	38	272
46	39	43	259	47	36	224
47	39	42	216	36	40	215
48	39	38	209	34	37	202
49	49	39	254	40	35	236
50	48	37	230	40	27	190
51	34	30	221	37	36	230
52	39	45	248	44	37	232
53	44	43	242	45	42	255
54	53	40	229	49	40	258
55	39	33	228	43	33	229
56	35	41	204	39	39	202
57	32	37	205	28	40	217
58	56	43	298	51	38	276
59	42	38	233	43	39	244

APPENDIX K

SATS SCORES FOR EXPERIMENTAL GROUP

Subject	Pre-test sub-test 3 score	Pre-test sub-test 5 score	Pre-test total score	Post-test sub-test 3 score	Post-test sub-test 5 score	Post-test total score
1	37	34	221	40	41	239
2	38	37	213	34	40	208
3	40	47	244	39	37	231
4	47	44	273	43	43	262
5	40	35	245	45	37	253
6	48	34	242	45	40	254
7	39	39	217	35	45	210
8	34	39	206	39	38	217
9	44	36	239	44	33	243
10	55	37	275	44	49	283
11	38	40	252	42	38	239
12	27	41	199	37	35	194
13	40	35	203	33	37	201
14	42	42	242	38	38	214
15	28	40	180	27	32	188
16	40	38	248	40	39	243
17	37	37	230	42	40	233
18	54	43	269	53	45	259
19	42	34	261	45	39	268
20	45	41	265	46	42	276
21	39	33	198	32	32	188
22	45	38	250	46	41	251
23	37	38	238	47	36	232
24	42	42	257	47	37	255
25	40	39	237	56	42	257
26	42	39	273	46	46	273
27	37	34	214	38	34	210

APPENDIX K (continued)

Sub-ject	Pre-test sub-test 3 score	Pre-test sub-test 5 score	Pre-test total score	Post-test sub-test 3 score	Post-test sub-test 5 score	Post-test total score
28	40	39	232	43	37	235
29	33	34	202	30	26	171
30	50	39	272	49	37	273
31	34	45	242	36	40	231
32	38	30	234	34	33	229
33	39	35	239	42	39	224
34	38	39	205	33	40	211
35	47	29	242	45	31	233
36	41	35	210	32	37	202
37	34	38	225	35	39	209
38	46	42	274	47	42	260
39	36	38	227	38	39	237
40	34	29	209	37	32	205
41	37	35	209	36	35	213
42	38	44	265	38	34	208
43	32	35	209	31	38	211
44	45	36	244	51	40	281
45	49	35	244	40	36	226
46	41	33	207	35	28	186
47	58	33	237	50	37	236
48	33	42	218	46	35	236
49	37	31	211	39	33	227
50	39	40	247	42	38	240
51	42	42	248	36	46	276
52	36	42	231	36	40	202
53	50	37	281	54	46	303
54	53	45	298	70	45	306

APPENDIX L

ACHIEVEMENT SCORES IN BIOLOGY FOR CONTROL GROUP

Subject	Course work	Laboratory work	Subject	Course work	Laboratory work
1	74	14	31	66	8
2	58	15	32	73	11
3	64	13	33	70	16
4	62	12	34	35	11
5	50	13	35	41	15
6	66	10	36	64	14
7	76	15	37	72	11
8	77	15	38	80	21
9	74	15	39	50	14
10	72	19	40	66	11
11	62	14	41	66	8
12	43	8	42	37	11
13	34	13	43	56	15
14	45	14	44	81	12
15	88	12	45	81	19
16	61	15	46	35	15
17	86	19	47	77	10
18	79	15	48	24	12
19	36	4	49	76	21
20	31	7	50	78	14
21	74	10	51	64	12
22	33	12	52	26	6
23	72	14	53	89	23
24	70	13	54	67	15
25	56	10	55	66	15
26	68	16	56	36	11
27	78	19	57	50	7
28	74	11	58	90	18
29	50	10	59	53	13
30	28	12			

APPENDIX M

ACHIEVEMENT SCORES IN BIOLOGY FOR EXPERIMENTAL GROUP

Subject	Course work	Laboratory work	Subject	Course work	Laboratory work
1	32	11	28	78	17
2	56	8	29	71	10
3	59	11	30	61	7
4	50	11	31	67	14
5	67	13	32	50	13
6	62	14	33	80	14
7	68	13	34	50	12
8	31	10	35	83	20
9	87	15	36	36	5
10	81	17	37	42	10
11	83	15	38	46	9
12	36	10	39	30	12
13	46	13	40	63	11
14	50	12	41	62	11
15	52	17	42	42	13
16	72	17	43	35	12
17	50	13	44	50	12
18	88	21	45	41	17
19	91	15	46	59	14
20	81	13	47	82	17
21	57	16	48	50	17
22	50	12	49	76	11
23	68	12	50	41	12
24	71	12	51	65	8
25	69	16	52	42	11
26	69	11	53	80	19
27	56	14	54	94	18