A COMPARISON OF THE DISCOVERY APPROACH
WITH THE LECTURE APPROACH IN
TEACHING GENERAL BOTANY

By

VINCENT ALLEN HALL

Bachelor of Science
South Dakota State University
Brookings, South Dakota
1956

Master of Science
South Dakota State University
Brookings, South Dakota
1957

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Thesis Approved:

Kenneth E. Wiggins
Thesis Adviser

Kenneth St. Clair

Thomas D. Johnston

L. Herbert Bruneau

D. D. Durham
Dean of the Graduate College

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Chapter I

INTRODUCTION

Teaching is as old as civilization. Comparatively, concern about the most effective way to teach is rather recent, if the number of different methods available and in use is a criterion. Many people still prefer much of the old, yet American society appears to want to provide the greatest amount of education possible with the fewest teachers.

Many modern approaches to teaching science in high school, such as BSCS, PSSC, CBA, and CHEM studies, stress individual learning approaches. In essence, these are compromises between the individual approach and the teacher dominated classroom. Although these approaches emphasize individual learning, in most instances the teacher is still the central figure in the classroom.

A basic and frequently studied problem in education is the retention of knowledge. Investigations have shown retention after one or two years to be practically nil in some cases and 100 percent in others. Although many variables enter the picture, retention seems to rely heavily on meaningfulness of material.

The present study was made in an attempt to determine the effectiveness of using the discovery method in promoting learning of General Botany and the retention of this material at the college level.

The Need for the Study

Science is not a favorite subject of many students. Some have expressed the opinion that science courses often do not involve the student in the same types of activity that the scientist performs.

The discovery method is an attempt to make "miniature scientists" of the students. The student performs laboratory exercises and "discovers" the answers to questions himself. Practice at formulating questions which can be answered by experimentation is provided. The desirability of accurate and close observation becomes obvious to him as he works.

Various studies have been made comparing the discovery method with a traditional method. The large majority of research on the discovery approach as a method of learning in the area of science and mathematics has been done in mathematics. Relatively little has been done in the area of biology. Most research investigations done on this method have involved relatively short learning periods of usually no more than one or two week duration. The present investigation is concerned with the retention and understanding of information involving the entire plant kingdom and its evolutionary aspects. This amount of information normally constitutes a one semester course.

The discovery method may have many advantages for the instruction of biology. It is important that investigations be conducted to determine whether the discovery method is suitable for college biology classes. This study was designed to assess the desirability of the discovery method as a method of teaching General Botany at the freshman college level.

Statement of the Problem

This study was an investigation of two methods of teaching college Botany for effectiveness in promoting learning at the "knowledge" and "above knowledge" levels, as judged by an achievement test. The two methods were the lecture method and the discovery method.

The lecture method utilized lecture, a laboratory period and a textbook as means of transferring information to the student. The instructor played a central role in the educational process. The laboratory followed a normal, prescribed pattern with specific exercises to be performed by the students. This was the control group and is occasionally referred to as the traditional method in this paper

The second method was the discovery method. Basically the same material was presented to this group. The discovery method stressed student involvement. Specific exercises were not assigned. The students were expected to formulate the exercises or experiments necessary to determine the characteristics of the various plants. The instructor acted as a moderator to provide direction and guidance throughout the semester.

The independent variable was the material studied by the students. The dependent variables were the methods of teaching this material.

Specifically, this study attempted to answer the following questions:

1. How does the achievement of students taught by the discovery method compare with the achievement of students taught by the lecture method?
2. How does the retention of learning of students taught by the discovery method compare to the retention of learning of students taught by the lecture method?
3. How do the answers to a course evaluation opinion survey compare for the two groups?

Hypotheses

For the reasons expressed in Chapter III, the hypotheses are stated in a greater than, less than or equal manner. The hypotheses tested were:

1. The mean of the scores of the control group (Group II, lecture method) is equal to the mean of the scores of the experimental group (Group I, discovery method) on the final examination.
2. The mean of the scores of the control group (Group II, lecture method) is greater than the mean of the scores of the experimental group (Group I, discovery method) on the final examination.
3. The mean of the scores of the control group (Group II, lecture method) is less than the mean of the scores of the experimental group (Group I, discovery method) on the final examination.
4. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is equal to

the mean of the scores of the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.

5. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is greater than the mean of the scores for the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
6. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is less than the mean of the scores for the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
7. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is equal to the mean of the scores for the "above knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
8. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is greater than the mean of the scores for the "above knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
9. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is less than the mean of the scores for the "above knowledge" level questions of the experimental group (Group I,

discovery method) on the final examination.

10. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is equal to the mean of the scores of the top half, as judged by the students' ACT composite scores, of the experimental group (Group I, discovery method).
11. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is greater than the mean of the scores of the top half, as judged by the students' ACT composite scores, of the experimental group (Group I, discovery method).
12. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is less than the mean of the scores of the top half, as judged by the students' ACT composite scores, of the experimental group (Group I, discovery method).
13. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students' ACT composite scores, is equal to the mean of the scores of the bottom half of the experimental group (Group I, discovery method), as judged by the students' ACT composite scores.
14. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students'

ACT composite scores, is greater than the mean of the scores of the bottom half of the experimental group (Group I, discovery method), as judged by the students' ACT composite scores.

15. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students' ACT composite scores, is less than the mean of the scores of the bottom half of the experimental group (Group I, discovery method), as judged by the students' ACT composite scores.
16. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is equal to the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).
17. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is greater than the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).
18. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is less than the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).

Definition of Terms

Control group refers to those students who were taught by the conventional lecture with a laboratory period. This group had three one-hour lecture periods and one three-hour laboratory each week. This is Group II.

Lecture group refers to the control group.

Traditional method refers to the manner in which information was presented to the control group. This is sometimes referred to as the lecture method.

Experimental group refers to those students who were taught by the discovery method. This group had two two-hour laboratory sessions and two one-hour reporting-discussion periods each week. This is Group I.

Discovery method refers to the manner in which information was presented to the experimental group. The student learned by the same method scientists use in conducting research. An expanded definition is contained in Appendix A.

Limitations of the Study

This study was limited to one control group and one experimental group at Dakota State College in Madison, South Dakota.

The study did not attempt to determine the effectiveness of the teacher in using the two teaching methods.

Assumptions of the Study

1. The sample size was adequate to provide reliable data.

2. The test instrument was valid and reliable in measuring student achievement for both teaching methods.

3. There was no difference in the amount of stimulation of the two groups resulting from the experimental design of this study.

4. The instructor was able to provide the same quality of instruction with each method.

5. External factors which may affect student achievement and attitude were evenly distributed between the two groups.

CHAPTER II

REVIEW OF SELECTED LITERATURE

Holt (14) describes discovery learning as the natural learning style of young children. One does not have to observe preschool children long to determine that for these children learning is full of fun and excitement. Experimentation with the use of discovery in formal education is, at least in part, an attempt to bring the thrill of learning into the classroom.

Another aspect of learning is student involvement. Schramm and Oberholtz (28) report that a more or less accidental involvement of students in the periodic repairing of a programmed learning machine increased learning and retention. Lindgren (19) points out that "one of the shortcomings of traditional educational programs is that they do not get the student sufficiently interested and involved. The traditional concept of the student is that of the individual who passively absorbs whatever learning the teacher pours into him." He further states that we need to "develop techniques and approaches that will get children (students) involved in the educational process." He points out that earlier plans which involved students more in the learning process apparently produced superior results, but because they were radical departures from the traditional, they did not become popular methods.

The BSCS Biology Program emphasizes student involvement. The teacher role stresses free two-way communication between pupils and teachers, cooperative interaction, independence in thinking and self discovery. Hoy and Blankenship (15) found that teachers rated as "acceptors" of the BSCS Biology Program were more humanistic in their pupil control ediology and their capacity for independent thought and action than were teachers rated as "rejectors." Teachers were rated as "acceptors" if they possessed favorable attitudes toward the BSCS Biology Program and if they implemented the Program in their school. "Rejectors" had unfavorable attitudes toward BSCS and did not implement the Program in their school.

Kersh (16), using the principle in mathematics of "the sum of the first $\underline{n}$ odd numbers is $\underline{n}^2$," suggests that there are several different discovery approaches that can be used in learning. The type of discovery approach used depends on the type of information provided and the type withheld. He is critical of those who simply categorize methods as "discovery" or "lecture" without recognizing variations in each and of those who evaluate these methods simply as good or bad.

Scandura (27) concluded from a study of discovery, guided discovery and lecture methods that what is learned during mathematical discovery can be identified and taught by the lecture method with equivalent results. If a person already knows the desired responses, he is not likely to discover a higher order rule by which such responses may be derived.

Hardy (13) performed a study on whether the opportunity to participate in discovery learning by means of an archaeological dig significantly enhances the development in sixth grade pupils of concepts and principles of archaeology and anthropology, as compared with using the same data in conventional instruction. The students were separated on the basis of sex and were assigned at random into two classes of 29 students each. The same teacher taught both groups. On the basis of an investigator prepared pretest and post test, it was concluded that: the students in the discovery section were (1) more logical in organizing information; (2) more active in the task of learning; (3) and apparently more highly motivated than those in the control group. He also concluded that the discovery learning activity produced significant differences in favor of the students in the discovery group on the tests which measured anthropological understandings.

Dennison (10) studied the relative effectiveness of a verbal approach and a guided discovery approach to learning science principles with seventh and ninth graders. A total of 72 subjects were randomly selected from the seventh and ninth grades and divided into two groups for each grade level. A unit of Force was presented on Group X by the guided discovery method and to Group Y by the verbal method. The roles of the subjects were then reversed in presenting a unit on Mass. The guided discovery method was significantly better than the verbal method for the seventh grade students for the unit on Force. The verbal method was significantly better for the ninth grade students over the same unit. There was no significant difference between the two methods for the unit on Mass. With regard to retention and transfer of learning when measured four weeks after treatment, there was no significant difference between the two methods for either grade level.

Tanner (35) performed a study in which the principles of mechanics and simple machines were taught to ninth grade general science classes. Three different methods of teaching were used: (1) an expository-deductive program in which the subject read the statement and explanation of a principle and then worked with example frames illustrating the principle; (2) a discovery program in which the student worked with the example frames but without the statement of principle; and (3) an unsequenced discovery program containing the same frames but in random order and without the statement of principle. No significant differences were found among the groups.

Retzer (26) reported the results of a study designed to test the effects of a programmed unit in fundamentals of logic on the ability of college-capable junior high students to verbalize mathematical generalizations. The students were led to discover three generalizations about vectors. Verbalization was scored according to the number of required hints and the quality of the sentence structure. The students who had received the unit on logic did significantly better than the control group.

In a discussion of computer-assisted instruction, Bunderson (6) claims that bright students do better with discovery learning but that average or below average students learn more from expository instruction.

Guided discovery groups generally achieve higher problem-solving scores than groups taught by the lecture method, although generally there is no difference on computation skill (31).

Suydam concluded that meaningful developmental activities facilitate retention followed by systematic review and practice. To increase transfer, the teaching must be planned with transfer as an objective. Students should be taught how to transfer and generalize, preferably at their own ability level.

Chambers (7) performed a laboratory study with four levels of discovery and two levels of an overlearning factor. The results of the study indicate that overlearning has a considerably more powerful effect on transfer than does discovery. Over-learning seems to be an important condition for the transfer of a discovered principle. This is true, not because the principle is apt to be discovered during overlearning, but because a certain amount of practice is necessary to make the discovered principle available for transfer.

A study for the effects of discovery and expository methods of presenting geometry concepts on immediate acquisition and retention of concepts was conducted by Nelson and Frayer (22). They used 228 seventh graders who had not previously mastered the geometry concepts. Results showed that students in the expository groups spent less time studying the lessons, yet had superior immediate acquisition scores and equal retention scores.

Bruner (5) suggests four benefits derived from the discovery method: "(1) the increase in intellectual potency, (2) the shift from extrinsic to intrinsic rewards, (3) learning the heuristics of discovering, and (4) the aid to memory processing." He summarizes by saying, "the very attitudes and activities that characterize 'figuring out' or 'discovering' things for oneself also seems to have the effect of making material more readily accessible in memory." Although he thinks that retention or recall is improved by the use of the discovery approach in learning, he puts this fourth in the lists of benefits derived.

Although retention requires initial learning, the reverse is not true. Any method which will increase retention is a significant advancement. Several studies have indicated that retention is often at disappointing levels.

Sorenson (33) cites a college botany class in which retention was only 18 percent after 16 months, and points out that college zoology and high school chemistry courses frequently follow the same pattern. Smeltz (32) showed that where facts in chemistry were not taught as rote, but as meaningful "parts of an organic whole," retention after one year was an average 68 percent for a class of 180 students.

McKeachie and Solomon (21) found 81 percent retention in material learned in a psychology course seven months after completion of the course. Cronbach (8) also points out a study where students showed 100 percent retention after an interval of one year, and another study where, after one year, students did even better on examinations than immediately after learning the material.

Klausmeier (17), in summarizing a number of retention studies, indicated that "studies in college science courses show a definite loss over the time intervals measured. The amount of loss varies from 50 percent over a four-month period to as high as 94 percent loss of initial gain after one year."

The effect of the discovery method on retention and transfer of geometry concepts by sixth grade students was studied by Scott (29). The control group was taught by the traditional method. The results of his experiments indicated that the method of presentation did not affect either the acquisition or transfer of the material. The students taught by the discovery method were significantly better than the traditionally taught students in regard to retention when tested 11 and 21 days after the material was presented.

Ray (25) used a micrometer caliper as the experimental instrument in his "teaching-learning" experiment. The students in one group were taught the functions and principles involved in use of the caliper, and members of the other group were allowed to discover these for themselves. The students achieved equal results in the "direct and detailed" and "discovery" methods in initial learning and one-week retention. He found the discovery method to be superior in both six-week retention and in transfer of learning.

Bittinger (3), however, in a rather extensive review questioned the quality of Ray's "direct and detailed" approach and hinted that many who favor the discovery approach may not be willing to put the time and effort into a lecture approach to make it of top quality. Others have leveled this same criticism at those who support the discovery approach.

In a comparison of three methods of teaching General Mathematics, Maynard and Strickland (20) found no difference in retention of material. The three methods were discovery, student-teacher development of principle, and a traditional presentation.

None of the three methods was superior for male students, but the female subjects achieved significantly better under the traditional method.

Kleckner (18) studied the effect of discovery-type teaching methods on the achievement and attitudes of low achievers in mathematics in the ninth and tenth grades. He found the control group achieved significantly more general mathematics content than the discovery classes and there was no significant difference in attitude.

It is desirable that any instructional method create a favorable attitude toward the method and the subject matter. In a social studies method class, Seifman (30) provided a firsthand experience with the discovery approach to teaching. He defined this as being a structured learning activity in which the learner is encouraged to learn for himself that which is to be learned or discovered. The discovery learning process was both the technique of his lesson and the object for discovery. The 26 students in the methods course were presented with an unidentified fable and given the task of identifying as much about it as possible. After this, the students designed and taught an original social studies discovery lesson in a public school. The students' attitudes toward discovery teaching were mostly negative after Seifman's lesson. These attitudes did not change after their own teaching experience. However, many of those students who disapproved of the discovery method asked for the instructor's lesson for use in their own student teaching during the next semester.

Most teachers believe "concept" teaching is desirable. However the number of definitions of the term "concept" is almost as great as the number of people using the term. Novak (23) suggests that a "taxanomy of conceptual levels" be constructed to include all the various definitions and levels of the term "concept." He states that "learning through inquiry may not result in an understanding of the concepts of science."

Novak _et al_ (24) performed a review of 156 studies and attempted to interpret the research finding in terms of Ausubel's theory. The study was done to determine if the various research findings could be explained by the educational theory. Ausubel's (2) theory is concerned with "reception learning" where material is presented rather than discovered by the learner. He makes a distinction between "rote reception learning" and "meaningful reception learning." With "meaningful reception learning" new knowledge is associated with previously learned ideas or concepts. Thus, according to Ausubel's theory an important consideration of instruction is to link new material with past concepts learned by the students. Novak states that most of the studies were based on no learning theory.

Cronbach (9) has expressed the belief that inductive teaching is rarely superior to other meaningful teaching for single generalizations. He believes that an interaction between pupil characteristics and discovery may occur. He states: "I am tempted by the notion that pupils who are negativistic may blossom under discovery training, whereas pupils who are anxiously dependent may be paralyzed by demands for self-reliance."

CHAPTER III

METHODOLOGY AND DESIGN

Introduction

This study is an investigation of two methods of teaching college Botany at Dakota State College. Dakota State College is a member of the seven-college South Dakota system of higher education. The college is located in Madison, South Dakota, a city of approximately 7000. The enrollment at the time of the study was 1275. Most of the students are from the rural areas of the state.

The academic unit of Dakota State College is composed of six divisions: Science and Mathematics, Education and Psychology, Language Arts, Fine and Applied Arts, Social Science and Business, and Health and Physical Education. The main emphasis is training teachers. About 85 percent of the graduates earn elementary or secondary teaching certificates. The degrees granted are the Bachelor of Science and the Bachelor of Science in Education.

The Sample

The sample population consisted of students enrolled in General Botany, Biology 108. All of the students had a minimum of one semester of biological science previous to enrolling in the course. Each student was given a number at preregistration session, and a table of random numbers was utilized to make the group assignment. One of the groups was randomly selected to be the experimental group, and the remaining group became the control group. A total of 28 students enrolled in Botany 108, thus each group had an enrollment of 14 students.

Description of the Training Programs

Independent variables in this study were the course material and the instructor. The dependent variable was the method of teaching the Botany course. The study encompassed a one-semester period of time. Both sections studied the same areas of plant science, the same specific life cycles within each plant division, and in the same sequence.

The textbook, Botany, fourth edition, by Wilson and Loomis (37) was available to both sections. However, assignments were made only to the control group. The following chapters were assigned, although in some cases only a part of the chapter was utilized.

Chapter 2. The Plant Plan and its Modification
Chapter 3. The Cell as the Basis of Plant Life
Chapter 5. Photosynthesis and the Leaf
Chapter 7. The Structure and Growth of Stems
Chapter 8. Plants and Water
Chapter 9. The Root and the Soil
Chapter 13. The Flower and Seed Production
Chapter 14. The Fruit, the Seed, Seed Germination
Chapter 19. The Algae
Chapter 20. Bacteria and Viruses and some Relations to Man
Chapter 21. The Fungi: Slime Molds, Phycomycetes, Ascomycetes, Lichens
Chapter 22. The Fungi: Basidiomycetes and Fungi Imperfecti
Chapter 23. The Liverworts and the Mosses
Chapter 24. The Ferns
Chapter 26. The Club Mosses and the Horsetails
Chapter 27. The Gymnosperms
Chapter 28. The Angiosperms

Table I lists the plant divisions studied, the major plants used for each division and the order in which they were studied. The information of the first eight chapters was covered during the study of the angiosperms. Both the control and experimental groups followed this general sequence.

The students were told at the preregistration sessions that an analysis would be made of their performance. They were not told which group was the experimental group nor how the analysis would be made. On the first day of class a pretest was given. This pretest was also used for their final examination.

The students in each group were ranked according to their ACT composite test scores. Whenever a tie existed in their scores, the ranking was done by use of the ACT science subtest scores.

The control group, Group II, consisted of ten males and four females. Their ACT composite scores ranged from 16 to 29 with a mean of 22.4 Their ACT science subtest scores ranged from 16 to 32 with a mean of 24.0

The experimental group, Group I, which was taught by the discovery method, consisted of nine males and five females. Their ACT composite scores ranged from 15 to 26 with a mean of 20.9. Their ACT science subtest scores ranged from 15 to 31 with a mean of 23.1.

Table II lists the student rank, his ACT composite score and ACT science subtest score for each group.

The control group was taught by the conventional lecture and laboratory method. The group had three one-hour lecture periods

TABLE I

PLANT DIVISION, THE REPRESENTATIVE SPECIMEN USED AND ORDER OF MATERIAL

Division	Specimens
Angiosperms	Zea mays, Phaseolus, Lilium
Bacteria	
Phycomycetes	Rhizopus
Ascomycetes	Penicillium, Aspergillus
Basidiomycetes	Coprinis
Algae, Blue-green	Nostoc, Oscillatoria
Algae, Green	Spirogyra, Oedogonium
Liverworts	Marchantia
Mosses	Polytrichum
Ferns	Pteris
Club Mosses	Lycopodium, Selaginella
Gymnosperms	Pinus

TABLE II

RANKING WITHIN GROUPS BY ACT COMPOSITE SCORE AND ACT SCIENCE SCORE

	Group I Experimental Group			Group II Control Group	
	ACT Score			ACT Score	
Rank	Composite	Science	Rank	Composite	Science
1	26	25	1	29	32
2	24	31	2	28	32
3	24	30	3	26	29
4	24	26	4	25	26
5	23	20	5	24	27
6	21	25	6	24	27
7	20	28	7	24	23
8	20	25	8	23	29
9	20	19	9	23	16
10	20	19	10	19	18
11	19	23	11	19	17
12	18	22	12	17	22
13	18	15	13	17	17
14	15	15	14	16	21
$\bar{x}$	20.9	23.1	$\bar{x}$	22.4	24.0

and one three-hour laboratory each week for a total of six hours of class time per week. The lecture period met on Monday, Wednesday and Friday. The laboratory period was held on Thursday.

The experimental group had two two-hour laboratory sessions and two one-hour reporting-discussion periods for a total of six hours of class time per week. The laboratory sessions, which met on Tuesday and Thursday, were of the "discovery" type. The reporting-discussion periods were held on Wednesday and Friday. The students were to study a plant and make observations about it. From these observations, conclusions were made to help in understanding plants and plant life. The reporting-discussion periods were utilized to pool the information gained from the examination of the plants or in planning the work for the following laboratory period. The students were provided with living specimens of the plants, prepared slides and preserved material for study. Each student was required to make a written record of his observations. In addition, each student was required to make a composite of all the information discovered by the class. This was to be the student's "class notes" and his "textbook." A handout, "Introduction to Botany," was given to each student in the experimental group on the first day of class. This handout explained what was expected of the student and how the class was to function. A copy of this handout is Appendix A.

The instructor received his Ph.D. in Botany from the University of Nebraska and holds the rank of Professor of Biology. He was and is chairman of the Division of Science and Mathematics at Dakota State College. He had previously taught Botany several times, using the lecture method. He assisted J. F. Davidson in a Botany course using the discovery method at the University of Nebraska.

The Test Instrument

The same test instrument was utilized for the pretest, final test and post-final test. The pretest was given at the first class session of each group. The final test served as the final test of this study and also as the course's final examination. It was given during the last class period. The post-test was mailed to each student 17 months after the final examination. Although the data from the post-test are included in the report, it is not a major part of the study.

The test instrument consisted of 92 multiple choice questions with five or less possible responses and 10 questions with nine possible responses. Because of the length of time (an entire semester) between the pretest and the final, it was decided to use the same instrument for both. The pretest was not returned to the students, nor were their scores made known to them.

The test items were developed from the general course outline which served both groups and a table of specifications designed for the control group. The nature of the way in which the experimental group functioned did not lend itself to establishing a table of specifications with the same accuracy as for the control group.

At the conclusion of the course the instructor in conjunction with the author of this report judged the content validity of the instrument to be high in regard to the course outline, the table of specifications, and what had occurred in each of the groups during the semester.

Questions 30 and 66 were omitted prior to any evaluation of the instrument because no one response was clearly better than the other distractors.

The other 100 quesions were analyzed for difficulty level and discriminating power. The item difficulty was determined using the formula (1):

$$P = \frac{N_R}{N_t} (100)$$

where

P = percentage of pupils who answered the test item correctly.

N_R = number of pupils in both groups who answered the test item correctly.

N_t = total number of students in both groups who attempted to answer the test item.

Every student was considered to have attempted each item because he had answered another item following the omitted one. Only one student did not select a response for each question. That student did not indicate a choice of the responses for two items. Also, adequate time was allowed so that each student would have the opportunity to answer each item.

Ebel (11) suggests that only those test items having a level of difficulty between 40 and 70 percent be used. This range limited the number of acceptable test items to 23 when the discriminating power was also considered. Therefore, the decision was made to include those items between 35 and 75 percent. This increased the number of acceptable items to 38, an increase of 15 items. Each test item is listed in Table III with the number of students answering the item correctly in each group, the total number of correct answers and the level of difficulty.

The instrument was also analyzed to determine the discriminating power of the test items. The items were evaluated using the internal-consistency method as described by Ahmann and Glock (1) using the following formula:

$$D = \frac{U - L}{N}$$

where

D = index of item discriminating power.

U = number of students in the upper group who answered the test item correctly.

N = number of students in each of the two groups.

A distribution of final test scores of the combined groups is shown in Table IV. The group, experimental (I) or control (II), with the student's rank within that group as described earlier, is given. To avoid tie scores the upper and lower groups may have consisted of 1, 5, 6, 7, or 10 students in each group. This is 35.7 percent of the students in each group. If 6 or 7 students would have been used, the percentages would have been 21.4 and 25.0 respectively.

Ahmann (1) recommends that any item with a discriminating power of less than + 0.20 not be used. Therefore, only those items with a discriminating power index of + 0.20 or above were

TABLE III

LEVEL OF DIFFICULTY INDEX OF TEST ITEMS

Item Number	Group I Experimental	Group II Control	Total	Item Difficulty
1	14	14	28	1.00
2	8	9	17	.61 *
3	10	7	17	.61 *
4	10	10	20	.71 *
5	12	12	24	.86
6	13	14	27	.96
7	11	8	19	.68 *
8	12	11	23	.82
9	14	13	27	.96
10	14	12	26	.93
11	9	8	17	.61 *
12	13	12	25	.89
13	5	9	14	.50 *
14	12	14	26	.93
15	10	10	20	.71 *
16	14	10	24	.86
17	10	11	21	.75 *
18	4	6	10	.36 *
19	6	4	10	.36 *
20	5	3	8	.29
21	1	5	6	.21
22	14	11	25	.89
23	14	14	28	1.00
24	14	8	22	.79
25	6	9	15	.54 *
26	11	9	20	.71 *
27	8	10	18	.64 *
28	13	13	26	.93
29	8	9	17	.61 *
30	--	--	--	---

TABLE III (Continued)

31	5	8	13	.46 *
32	8	4	12	.43 *
33	5	4	9	.32
34	5	5	10	.36 *
35	6	10	16	.57 *
36	13	12	25	.89
37	11	10	21	.75 *
38	3	6	9	.32
39	12	13	25	.89
40	7	9	16	.57 *
41	8	6	14	.50 *
42	14	12	26	.93
43	11	13	24	.86
44	8	12	20	.71 *
45	11	13	24	.86
46	8	10	18	.64 *
47	11	9	20	.71 *
48	11	8	19	.68 *
49	12	10	22	.79
50	12	11	23	.82
51	4	9	13	.46 *
52	13	10	23	.82
53	11	12	23	.82
54	12	9	21	.75 *
55	8	8	16	.57 *
56	8	6	14	.50 *
57	5	7	12	.43 *
58	11	10	21	.75 *
59	13	12	25	.89
60	12	11	23	.82
61	3	6	9	.32
62	13	12	25	.89
63	9	13	22	.79
64	9	13	22	.79
65	9	10	19	.68 *
66	--	--	--	---
67	10	10	20	.71 *
68	12	12	24	.86
69	3	5	8	.29
70	8	9	17	.61 *

TABLE III (Continued)

71	10	9	19	.68 *
72	10	7	17	.61 *
73	6	9	15	.54 *
74	5	6	11	.39 *
75	14	14	28	1.00
76	5	5	10	.36 *
77	10	2	12	.43 *
78	12	11	23	.82
79	13	13	26	.93
80	14	10	24	.86
81	12	13	25	.89
82	12	11	23	.82
83	9	13	22	.79
84	4	7	11	.39 *
85	10	7	17	.61 *
86	4	6	10	.36 *
87	1	5	6	.21
88	4	7	11	.39 *
89	14	14	28	1.00
90	12	13	25	.89
91	10	10	20	.71 *
92	8	9	17	.61 *
II-1	7	11	18	.64 *
II-2	5	7	12	.43 *
II-3	8	6	14	.50 *
II-4	12	9	21	.75 *
II-5	5	2	7	.25
II-6	4	2	6	.21
II-7	9	8	17	.61 *
II-8	6	10	16	.57 *
II-9	4	5	9	.32
II-10	6	6	12	.43 *
	914	921	1835	

* Item with a difficulty index within acceptable range of 35 to 75 percent.

TABLE IV

DISTRIBUTION OF STUDENT SCORES ON FINAL EXAMINATION TO ALLOW THE SELECTION OF UPPER AND LOWER GROUPS

	Score	Student Group and Number
	90	II - 1
	87	II - 12
	87	I - 8
	83	I - 2
Upper Group	76	II - 6
	73	I - 5
	72	I - 14
	71	II - 5
	68	I - 11
	68	I - 13

	67	II - 4
	67	II - 11
	65	II - 10
	65	II - 13
	65	II - 2
	63	I - 6
	63	I - 12
	62	I - 4

	61	II - 14
	60	I - 1
	60	II - 8
	57	I - 3
Lower Group	56	II - 3
	54	I - 7
	53	I - 10
	53	II - 7
	53	I - 9
	39	II - 9

judged acceptable. Table V provides the item number, the number in the upper group and lower group that answered the item correctly and the discriminating power index of each question. Those found acceptable, a total of 57 items, are indicated.

Table VI lists the items which were acceptable, based upon either item difficulty level or discrimination power. Those items meeting both criteria are indicated and are the items used for all analyses of the pretest, final test and post-test.

Each acceptable test item was judged using the cognitive domain of Bloom's taxonomy (4) as being at the "knowledge" or "above knowledge" level. The questions were judged by the author in conjunction with the instructor. Seventeen questions were ranked at the "knowledge" level, and 21 items were judged to be at the "above knowledge" level. Table VII indicates at which level each item was ranked. The test itself is Appendix B.

To determine the reliability of the test instrument the split-half procedure was used on the final examination. The Pearson product-moment coefficient of correlation was calculated using the following formula (1):

$$r = \frac{\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right]}}$$

where

r = product - moment coefficient of correlation

ΣX = sum of the scores on the "x" half of the test

ΣY = sum of the scores on the "y" half of the test

TABLE V

DISCRIMINATING POWER INDEX
OF TEST ITEMS

Item Number	U	L	U - L	D
1	10	10	0	0
2	9	4	5	.50*
3	7	7	0	0
4	7	6	1	.10
5	9	8	1	.10
6	10	9	1	.10
7	8	6	2	.20*
8	10	7	3	.30*
9	9	9	0	0
10	10	8	2	.20*
11	9	3	6	.60*
12	10	8	2	.20*
13	8	3	5	.50*
14	9	9	0	0
15	9	5	4	.40*
16	9	8	1	.10
17	7	7	0	0
18	5	3	2	.20*
19	5	4	1	.10
20	6	2	4	.40*
21	2	2	0	0
22	9	8	1	.10
23	10	10	0	0
24	9	8	1	.10
25	5	5	0	0
26	10	5	5	.50*
27	10	2	8	.80*
28	9	10	-1	-.10
29	7	6	1	.10
30	--	--	-	----
31	6	3	3	.30*
32	3	7	-4	-.40*
33	5	2	3	.30*
34	6	1	5	.50*
35	6	5	1	.10

TABLE V (Continued)

Item Number	U	L	U - L	D
36	10	8	2	.20*
37	10	6	4	.40*
38	4	1	3	.30*
39	10	8	2	.20*
40	7	6	1	.10
41	6	4	2	.20*
42	10	8	2	.20*
43	8	8	0	0
44	9	6	3	.30*
45	8	8	0	0
46	7	4	3	.30*
47	9	5	4	.40*
48	9	6	3	.30*
49	9	7	2	.20*
50	10	7	3	.30*
51	4	4	0	0
52	9	8	1	.10
53	9	8	1	.10
54	9	7	2	.20*
55	8	3	5	.50*
56	7	3	4	.40*
57	6	5	1	.10
58	10	5	5	.50*
59	9	8	1	.10
60	10	5	5	.50*
61	3	2	1	.10
62	10	7	3	.30*
63	8	7	1	.10
64	8	8	0	0
65	7	7	0	0
66	--	--	-	-----
67	9	6	3	.30*
68	10	6	4	.40*
69	2	3	-1	-.10
70	7	4	3	.30*
71	9	7	2	.20*
72	8	5	3	.30*
73	8	5	3	.30*
74	4	3	1	.10
75	10	10	0	0
76	6	1	5	.50*

TABLE V (Continued)

Item Number	U	L	U - L	D
77	8	2	6	.60*
78	8	9	-1	-.10
79	10	8	2	.20*
80	10	7	3	.30*
81	9	10	-1	-.10
82	9	8	1	.10
83	9	8	1	.10
84	4	5	-1	-.10
85	8	2	6	.60*
86	5	3	2	.20*
87	4	0	4	.40*
88	7	2	5	.50*
89	10	10	0	0
90	9	9	0	0
91	10	3	7	.70*
92	9	4	5	.50*
II - 1	7	6	1	.10
II - 2	6	2	4	.40*
II - 3	9	2	7	.70*
II - 4	9	6	3	.30*
II - 5	5	0	5	.50*
II - 6	5	0	5	.50*
II - 7	7	5	2	.20*
II - 8	8	3	5	.50*
II - 9	2	2	0	0
II -10	8	1	7	.70*

D = Discriminating power index
U = Number in upper group who answered item correctly
L = Number in lower group who answered item correctly
N = Number in each group
N = 10
* = Item with a discriminating power index of +0.20 or greater

TABLE VI

ITEMS WITH A DISCRIMINATING POWER OF +0.20 OR GREATER OR BETWEEN 35% AND 75% LEVEL OF DIFFICULTY

Item Number	Item Difficulty Index, 35 - 75%	Discriminating Power Index, +0.20 or above
2 *	.61	.50
3	.61	
4	.71	
7 *	.68	.20
8		.30
10		.20
11 *	.61	.60
12		.20
13 *	.50	.50
15 *	.71	.40
17	.75	
18 *	.36	.20
19	.36	
20		.20
25	.54	
26 *	.71	.50
27 *	.64	.80
29	.61	
31 *	.46	.30
32	.43	
33		.30
34 *	.36	.50
35	.57	
36		.20
37 *	.75	.40
38		.30
39		.20
40	.57	
41 *	.50	.20
42		.20
44 *	.71	.30
46 *	.64	.30
47 *	.71	.40
48 *	.68	.30

TABLE VI (Continued)

Item Number	Item Difficulty Index, 35 - 75%	Discriminating Power Index, +0.20 or above
49		.20
50		.30
51	.46	
54 *	.75	.20
55 *	.57	.50
56 *	.50	.40
57	.43	
58 *	.75	.50
60		.50
62		.30
65	.68	
67 *	.71	.30
68		.40
70 *	.61	.30
71 *	.68	.20
72 *	.61	.30
73 *	.54	.30
76 *	.36	.50
77 *	.43	.60
79		.20
80		.30
84	.39	
85 *	.61	.60
86 *	.36	.20
87		.40
88 *	.39	.50
91 *	.71	.70
92 *	.61	.50
II - 1	.64	
II - 2 *	.43	.40
II - 3 *	.50	.70
II - 4 *	.75	.30
II - 5		.50
II - 6		.50
II - 7 *	.61	.20
II - 8 *	.57	.50
II -10 *	.43	.70

* Item meeting both criteria.

TABLE VII

RATING OF TEST ITEM AT THE "KNOWLEDGE" OR "ABOVE KNOWLEDGE" LEVEL

Item Number	Rating*	Item Number	Rating
2	A	58	K
7	K	67	K
11	K	70	K
13	A	71	A
15	A	72	K
18	A	73	A
26	K	76	A
27	A	77	A
31	K	85	K
34	K	86	A
37	K	88	A
41	A	91	A
44	K	92	K
46	A	II - 2	A
47	K	II - 3	A
48	K	II - 4	A
54	K	II - 7	A
55	K	II - 8	A
56	A	II -10	A

* A = "Above Knowledge"

K = "Knowledge"

ΣX^2 = sum of squares for "x" half of test

ΣY^2 = sum of the squares for "y" half of test

N = number of students taking test

Thus

$$r = \frac{3713 - \frac{(328)(291)}{28}}{\sqrt{\left[4256 - \frac{(328)^2}{28}\right]\left[3463 - \frac{(291)^2}{28}\right]}} = 0.71$$

The coefficient of correlation between the "x" half scores and the "y" half scores was 0.71. To assess the coefficient of reliability of the total test the following formula was used (1):

$$r_t = \frac{2r}{1 + r} \qquad \frac{2(0.71)}{1 + 0.71} = 0.83$$

where

r_t = coefficient of reliability of total test

The "x" and "y" halves of the test were obtained by utilizing every other question for the "x" half and assigning the remaining questions to the "y" half. Divided in this manner the "x" half contained eight "knowledge" level and eleven "above knowledge" level questions whereas the "y" half contained nine "knowledge" level and ten "above knowledge" level questions.

The specific questions used in each half and the data used in the calculation of the coefficient of reliability are indicated in Table VIII.

The Opinion Survey

During the class period immediately preceding the final examination period, the students were asked to respond to a

TABLE VIII

DISTRIBUTION OF RAW SCORES FOR "X" HALF AND "Y" HALF QUESTIONS OF THE FINAL EXAMINATION

Student Number	X*	Y**	XY	X^2	Y^2
I - 1	5	10	50	25	100
I - 2	14	17	238	196	289
I - 3	10	8	80	100	64
I - 4	7	12	84	49	144
I - 5	14	11	154	196	121
I - 6	11	9	99	121	81
I - 7	10	4	40	100	16
I - 8	19	16	304	361	256
I - 9	8	3	24	64	9
I -10	8	6	48	64	36
I -11	17	13	221	289	169
I -12	11	11	121	121	121
I -13	15	12	180	225	144
I -14	17	15	255	289	225
II - 1	16	17	272	256	289
II - 2	8	10	80	64	100
II - 3	10	5	50	100	25
II - 4	13	10	130	169	100
II - 5	13	14	182	169	196
II - 6	15	14	210	225	196
II - 7	9	6	54	81	36
II - 8	9	8	72	81	64
II - 9	4	7	28	16	49
II -10	10	10	100	100	100
II -11	12	12	144	144	144
II -12	19	17	323	361	289
II -13	13	8	104	169	64
II -14	11	6	66	121	36
Sum	328	291	3713	4256	3463

* Score on questions 2, 11, 15, 26, 31, 37, 44, 47, 54, 56, 67, 71, 77, 86, 91, II- 2, II - 4, and II - 8.

** Score on questions 7, 13, 18, 27, 34, 41, 46, 48, 55, 58, 70, 72, 76, 85, 88, 92, II - 3, II - 7, and II -10.

"course evaluation" questionnaire, a copy of which is contained in Appendix C. Through this questionnaire the author attempted to determine the students' "feelings" for Botany and for the manner in which they were taught. The students were asked to rate each of the nine items on a continuous scale from 1 to 9. On this form the students answered items concerned with aspects of the course such as the type of learning required by the course, level of difficulty of the course, whether they liked or disliked the course, whether they preferred the lecture or "discovery" method, etc.

Two essay type questions were asked concerning the "poorest" and "best" thing about their course from the "standpoint of promoting learning." A space was provided for "other comments."

No statistical analysis was made on the opinoin survey. However, the results were tabulated and are included in Chapter IV.

Statistical Analysis

The groups were tested for homogeneity of variance according to the procedure described by Wert et al (36) with respect to ACT composite scores, ACT science scores, and previous knowledge as judged by the pretest scores. The formula used was:

$$F = \frac{S_L^2}{S_s^2}$$

where

S_L2 = variance of the group with the larger variance.

S_s2 = variance of the group with the smaller variance.

The F Value calcualted in the above manner is two-tailed, whereas the F value from the table of F values is for a one-tailed test; thus the doubling of the F value obtained from the table is desirable (12).

Prior to the analysis the author decided that if the resultant F value was greater than twice that obtained from the table of F values at the 1 percent level, the two samples would not be considered homogenous in regard to that measurement.

An analysis of variance was performed on the data for the raw scores on the final examination, the raw scores of the "knowledge" level questions on the final examination, the raw scores of the "above knowledge" level questions on the final examination, the raw scores on the final examination of the top half of each group as judged by the ACT composite scores, the raw scores on the final examination of the bottom half of each group as judged by the ACT composite scores, and the raw scores on the post-final test scores.

The variance was determined using the formula (11):

$$s^2 = \frac{\Sigma x^2 = N\bar{x}^2}{N-1}$$

where

s^2 = variance.

Σx^2 = sum of squares.

N = number in group (sample).

$\bar{X}$ = mean of sample.

The unbiased estimate of the population variance was calculated using:

$$\sigma^2 = \frac{\sum x_1^2 - N_1 \bar{X}_1^2 + \sum x_2^2 - N_2 \bar{X}_2^2}{N_1 + N_2 - 2}$$

where

σ^2 = unbiased estimate of population variance.

$\sum x_1^2$ = sum of squares for Group I.

N_1 = number in Group I.

$\bar{X}_1$ = mean for Group I.

$\sum x_2^2$ = sum of squares for Group II.

N_2 = number in Group II.

$\bar{X}_2$ = mean of Group II.

$N_1 + N_2 - 2$ = degree of freedom.

The standard error of the means was calculated using the following formula with the same notations as above:

$$\sigma^2_{\bar{x}_1 - \bar{x}_2} = \frac{\sigma^2}{N_1} + \frac{\sigma^2}{N_2}$$

The F value was calculated in the following manner:

$$F = \frac{(\bar{x}_1 - \bar{X}_2)^2}{\sigma^2_{\bar{x}_1 - \bar{x}_2}}$$

If the calculated F value exceeds the value obtained from the table of F values at the 5 percent level, the difference is considered significant, and a true difference in the achievement of the two groups will be said to exist (11).

CHAPTER IV

PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

Although the students were randomly assigned to either the control or experimental group, the groups were tested for homogeneity of variance with respect to ACT composite scores, ACT science scores, and previous knowledge. The variance of ACT composite scores for Group I was 8.93; for Group II, it was 17.28. This resulted in a calculated F value of 1.94. The tabular F value for 13 degrees of freedom asscoiated with the numerator and 13 degrees of freedom associated with the denominator at the 1 percent level of significance was 3.60. For the reasons expressed previously, this value was doubled, resulting in a F value of 7.20. Because the calculated F value was less than this, the two groups were said to be homogenous with respect to ACT composite scores. Table IX presents the distribution of ACT composite scores for Groups I and II, the variance and F value.

With respect to ACT science subtest scores, the variance within Group I was 25.38; for Group II, it was 31.69. The calculated F value of 1.25 was less than twice the tabular F value of 7.20. Therefore, the two groups were said to be homogenous with respect to ACT science subtest scores. These data are presented in Table X.

TABLE IX

DISTRIBUTION OF ACT COMPOSITE SCORES FOR GROUPS I AND II, THE VARIANCE WITHIN AND BETWEEN GROUPS AND THE F VALUE

Student Number	Group I (Experimental)	Group II (Control)
1	26	29
2	24	28
3	24	26
4	24	25
5	23	24
6	21	24
7	20	24
8	20	23
9	20	23
10	20	19
11	19	19
12	18	17
13	18	17
14	15	16
N	14	14
$\bar{X}$	20.86	22.43
ΣX	292	314
ΣX^2	6208	7268
$\bar{X}^2$	435.14	503.10
$N\bar{X}^2$	6091.96	7043.40
$\Sigma X^2 - N\bar{X}^2$	116.04	224.60
s^2	8.93	17.28

$F = 17.28/8.93 = 1.94$

$.01\ F_{13,13} = 3.91$

$.01\ F_{13,13}$ doubled $= 7.82$

TABLE X

DISTRIBUTION OF ACT SCIENCE SUBTEST SCORES FOR GROUPS I AND II, THE VARIANCE WITHIN AND BETWEEN GROUPS, AND THE F VALUE

Student Number	Group I (Experimental)	Group II (Control)
1	25	32
2	31	32
3	30	29
4	26	26
5	20	27
6	25	27
7	28	23
8	25	29
9	19	16
10	19	18
11	23	17
12	22	22
13	15	17
14	15	21
N	14	14
$\bar{X}$	23.07	24
ΣX	323	336
ΣX^2	7781	8476
$\bar{X}^2$	532.22	576
$N\bar{X}^2$	7451.08	8064
$\Sigma X^2 - N\bar{X}^2$	329.92	412
S^2	25.38	31.69

$F = 31.69/25.38 = 1.25$

$.01\ F_{13,13} = 3.91$

$.01\ F_{13,13}$ doubled $= 7.82$

The greatest difference between the two groups was in the range of scores on the pretest. In Group I, the range was 7 through 11; the range of Group II was 6 through 13. This resulted in a variance of 1.42 for Group I and 6.50 for Group II. The calculated F value for variance between groups was 4.57. However, this was less than twice the F value of 7.20. Therefore, the two groups were said to be homogenous with respect to previous knowledge, as judged by the pretest scores. Data on pretest scores are presented in Table XI.

Thus, statistically, the two groups were homogenous for ACT composite scores, ACT science subtest scores and previous knowledge. For the purposes of this study the two samples were considered to be from the same population.

Ferguson (12) describes the use of one-tailed and two-tailed statistical hypotheses and the validity of the null hypothesis stated in a greater than, less than, or equal manner. Because direction is an important consideration when composing teaching methods, the hypotheses of this study are stated so that one-tailed statistical analyses can be used. Thus, the hypotheses occur in triplicate.

Hypotheses 1, 2 and 3

1. The mean of the scores of the control group (Group II, lecture method) is equal to the mean of the scores of the experimental group (Group I, discovery method) on the final examination.

TABLE XI

DISTRIBUTION OF PRETEST SCORES FOR GROUPS I AND II, THE VARIANCE WITHIN AND BETWEEN GROUPS, AND THE F VALUE

Student Number	Group I (Experimental)	Group II (Control)
1	10	6
2	10	12
3	11	11
4	8	8
5	8	7
6	9	10
7	8	4
8	11	8
9	7	9
10	9	13
11	10	9
12	9	8
13	9	11
14	9	12
N	14	14
$\bar{X}$	9.14	9.14
ΣX	128	128
ΣX^2	1188	1254
$\bar{X}^2$	83.54	83.54
$N\bar{X}^2$	1169.56	1169.56
$\Sigma X^2 - N\bar{X}^2$	18.44	84.44
s^2	1.42	6.50

$F = 6.50/1.42 = 4.57$

$.01\ F_{13,13} = 3.91$

$.01\ F_{13,13}$ doubled $= 7.82$

2. The mean of the scores of the control group (Group II, lecture method) is greater than the mean of the scores of the experimental group (Group I, discovery method) on the final examination.
3. The mean of the scores of the control group (Group II, lecture method) is less than the mean of the scores of the experimental group (Group I, discovery method) on the final examination.

The results of the final examination, the variance and *t* value are given in Table XII. The calculated *t* value is 0.1732. The table value of *t* at the .05 percent level of significance for a one-tailed test with 26 degrees of freedom is 1.706. Therefore, hypothesis 1 was accepted and hypotheses 2 and 3 were rejected.

Hypotheses 4, 5 and 6

4. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is equal to the mean of the score for the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
5. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is greater than the mean of the scores for the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
6. The mean of the scores for the "knowledge" level questions of the control group (Group II, lecture method) is less

TABLE XII

DISTRIBUTION OF RAW SCORES OF GROUPS I AND II ON THE FINAL EXAMINATION, VARIANCE AND CALCULATED *t* VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
1	15	33
2	31	18
3	18	15
4	19	23
5	25	27
6	20	29
7	14	17
8	35	17
9	11	11
10	14	20
11	30	24
12	22	36
13	27	21
14	32	17
N	14	14
$\bar{X}$	22.36	21.86
ΣX	313	306
ΣX^2	7771.00	7374.00
$\bar{X}^2$	499.97	477.86
$N\bar{X}^2$	6999.58	6690.04
$\Sigma X^2 - N\bar{X}^2$	771.42	683.96
s^2	59.34	52.61

$F = 59.34/52.61 = 1.13$

$.01\ F_{13,13} = 2.58$ Variances are equal

$\sigma^2 = (771.42 + 683.96)/\ 26 = 55.98$

$\sigma^2_{\bar{x}_1 - \bar{x}_2} = (55.98/14) + (55.98/14) = 8$

$F = 0.25/8 = 0.03$ $t = 0.173$

than the mean of the scores for the "knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.

The data for the "knowledge" level questions are found in Table XIII. Very little difference was found between the two groups, with a resultant t value of .7211. The t value obtained from the table with 26 degrees of freedom at the .05 percent level of significance for a one-tailed test is 1.706. Therefore, hypothesis 4 was accepted and hypotheses 5 and 6 were rejected.

Hypotheses 7, 8 and 9

7. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is equal to the mean of the scores for the "above knowledge" level questions of the experimental group (Group I, discovery method) on the final examiantion.
8. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is greater than the mean of the scores for the "above knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.
9. The mean of the scores for the "above knowledge" level questions of the control group (Group II, lecture method) is less than the mean of the scores for the "above knowledge" level questions of the experimental group (Group I, discovery method) on the final examination.

TABLE XIII

DISTRIBUTION OF RAW SCORES FOR GROUPS I AND II OF THE "KNOWLEDGE" LEVEL QUESTIONS ON THE FINAL EXAMINATION, THE VARIANCE, AND CALCULATED t VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
1	10	17
2	15	8
3	9	8
4	8	12
5	14	10
6	12	14
7	6	8
8	16	8
9	6	6
10	9	11
11	15	11
12	12	16
13	12	10
14	15	7
N	14	14
$\bar{X}$	11.36	10.43
ΣX	159	146
ΣX^2	1957	1668
$\bar{X}^2$	128.98	108.74
$N\bar{X}^2$	1805.73	1522.40
$\Sigma X^2 - N\bar{X}^2$	151.27	145.60
S^2	11.64	11.20

F = 11.64/11.20 = 1.04

$.01\ F_{13,13} = 2.58$ Variances are equal

$\sigma^2 = (151.27 + 145.60)/26 = 11.42$

$\sigma^2_{\bar{X}_1 - \bar{X}_2} = (11.42/14) + (11.42/14) = 1.64$

F = .86/1.64 = 0.52 $\quad$ $t = 0.721$

The distribution for Groups I and II of the raw scores of the "above knowledge" questions of the final examination, the variance and calculated _t_ value for these scores are presented in Table XIV. The calculated _t_ value is only 0.0245; thus there was no significant difference between the two groups. The tabular _t_ value at the .05 percent level of significance for a one-tailed test with 26 degrees of freedom is 1.706. Therefore, hypothesis 7 was accepted and hypotheses 8 and 9 were rejected.

Hypotheses 10, 11 and 12

10. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is equal to the mean of the scores of the top half, as judged by the students' ACT composite scores, of the experimental group (Group I, discovery method).
11. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is greater than the mean of the scores of the top half, as judged by the students' ACT composite scores, of the experimental group (Group I, discovery method).
12. The mean of the scores of the top half, as judged by the students' ACT composite scores, of the control group (Group II, lecture method) is less than the mean of the scores of the top half, as judged by the students' ACT

TABLE XIV

DISTRIBUTION FOR GROUPS I AND II OF RAW SCORES ON THE "ABOVE KNOWLEDGE" LEVEL QUESTIONS OF THE FINAL EXAMINATION, THE VARIANCE, AND CALCULATED t VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
1	5	16
2	16	10
3	9	7
4	11	11
5	11	17
6	8	15
7	8	7
8	19	9
9	5	5
10	5	9
11	15	13
12	10	20
13	15	11
14	17	10
N	14	14
$\bar{X}$	11.00	11.43
ΣX	154	160
ΣX^2	1982	2066
$\bar{X}^2$	121.00	130.64
$N\bar{X}^2$	1694.00	1828.96
$\Sigma X^2 - N\bar{X}^2$	288	237.04
s^2	22.15	18.23

$F = 22.15/18.23 = 1.22$

$.01\ F_{13,13} = 2.58$ Variances are equal

$\sigma^2 = (288.00 + 237.04)/26 = 20.19$

$\sigma^2_{\bar{x}_1 - \bar{x}_2} = (20.19/14) + (20.19/14) = 2.88$

$F = .18/2.88 - 0.06$ $\underline{t} = .024$

composite scores, of the experimental group (Group I, discovery method).

The results of this part of the study are presented in Table XV. The calculated *t* value is 0.4583, and therefore no significant difference existed. The tabular *t* value for a one-tailed test at the .05 percent level of significance with 12 degrees of freedom is 1.782. Therefore, hypothesis 10 was accepted, and hypotheses 11 and 12 were rejected.

Hypotheses 13, 14 and 15

13. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students' ACT composite scores, is equal to the mean of the scores of the bottom half of the experimental group (Group I, discovery method), as judged by the students' ACT composite scores.
14. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students' ACT composite scores, is greater than the mean of the scores of the bottom half of the experimental group (Group I, discovery method), as judged by the students' ACT composite scores.
15. The mean of the scores of the bottom half of the control group (Group II, lecture method), as judged by the students' ACT composite scores, is less than the mean of the scores of the bottom half of the experimental group

TABLE XV

DISTRIBUTION FOR GROUPS I AND II OF RAW SCORES OF THE TOP HALF OF EACH GROUP AS JUDGED BY THE STUDENTS' ACT COMPOSITE SCORES ON THE FINAL EXAMINATION, THE VARIANCE AND CALCULATED t VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
1	15	33
2	31	18
3	18	15
4	19	23
5	25	27
6	20	29
7	14	15
N	7	7
$\bar{X}$	20.29	22.86
ΣX	142	160
ΣX^2	3092	3962.00
$\bar{X}^2$	411.68	522.58
$N\bar{X}^2$	2881.76	3658.06
$\Sigma X^2 - N\bar{X}^2$	210.24	303.94
s^2	35.04	50.66

F = 50.66/35.04 = 1.45

.01 $F_{6,6}$ = 4.28 Variances are equal

σ^2 = (210.24 + 303.94)/12 = 42.85

$\sigma^2_{\bar{x}_1-\bar{x}_2}$ = (42.85/7) + (42.85/7) = 12.24

F = 2.57/12.24 = 0.21 t = 0.458

(Group I, discovery method), as judged by the students' ACT composite scores.

Table XVI presents the raw scores, variance and calculated t value for these data. The calculated t value is .4123. The value obtained from a table of t values at the .05 percent level of significance for a one-tailed test with 12 degrees of freedom is 1.782. Therefore, hypothesis 13 was accepted, and hypotheses 14 and 15 were rejected.

Hypotheses 16, 17 and 18

16. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is equal to the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).
17. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is greater than the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).
18. The mean of the scores on the post-final examination of the control group (Group II, lecture method) is less than the mean of the scores on the post-final examination of the experimental group (Group I, discovery method).

Only 11 students of Group I and 10 students of Group II returned the post-final examination. The data on these scores are presented in Table XVII. The t value was determined to be 0.400. The tabular t value at the .05 percent level of significance for

TABLE XVI

DISTRIBUTION OF RAW SCORES FOR GROUPS I AND II OF THE BOTTOM HALF OF EACH GROUP AS JUDGED BY THE STUDENTS' ACT COMPOSITE SCORES ON THE FINAL EXAMINATION, THE VARIANCE AND CALCULATED $\underline{t}$ VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
8	35	17
9	11	11
10	14	20
11	30	24
12	22	36
13	27	21
14	32	17
N	7	7
$\bar{X}$	24.43	20.86
ΣX	171	146
ΣX^2	4679	3412
$\bar{X}^2$	596.82	435.14
$N\bar{X}^2$	4177.74	3045.98
$\Sigma X^2 - N\bar{X}^2$	501.26	366.02
S^2	83.54	61.00

$F = 83.54/61.00 = 1.37$

$.01\ F_{6,6} = 4.28$ Variances are equal

$\sigma^2 = (501.26 + 366.02)/12 = 72.27$

$\sigma^2_{\bar{x}_1 - \bar{x}_2} = (72.27/7) + (72.27/7) = 20.65$

$F = 3.57/20.65 = 0.17$

$\underline{t} = 0.412$

TABLE XVII

DISTRIBUTION OF RAW SCORES FOR GROUPS I AND II ON THE POST-FINAL EXAMINATION, THE VARIANCE, AND CALCULATED _t_ VALUE FOR THESE SCORES

Student Number	Group I (Experimental)	Group II (Control)
1	3	26
2	22	14
3	14	14
4		
5	11	11
6	10	21
7		
8	17	
9	9	7
10		
11	15	15
12	20	21
13	18	15
14	16	7
N	11	10
$\bar{X}$	14.09	15.10
ΣX	155	151
ΣX^2	2485	2619
$\bar{X}^2$	198.53	228.01
$N\bar{X}^2$	2183.83	2280.10
$\Sigma X^2 - N\bar{X}^2$	301.17	338.90
s^2	30.12	37.66

F = 37.66/30.12 = 1.25

$.01\ F_{9,10} = 3.02$ Variances are equal

$\sigma^2 = (301.17 + 338.90)/19 = 33.69$

$\sigma^2_{\bar{X}_1 - \bar{X}_2} = (33.69/11) + (33.69/10) = 6.43$

F = 1.01/6.43 = 0.16 _t_ = 0.400

a one-tailed test with 19 degrees of freedom is 1.729. Therefore, hypothesis 16 was accepted and hypotheses 17 and 18 were rejected.

The Opinion Survey

Although no statistical analysis was performed on the opinion survey, the results were interesting and may provide some insight on the students. The opinion survey questionnaire, or "course evaluation," is contained in Appendix C. Table XVIII is the tabulation of the results of the opinion survey of the experimental group (Group I, discovery method) and the mean for each item. The same data for Group II, lecture method, are found in Table XIX. Both tables are contained in Appendix D.

Both groups had nearly the same mean, within one-half point on the scale, on the type of learning required by the course, on the level of difficulty of the course, on how well they liked the course, on how well they liked the type of learning situation, on their attitude toward Botany at the beginning and at the end of the course, on the level of the course material, and the method they would use to teach general Botany.

The next-to-largest difference in responses was to the question, "How much have you been stimulated intellectually by this course?" The discovery method group rated the course at 1.5 units above "an average amount," whereas the control group responded .2 units above "an average amount," for a difference of 1.7 units.

The largest difference in response concerned which type of learning situtation, discovery or lecture, they would select for a future course. The lecture group gave a response of 7.4 toward the lecture method. The discovery group selected an average response of 5, midway between the discovery method and the lecture method. A rating of 5 indicated "whichever section would give me the best schedule."

A tabulation of their responses is found in Appendix D. Appendix E consists of the comments made to the essay questions 10, 11 and 12. The students did not put their names on the opinion survey. For purposes of tabulation, each paper was assigned a letter designation. Student A is the same individual in Appendix D and Appendix E.

Discussion of Results

The tests of homogeneity indicated the two samples were drawn from the same population. Both the ACT composite scores and ACT science subtest scores were far below the F value required for a significant difference. The control group, Group II, had the higher mean for both the ACT composite scores, 22.4 vs. 20.9, and the ACT science subtest scores, 24.0 vs. 23.1. There was an insignificant tendency for the control group to be superior students, according to the ACT scores.

None of the comparisons resulted in significant differences occurring between the groups. The statistical analyses would indicate that the two groups performed almost identically. Thus, if either teaching method possesses additional advantages for a particular teaching situation, then that method may be the better one to use. The personality and personal choice of the instructor may make one method more desirable than the other.

Students may receive additional motivation when taking part in an experiment, and may perform at a higher level. The author does not believe such motivation would be likely to last over an entire semester, the period of this study. From some of the opinion ratings and comments, there is some evidence to indicate a negative effect may have developed in the experimental group.

The students in both groups rated the type of learning required on the scale from 1 to 9 at 6.0. This was unexpected, since the discovery approach is to emphasize understanding and contains a minimum of terminology and rote memory.

The students in the discovery group rated the course as being 0.4 of a unit more difficult than did the students in the lecture-laboratory method group. The students in the discovery group did not like the "type of learning situation" as well as the control group by 0.5 of a unit. This factor may have been influenced by the students finding the course more difficult. However, both groups "liked" the course at about the same level, 5.4 and 5.5.

Although the discovery students found the course more difficult and did not like the learning situation as well as the control group, they indicated they had been "stimulated intellectually by the course" more and changed their attitude (favorably) toward Botany more. The discovery group rated the amount of intellectual stimulation at 6.5 vs. 5.2 for the control group, a difference of 1.3 units. This was the largest difference between the groups on any item directly concerning the course.

Item 7 asked if the student would select a discovery method section or a lecture method section in a future course. Rating 1 was the discovery method, rating 9 was the lecture method, and a rating of 5 indicated "whichever section would give me the best schedule." The group II, lecture method, students gave a rather strong preference to the lecture method. These same students indicated they were "undecided" what method they would use to teach General Botany. The group I, discovery method, students selected a rating of 5 for item 7. They also were "undecided" about which method they would use to teach the course. The answers of the discovery group for the questions of how they liked the learning situation and which section they would choose in a future course agreed quite closely, 5.4 and 5.0 respectively. Apparently, the group I students did not "sell" the discovery method to the control students because the control group indicated a rating of 7.4 toward the lecture method in a future course. On a campus of this size, communication between the two groups must have occurred to a considerable extent.

Item 9, "If you were to teach this course, would you use the method that was used this semester?" may have been misinterpreted. The students may have interpreted "the method" as meaning both traditional and discovery sections rather than referring only to the method by which they were taught.

Both groups rated "the level of course material" between rating 5, "almost always at my level," and rating 7, "generally at my level, about 40 percent above my level." The discovery group indicated the material was a little nearer their level, with a rating of 5.6 vs. 6.0 for the control group.

Perhaps the greatest difference between the two groups appeared in their answers to the two essay-type questions and the "other comments" section. The discovery group seemed able to evaluate and express their ideas better than the control group. The comments were longer, and in general their ideas were expressed more clearly. Perhaps this was true because of the discussion-reporting sessions. In effect, they were practicing the expression of their ideas throughout the semester at these sessions.

No information was available on the students' ability to express themselves at the beginning of the semester. Therefore, no definite conclusion can be made in this regard. Although ability to express ideas may not be a prime objective of General Botany, it is a prime objective of a college education. If the discovery method enhanced this ability, then it may be the preferred method of teaching when the overall value of a college education is considered.

The following comments are general impressions of the students at Dakota State College formed by the author. As such, their validity is open to question. However, the author believes such an evaluation is appropriate for this report and in determining the educational experiences needed by students at any institution.

Most of the students at DSC have rural backgrounds and attended relatively small high schools. Few of these rural schools were teaching courses such as BSCS Biology at the time the sample students were in high school. Thus, most of the students had had 12 years of traditional schooling. Many of the schools provided only a limited laboratory experience of any type.

Because of the large number of students returning home on weekends, the college cafeteria stopped serving meals on the weekends. Over 50 percent of the students have not been to another state. This figure probably would be much higher if most of the state's population was not located within 50 miles of the Iowa or Minnesota borders.

The students tend to be shy and lack self confidence. Any new situation makes them uneasy, and they resist the change. Thus, the discovery laboratory may have placed stress upon the students. The response to this stress may have been expressed as a dislike toward the system and learning situation. Also, the stress may have been increased because the different method was forced upon them. One student mentioned in the comments that the discovery section "may have worked better if some students hadn't known it was an experiment. This developed negative attitudes in some cases."

The results of this study indicated that the lecture-laboratory method and the discovery method were equally effective in teaching General Botany, at least concerning the items tested. In addition, the retention of information for a period of approximately 17 months was the same. However, the discovery method may have helped the students in developing the ability to express their ideas. The author believes that for students such as those at Dakota State College, the challenge presented by the discovery method is a worthwhile experience. And, because the college is concerned with the education of future teachers, exposure to different teaching methods is desirable.

CHAPTER V

CONCLUSIONS, SUMMARY, AND RECOMMENDATIONS

Conclusions

The most general conclusion drawn by the author from this study is: A teacher may feel free to select either the lecture or discovery method as a manner of presentation without fear of reducing the amount of learning of botanical information by the method of his choice. Other factors such as the teacher's personal choice, his personality, and his estimation of the type of learning situation needed by the students, should be the determining considerations. More specific conclusions are given below.

1. The immediate acquisition of botanical information, as measured by the final examination, was not influenced by the teaching method.
2. The retention of botanical information over a 17 month period, as measured by the post-final examination, was not influenced by the teaching method.
3. The acquisition of botanical information at either the "knowledge" or "above knowledge" level was not significantly different for either the lecture or discovery method.
4. The ability level of the students, as judged by the students' ACT composite scores, did not make one

method of presentation more effective than the other method.

The above conclusions, coupled with the results of the opinion survey, may indicate that the greatest value of using a discovery method lies in areas other than the subject matter. The ability to organize and express ideas clearly is a goal of science. It is also the goal of general education courses such as oral or written communications.

Summary

This study is a comparison of the effectiveness of teaching freshman Botany by the lecture and discovery methods. Comparisons were made between the two methods on immediate acquisition, retention, ability level of the student, "knowledge" and "above knowledge" levels of information. The students enrolled in General Botany at Dakota State College, Madison, South Dakota, were randomly assigned to one of the two groups. One of these groups was randomly selected to be the control group utilizing the lecture method while the remaining group became the experimental group which used the discovery method.

The students were tested using an investigator-made instrument over material presented in a one semester General Botany course. Analyses were performed on the two groups, the two groups using only test items of the "knowledge" level, the two groups using only the test items at the "above knowledge" level, the top half of each group, the bottom half of each group and the two groups 17 months after the course was completed.

The statistical results of the study indicated there is no difference between the two methods for the parameters tested. An opinion survey suggested that the students taught by the discovery method were able to express their opinions and ideas more clearly than the control group.

Recommendations

The small sample size indicates the desirability of repeating this study under approximately the same conditions. To control for individual differences in instructors an evaluation instrument may be utilized. Because BSCS Biology is similar to the discovery method used in this study, the instructors could be evaluated utilizing the instruments of Hoy and Blankenship (15) mentioned earlier.

The test instrument should be improved. Although only acceptable items were used for comparisons, no information is available on the effect, if any, of the other items. The test was constructed so that only the information covered in both groups was included. This study indicates that the discovery method is equal to the lecture method in disseminating information. There is no indication that the lecture method is equal to the discovery method in areas such as: understanding the scientific method, organizing and carrying out an investigation, expressing ideas and developing favorable attitudes toward science. Although this study did not provide information indicating the discovery method was superior in these aspects, it is possible that these may be better developed using the discovery approach. Also, the test instrument tends to contain too much terminology to evaluate a teaching method which de-emphasize terminology.

An attitude instrument should be developed to determine if any changes in attitude occur during the period under investigation. Attitudes change slowly, however, emotional responses are rapid. A short period of exposure to the discovery method may encounter overly favorable responses because of the "thrill of an experiment" or unfavorable response because of the "lack of structure and organization" provided. Therefore, the author recommends the use of extended periods, such as a semester, which was used in this study. If an extended period is used, care must be taken in the construction of quizzes or tests utilized during the period to determine a student's progress. Such quizzes must be designed in the same manner as the final examination or misleading clues as to what is important may be imparted to the student.

Because of the responses to the opinion survey, a formal evaluation could be conducted to determine if the student's ability to express himself changes from the beginning to the end of the investigation period.

In summary, the two teaching methods used in this study are quite different. No difference was obtained in achievement performance or retention as indicated by the test instrument. Additional research should be conducted to determine what differences were produced. It seems reasonable that two teaching methods, as different as the methods used, would not have the same total effect on the students.

This study provides information on the use of the discovery method at the college level in a Botany course. Perhaps other college courses lend themselves better to the discovery method. Additional studies should be conducted in courses such as: General Zoology, Biological Principles, and General Biology for non-majors.

SELECTED BIBLIOGRAPHY

(1) Ahmann and D. Glock. Evaluating Pupil Growth. Allyn and Bacon, Inc. (1959).

(2) Ausubel, D. P. Educational Psychology: A Cognitive View. Holt, Rinehart and Winston (1968).

(3) Bittinger, M. L. "A Review of Discovery," The Mathematics Teacher. Vol. 61 (1968) pp. 140-146.

(4) Bloom, Benjamin S. et al. Taxonomy of Educational Objectives. The Classification of Educational Goals. Handbook I: The Cognitive Domain. New York: Longmans, Green (1956).

(5) Bruner, J. S. "The Act of Discovery," Harvard Educational Review. Vol. 31 (1961) pp. 21-32.

(6) Bunderson, C. V. "Current Issues in the United States Regarding Computer-Assisted Instruction," Speech Given at the Conference on Computers and Education, University of Bari, Italy (October 1970).

(7) Chambers, D. W. "Putting Down the Discovery Learning Hypothesis," American Educational Research Association Meeting, Minneapolis, Minnesota (1970).

(8) Cronbach, L. J. Educational Psychology. Harcourt & Brace (1954).

(9) Cronbach, L. J. "The Logic of Experiments on Discovery," Learning by Discovery: A Critical Appraisal. Edited by L. S. Shulman and E. R. Keislar. Chicago: Rand McNally (1966) pp. 76-92.

(10) Dennison, C. C. "Evaluating a Verbal Approach and a Discovery Approach in Learning Selected Science Principles at Two Levels of Maturity," ERIC Document Ed 049042 (1969).

(11) Ebel, R. L. "Procedures for the Analysis of Classroom Tests," Educational and Psychological Measurement. Vol. 14 (Summer, 1954) pp. 352-364.

(12) Ferguson, G. A. Statistical Analysis in Psychology and Education. McGraw-Hill (1966).

(13) Hardy, D. W. "Inland Valley Elementary School Archaeology Project: An Experimental Comparison of Two Teaching Approaches," Final Report ERIC Document Ed 059862 (1967).

(14) Holt, John. How Children Learn. Pitman Publishing Corporation (1969).

(15) Hoy, W. K. and J. W. Blankenship. "A Comparison of the Ideological Orientations and Personality Characteristics of Teacher 'Acceptors' and 'Rejectors' of BSCS Biology," Science Education. Vol. 56 (January 1972) pp. 71-77.

(16) Kersh, B. Y. "Learning by Discovery: Instructional Strategies," The Arithmetic Teacher. Vol. 12 (1965) pp. 414-417.

(17) Klausmeier, H. J. Learning and Human Abilities. Harper & Row (1961).

(18) Kleckner, L. G. "An Experimental Study of Discovery Type Teaching Strategies with Low Achievers in Basic Mathematics I," Ph.D. Dissertation, Pennsylvania State University (1968).

(19) Lindgren, H. C. Educational Psychology in the Classroom. John Wiley & Sons (1967).

(20) Maynard, F. J. and J. F. Strickland, Jr. "A Comparison of Three Methods of Teaching Selected Mathematical Content in Eighth and Ninth Grade General Mathematics Courses, Final Report," ERIC Document Ed 041763 (1969).

(21) McKeachie, W. J. and D. Solomon. "Retention of General Psychology," Journal of Educational Psychology. Vol. 48 (1957) pp. 110-112.

(22) Nelson, B. A. and D. A. Frayer. "Discovery Learning Versus Expository Learning: New Insight Into An Old Controversy," Paper Presented at the Annual Meeting of the American Educational Research Association, Chicago, Illinois (April 3-7, 1972).

(23) Novak, J. D. "Concept Learning in Science," Theory Into Practice. Vol. 10 (April 1971) pp. 129-133.

(24) Novak, J. D., D. G. Ring and P. Tamir. "Interpretation of Research Findings in Terms of Ausubel's Theory and Implications for Science Education," Science Education. Vol. 55 (October 1971) pp. 483-526.

(25) Ray, W. E. "Pupil Discovery Vs. Direct Instruction," Journal of Experimental Education. Vol. 26 (1961) pp. 271-280.

(26) Retzer, K. A. "The Effect of Teaching Certain Concepts of Logic on Verbalization of Discovered Mathematical Generalizations," ERIC Document Ed 046699 (1967).

(27) Scandura, J. M. "Teaching College Students How to Learn Mathematics. What is Learned in Mathematical Discovery," ERIC Document Ed 017465 (1967).

(28) Schramm, W. and K. E. Oberholtz. Phi Delta Kappan. Vol. 46 (1964) p. 133.

(29) Scott, J. A. "The Effects on Short and Long Term Retention and on Transfer of Two Methods of Presenting Selected Geometry Concepts," Doctoral Dissertation, Wisconsin Research & Development Center for Cognitive Learning, University of Wisconsin (1970).

(30) Seifman, Eli. "An Encounter With Discovery: Performance and Reaction of Prospective Social Studies Teachers," ERIC Document Ed 059116 (1971).

(31) Shulman, L. S. and E. R. Keislar (Editors). Learning by Discovery: A Critical Appraisal. Chicago: Rand McNally (1966).

(32) Smeltz, J. R. "Retention of Learning in High School Chemistry," Science Teacher. Vol. 23 (1956) pp. 285-305.

(33) Sorenson, H. S. Psychology in Education. McGraw-Hill (1964).

(34) Suydam, M. N. and J. F. Weaver. "The Teaching-Learning Process Set A Using Research: A Key to Elementary School Mathematics," ERIC Document Ed 038323 (1970).

(35) Tanner, R. T. "Expository-Deductive Vs. Discovery-Inductive Programming of Physical Science Principles," ERIC Document Ed 027207 (1968).

(36) Wert, J. E., C. O. Neidt and J. S. Ahmann. Statistical Methods in Educational and Psychological Research. Appleton-Century-Crofts (1954).

(37) Wilson, C. L. and W. E. Loomis. Botany, Fourth Edition. Holt, Rinehart and Winston, Inc. (1967).

APPENDIX A

HANDOUT, "INTRODUCTION TO BOTANY," GIVEN TO EXPERIMENTAL GROUP, GROUP I

INTRODUCTION TO BOTANY

The science of botany is the study of plants. As a science, it is concerned with the search for truth about plants. In this search, observations are needed, and on the basis of these observations, tentative theories are proposed. These theories are then checked by many more observations, and if these agree with the theory proposed, the theory may be accepted, at least tentatively. If at any time observed facts contradict the theory, then the theory must be modified or discarded.

We propose to study botany by using the scientific approach. That is, we will make our own observations and from these observations, we will attempt to draw conclusions which will serve us in understanding plants and plant life. It should be noted that we shall make our observations directly from the plants themselves, not from what someone else says about the plants. The plant cannot be wrong, despite the fact that our observations may not agree with a description in a book. If a book says that a certain flower has five petals, and we find by looking at the flower that it has four or six petals, surely it is not the flower that is at fault.

It is important that observations be made without bias. If you expect to see something, it is amazing how frequently you can see it despite the fact that it isn't there! On the other hand, when looking without any specific expectation, how much more you usually see. As an example, when waiting on a street corner for a friend who is late, it is not uncommon to think you see your friend in many of the passers-by. At the same time, many of your other friends frequently pass by quite unnoticed--you weren't looking for them!

So in the laboratory, if you expect to see something, you will usually see it; but you will also miss quite a lot by looking for what you expect. However, if you can go into the laboratory with no preconceived ideas as to what you will see, you will discover a great deal. Hence, an attempt must be made to eliminate any bias before you go into the laboratory.

In the discussion periods, you will not be told what to expect when you go into the laboratory. The time in these periods will be utilized in pooling the information gained from examination of the plants, or in planning for the following laboratory period. Thus, the lecture periods will be of the discussion type, with the observations and ideas coming from the class, from you, not from the instructor.

The instructor's role will be essentially that of moderator in the discussion. He will probably ask many questions, which may stimulate you to investigate new aspects, or which may cause you to do some thinking about what you have already observed. The instructor will definitely NOT serve as an arbiter of decisions. These will be left to you, and you will, no doubt, be referred back to the specimens for such decisions.

SCOPE OF THE COURSE

It should be obvious that you will not be able to learn all about plants during a single semester's course. However, there is no maximum as to what you may learn, although there will probably be a minimum. Thus, quite frequently you will encounter a problem that cannot be satisfactorily solved during the course. Such matters should normally be left as "unsolved" problems, at least for the time being. Some of these problems may be cleared up later, others may not be. We will not leave any problem that you wish to attack, unless time or facilities are unavailable. However, since time and our facilities are limited, we cannot hope to do everything that the entire class membership would like to do. What we do attempt will be decided by the class--not by the instructor--as long as we operate within the general framework of the course. The main guideline established for the course is that you will begin with the bacteria and proceed through the various divisions of the plant kingdom to the flowering plants. Your first job will be to work out the life cycle of the plant representing the division and then learn as much about the structure of the plant at the various stages of the life cycle as you have time.

MATERIALS AND METHODS

During the course you will be given slides, preserved material or living specimens of plants for study. Your job will be to make close, accurate observations of this material in order to learn as much as possible about plants. The information that you and your group gather will be discussed by the class as a whole on Wednesdays and Fridays. Any statement about plants must be defended by observation of the plant under consideration. Your text cannot be used to defend any statement you make about the plant under study.

Apart from the original set of plants, you may grow any others that you wish. Pots, soil, and laboratory space will be provided. Remember, however, that after your original material has been given to you, you will be responsible for any plants that you grow. That is, if they grow differently, you will be responsible for reporting on the differences. You may examine any plants that you wish. In fact, you are encouraged to examine as many different kinds as you can. In expanding your observations to other members of the plant kingdom, especially note the characters that are common to all of the plants observed.

One word of caution about the use of prepared slides--become familiar with the plant as a natural entity first, and then use the prepared slides to supplement this familiarity and understanding. Know precisely which part of the plant you are exploring when using the prepared slides and be sure you coordinate the information gained from using the prepared slide with your overall knowledge of the plant.

You will be provided with a microscope, instruments for dissecting the plants, and certain aids to observe, such as stains which color specific parts of the plant. Normally, you will make your own dissections, but on occasion, you may obtain help from the laboratory assistant who will help you with techniques.

PLANNING THE APPROACH

At first sight, the problem before us looms up as of rather a large order. This is true of most problems that confront us in science, so we attempt to break the problem down. We have a lot to learn, but we cannot learn all at once. We cannot learn about the structure and the life cycle of a plant at the same time, at least, not <u>all</u> of the structure and <u>all</u> of the life cycle. Why not, then, concentrate for a while on one or the other of these aspects, and leave the other in abeyance?

By the same reasoning, it is hard to study the entire plant at the same time; we must take it part by part. Why not decide which parts we shall study, and the order in which we shall study them?

Since all of the plant parts on the flowering plants develop from what was once a seed, it might be a good idea to compare a seed with a very young seedling, and see what parts of the young plant were already present in the seed. It might also be of interest to find out what parts of the plant develop first, and where they come from.

There are many facts to be discovered. Some may be obtained by observation of the external structure of the plant; whereas others entail examination of the internal structures. Here is a place where team work will pay.

DIVISION OF LABOR

In the laboratory, each group at a lab table will constitute a team of investigators, tackling one or several problems. The table group is expected to work as a group, verifying each other's findings and pooling the results of these findings. Sometimes all tables in the lab will be working on the same problem; at other times, each table may have its own problem to solve.

It is desirable that the work at the table be divided up so each person is responsible for his investigation. On occasion a student will be undecided as to what the facts are, and he will have to call on one of his colleagues to check the facts, either by examination of the original materials or by making fresh preparations of the material. All preparations should be seen by the members of the group if conclusions are to be drawn from these preparations. In other words, a student should not be asked to support a conclusion if he is unfamiliar with the facts upon which the conclusion rests.

A few minutes at the beginning of the lab period should be sufficient for each student to find out what part he can play and what investigations he can make for the group. Any investigation should prove fruitful, if it finds facts about the plant. There is no such thing as an unimportant fact. Everything that we can find out about the plants is important in our investigations. Some of the facts we may later consider more important than others, but this is only when conclusions are being drawn. Therefore, we record everything that we encounter in our investigations, however trifling it may seem at the time.

INVESTIGATION

This might almost be headed "Search and Research," since that is primarily what is entailed. The limits of investigation should be the limits of the capacities of the tools employed. In looking at a plant with the naked eye, look carefully and you will probably be surprised at the presence of structures that you had never seen before. The hand lens and the microscope increase your potential for observing finer details, but without the inquisitive mind, the use of these tools helps very little.

Just as no two persons are wholly alike, even in the case of identical twins, so no two plants are identical. According to an old saying, complete similarity is expressed as, "Alike as two peas in a pod." You can find out that two peas from the same pod are really only superficially alike. Actually, each plant has its own individuality. Thus, the specimens that you study in lab have never been seen before. You are the first person to study them. You will certainly find out that your specimen differs from that of another student. Make a note of the variation that you find, but for the present, let us concentrate on the characters common to the specimens. Find out all you can about the plants supplied, and make a record of what you discover.

GROUP DISCUSSION

You are expected to discuss your problem and findings with the other members of your table group. In this manner, everyone at the table will be familiar with the findings of the other members. If there is disagreement as to observed facts, return to the plants and study more carefully. If disagreement persists, refer the question to another table group. If disagreement still persists, it may be because of interpretation of the facts rather than the facts themselves. First, ascertain the facts. Agreement as to interpretation of the facts is not necessarily required. A reminder of the fable of the blind men and the elephant might serve to show how apparently unlike observations can be made and interpreted.

Make a record of what you and your group have found out, and also make a record of investigations you would like to make in the future. Both of these should be brought up in the meeting of the whole class.

When the entire class meets on Wednesdays and Fridays, we have an opportunity of pooling all of the findings, and discussing their significance, in terms of the problem at hand. From the facts observed in lab, do not be afraid to confirm or disagree with statements made during the meeting. Also, do not be afraid to ask questions. If you knew all about plants, you would not be studying botany.

Each table or team should select a spokesman to represent that table in a panel for the next reporting period. This duty should be rotated from day to day so that every member of the table has the same number of opportunities to serve in the panel. Also, each team should have a secretary that serves to record the corroborated findings or the disagreements which will have to be re-searched in the lab. This duty should be rotated on a regular basis. Each member of the class, of course, should maintain at all times an up-to-date and complete notebook.

NOTEBOOKS

One of the most important things to a scientist is his notebook. In this, he keeps a record of his work, which includes his successes and failures. The book is usually at his side when he is working, ready for the recording of facts as he observes them. This practice of recording notes while the material is at hand should be encouraged. The form of the notes is not important as long as they are sufficient to recall the material to the worker. In some cases, a few words will suffice, in other cases, a fairly elaborate drawing might be needed. Whatever the observation, it should be recorded in the notebook as accurately as possible, under the date made. As time goes by, and as different problems are assigned by the group, your notebook will suffer from incoherence. It is not designed, however, to give a coherent picture of plants, but is the original record of your own personal observations, questions, and progress. It is a journal in which you record your day-to-day findings. Let us call it your "lab notebook."

After you have made your observations, and after you have had an opportunity to share your findings with other students, you may want to co-ordinate all of the findings into a coherent account of the facts. During the class periods, the lab notebook should be available so that you can augment your own observations with those of your colleagues. Once these are all noted, and any questions have been answered, you can begin to write a coherent treatment of the particular problem at hand. This full account should be written in as much detail as possible in your "class notebook." These, not your lab notes, constitute your notes on the course. Your "class notebook" should include all of your findings and conclusions written out completely. It will serve as your own personal text book. As such, you may wish to include drawings, if these serve to recall the material better than verbal descriptions. It would be desirable, therefore, to make your lab drawings (if any) on paper that can be included in your class notebook. If this is done, the drawing need not be copied into the notebook, and this is desirable, since every copy usually detracts from the accuracy of the illustration.

At the end of the course, you should have two personal reference books, the lab notebook which is essentially a set of rough notes and the class notebook which is the finished product.

TERMINOLOGY

For many beginners, botany is spoiled by the overabundance of terms. We shall use only those terms which <u>you</u> request. As we progress in our study of plants, we shall find that we cannot talk intelligently about specimens without some terminology. If you find that you want to talk about a structure on your specimen, the instructor will, if he is able, supply the accepted term. Most botanical terms are derived from Latin or Greek words, and as such are international in meaning.

APPENDIX B

EXAMINATION USED AS PRETEST, FINAL TEST, AND POST-TEST FOR BOTH GROUPS

Biology 108

I. In each of the following, select the choice that best answers the question or completes the statement.

____ 1. In algae which produce motile spores, the spores themselves are known as (a) zygotes (b) sporophytes (c) zoospores (d) isospores.

____ 2. The carpel of a flower is homologous with (a) a stamen of a flower (b) the sporophyll of a fern (c) the sporophyll of Lycopodium (d) the microsporophyll of lower vascular plants (e) the megasporophyll of Selaginella.

____ 3. Oedogonium is significant to the study of reproductive evolution in that (a) it illustrates isogamy (b) it possesses no sex organs, yet reproduces sexually (c) oogamy within a parent cell occurs (d) oogamy in surrounding water occurs.

____ 4. In cases of sexual reproduction in which the uniting gametes are indistinguishable in structure and appearance, the gametes are said to be (a) anisogamous (b) isogamous (c) heterogamous (d) gametangia.

____ 5. In most colonial green algae, the plant body belongs to the (a) diploid generation (b) the zygote generation (c) haploid generation (d) asexual generation.

____ 6. In the flowering plant, the mature megagametophyte is located within (a) the ovule (b) the stigma (c) the pollen grain (d) the anther.

____ 7. Reproduction involving two gametes which are markedly different from one another is known as (a) isogamy (b) gametogenesis (c) volvox (d) oogamy.

____ 8. An angiosperm zygote (a) is diploid (b) is haploid (c) may be either haploid or diploid (d) is diploid and the beginning of the gametophyte phase in plants (e) is haploid and the beginning of the sporophyte phase in plants.

____ 9. Blue-green algae are evolutionarily allied to bacterial cells primarily because (a) both cause diseases in men (b) many forms of each are poisonous to man (c) of similarities in subcellular construction (d) they are often both present in polluted waters.

____ 10. The gametangium which forms eggs is called (a) an oogonium (b) an antheridium (c) a capsule (d) a stigma.

____11. Although bacteria are commonly classified as plants, their cell walls lack (a) chloroplasts (b) nuclei (c) cellulose (d) mitochondria.

____12. The gametangium which produces sperms is called (a) an oogonium (b) an antheridium (c) a capsule (d) a stigma.

____13. Considering the number of generations represented within the confines of the integuments of a seed, which of the following more closely approaches the condition of a seed? (a) Lycopodium (b) Selaginella (c) Marchantia (d) fern.

____14. Which of the following does not fit? (a) petal (b) pollen tube (c) stigma (d) sepal.

____15. The ovulate cone scale of Pinus was probably (a) a new evolutionary innovation in the gymnosperms (b) modified from a leaf or branch (c) a degenerate evolutionary modification of a carpel (d) the evolutionary ancestor of the petal.

____16. Reproduction in bacteria most often occurs by (a) vegetative cell division (b) sexual union (c) spore formation (d) meiosis.

____17. The most common type of sexual reproduction which occurs among the many species of Chlamydomonas is (a) fission (b) isogamy (c) heterogamy (d) oogamy.

____18. The food used by the embryo of Pinus during its development and germination is evolutionarily most unlike to the food used by the embryo of (a) the moss (b) the clubmoss (c) the fern (d) the bean plant.

____19. Which of the following would probably be the least efficient from the standpoint of energy storage? (a) a blue-green alga (b) a green alga (c) a red alga (d) a fern cell.

____20. Which of the following is least homologous to the others? (a) rhizoid (b) root (c) holdfast (d) haustoria.

____21. Which of the following characteristics found in the club-mosses probably contributed more toward the evolution of the seed? (a) Heterospory (b) Heterogamy (c) Development of a strobilus (d) Development of a vascular system.

____22. In Ulothrix, and other algae, the filaments are usually attached to the substratum by a specialized cell called (a) an anchor (b) a retainer (c) a holdfast (d) a root.

____23. The plant body of fungi (mycelium) is made up of (a) hyphal threads (b) chitin from insect exoskeletons (c) cellulose from lower fungi (d) ingested pieces of organic matter cemented into walls.

____24. The embryo of which of the following would be more dependent upon a well developed transport system for food? (a) Pinus (b) Lycopodium (c) Selaginella (d) Moss.

____25. The food supply for the gametophytes in Selaginella is mainly derived from (a) the parent sporophyte plant (b) photosynthesis by the gametophyte (c) photosynthesis by the new sporophyte (d) heterospory, in which the larger supplies the smaller.

____26. Blue-green algae differ from other algae in that they have (a) no organized nucleus (b) no cell membrane (c) are never joined together in filaments (d) occur only in fresh water.

____27. Select the one from the following that does not fit: (a) a fern frond (b) a pine needle (c) a moss leaf (d) a bean leaf.

____28. Which of the following conditions would probably be most effective in the prevention of fertilization in Lycopodium? (a) absence of sunlight (b) absence of air currents (c) absence of moisture (d) absence of chlorophyll.

____29. In which of the following would you expect to find the least amount of RNA? (a) a fungal cell (b) a bacterial cell (c) a moss cell (d) a fern cell.

____30. Which of the following could probably survive the greatest temperature fluctuations? (a) Bacillus terminalis (b) Micrococcus pyogenes (c) Spirillum rubrum (d) Staphylococcus alba.

____31. Those fungi, the hyphae of which usually lack transverse walls (coenocytic) and which are in many respects similar to the green algae, are classified as (a) Deuteromycetes (b) Basidiomycetes (c) Ascomycetes (d) Phycomycetes.

____32. Which of the following was probably the first photosynthetic organism to be evolved? (a) a green alga (b) a bacterium (c) a red alga (d) a blue-green alga.

____33. Which of the following is least homologous to the others? (a) a filament of an anther (b) microsporophyll (c) a megasporophyll (d) ovulate cone scale.

____34. A bacterial cell could probably be most accurately referred to as (a) a sporophyte (b) a gametophyte (c) a meiospore (d) a heterogamete.

____35. A principal difference between a pine seed and a bean seed is (a) the bean seed contains cotyledons (b) the pine seed contains an embryo (c) the bean seed contains endosperm (d) the pine seed has no integuments.

____36. The common black mold which is frequently associated with stale bread is (a) Achlya (b) Rhizopus (c) Penicillium (d) Puccinia.

____37. In angiosperms, the individual plant is (a) predominantly sporophyte (b) predominantly gametophyte (c) equally sporophyte and gametophyte (d) neither sporophyte nor gametophyte.

____38. Select from the following the item that does not fit. (a) a microspore of Selanginella (b) a megaspore of Pinus (c) an ascospore (d) a sporangiospore of Rhizopus.

____39. In the life cycle of the black bread mold the entire organism consists of haploid cells except for the (a) gametangia (b) stolons (c) rhizoids (d) zygote.

____40. Select from the following, the item that does not fit. (a) Integuments (b) Protonema (c) Frond (d) Petal.

____41. The following is a list of gymnosperm characteristics. Which is probably the most evolutionarily primitive? (a) a woody stem (b) an archegonium (c) swimming sperm (d) heterospory.

____42. Flashy basidiocarps are structures associated with (a) wheat rust (b) the smuts (c) penicillin (d) mushrooms.

____43. In angiosperms, the pollen is produced within the (a) calyx (b) corolla (c) androecium (d) gynoecium.

____44. Which of the following genera is heterosporous? (a) Selaginella (b) Lycopodium (c) Pteris (d) Marchantia.

____45. Those dual organisms, composed of an alga and a fungus, are known as (a) lichens (b) liverworts (c) mosses (d) sponges.

____46. A protonema would be more homologous to (a) a rhizoid of Rhizopus (b) a fern prothallus (c) a Lycopodium rhizome (d) a pollen tube of Pinus.

____47. Most fruits are derived from a mature (a) ovule (b) ovary (c) bud (d) leaf.

____48. In the liverworts and mosses the independent plant body is (a) gametophytic (b) sporophytic (c) hydrophytic (d) heterotrophic.

____49. From the lower part of the hypocotyl develops the (a) root only (b) rhizoid only (c) lower part of the stem (d) all of the stem.

____50. The germinating moss spore develops into branching filamentous systems known as (a) septa (b) musci (c) protonema (d) flagellates.

____51. Which of the following does not fit? (a) ascospore (b) basidiospore (c) meiospore (d) sporangiospore.

____52. The flasklike structure which is the female sex organ in the mosses in known as (a) oogonium (b) antheridium (c) protonema (d) archegonium.

____53. Which of the following is the least well equipped to survive in an aquatic habitat: (a) a zoospore of Oedogonium (b) an isogamete of Ulothrix (c) an ascospore of a powdery mildew (d) a zoospore of Phytophthera.

____54. Food storage in the bean seeds is mainly in the (a) epicotyl (b) hypocotyl (c) cotyledons (d) endosperm.

____55. In mosses the zygote, as it begins development, (a) undergoes meiosis (b) develops without nuclear division (c) divides mitotically (d) develops into the gametophyte generation.

____56. A fern frond would be more homologous to (a) a sporophyll of Lycopodium (b) a microsporophyll of Selaginella (c) an ovulate scale of Pinus (d) a moss leaf.

____57. From the epicotyl develops the (a) flowers only (b) leaves only (c) shoot only (d) shoot and upper part of the root.

____58. In the mosses the sporophyte develops (a) saprophytically on dead organic matter (b) growing directly on the ground (c) parasitically on the gametophyte (d) growing directly from the water.

____59. Which of the following characteristics is not found in the gymnosperms? (a) pollen (b) microsporangium (c) spores (d) stamen.

____60. Meiosis in angiosperms produces (a) eggs and sperms (b) ootids and spermatids (c) zygote (d) microspores and megaspores.

____61. Within the seed coat of a seed is contained (a) only structures of one sporophyte generation (b) only structures of one gametophyte generation (c) structures of one sporophyte and one gametophyte generation (d) structures of two sporophyte and one gametophyte generation.

____62. A limiting factor in the size which liverworts can reach seems to be (a) lack of sufficient damp environments

(b) failure to reproduce sexually (c) absence of a gametophytic generation (d) lack of efficient water conducting tissue.

____63. In angiosperms the seeds are produced with the (a) calyx (b) corolla (c) androecium (d) gynoecium.

____64. In the vast majority of ferns, the largest organs of the plants are (a) roots (b) stems (c) leaves (d) rhizomes.

____65. Which of the following characteristics more closely ties the gymnosperms to the angiosperms than to any other group? (a) development of a vascular system (b) production of seed (c) development of a strobilus (d) loss of swimming sperm.

____66. Which of the following would probably spread the fastest in a terrestrial habitat? (a) Ulothrix (b) Sprolegnia (c) Aspergillus (d) Marchantia.

____67. With the exception of the tree ferns, fern stems are subterranean or prostrate and generally referred to as (a) rhizomes (b) rhizoids (c) Rhizopus (d) roots.

____68. Pollination in gymosperms is effected primarily by (a) water (b) wind (c) insects (d) man.

____69. Which of the following most resembles a sexually reproductive structure of the green alga? (a) a female gametangium of a bean (b) a female gametangium of Pinus (c) a male gamete of a bean (d) a male gamete of Pinus.

____70. In most ferns, the conducting elements of the xylem are exclusively (a) fibers (b) vessels (c) companion cells (d) tracheids.

____71. Which of the following is least similar? (a) heterocyst (b) isogametangium (c) anteridium (d) oogonium.

____72. Each localized region bearing sporangia is known as a receptacle, and this receptacle, with the group of sporangia, is termed (a) an indusium (b) a false indusium (c) a spore case (d) a sorus.

____73. Which of the following is evolutionarily more akin to the bryophytes? (a) Ulothrix (b) Oedogonium (c) Nostoc (d) Fucus (a brown alga).

____74. Pollination in angiosperms is effected primarily by (a) wind (b) rain (c) man (d) something other than the three above.

____75. In the majority of ferns the sporangia develop in localized regions on the surface of the (a) flower (b) leaf

(c) stem (d) rhizoid.

____76. A basidiospore would be more homologous to (a) a conidium of Aspergillus (b) a megaspore of Lycopodium (c) a moss spore (d) a zoospore of Oedogonium.

____77. The integuments of a bean seed would probably be more homologous to (a) an ascus wall of a fungus (b) a megasporangial wall of a clubmoss (c) a sporangial wall of a fern (d) the operculum of a moss.

____78. In Lycopodium the spore-bearing leaves of many species are localized in terminal portions of the axis which have especially short internodes and which are known as (a) rosettes (b) sporangia assemblies (c) strobili (d) false flowers.

____79. Most of the gymnosperms of South Dakota are (a) aquatic (b) extinct (c) evergreen (d) xerophytic.

____80. Which of the following probably evolved first? (a) a sperm (b) an egg (c) a diploid motile spore (d) a haploid motile spore.

____81. The conelike reproductive structures of Selaginella bear both microsporophylls and megasporophylls. The production of two different types of spores is termed (a) disporism (b) monospory (c) heterospory (d) dualism.

____82. The ancestors of which of the following were probably best adapted for a terrestrial habitat? (a) moss (b) fern (c) liverwort (d) alga.

____83. Seed plants are usually considered to be (a) heterosporus (b) homosporus (c) without spores (d) trisporus.

____84. A juniper berry would be more homologous to (a) a pine cone (b) a corn cob (c) a blueberry (d) a barberry.

____85. The large structure known as the cone which is retained by the pine tree over a period in excess of a year is the (a) flower (b) fruit (c) megastrobilus (d) microstrobilus.

____86. The original bryophytes were probably (a) taller than (b) shorter than (c) equally as tall as modern ferns.

____87. As compared with bryophytes, the male and female gametophytes of angiosperms are (a) much simpler (b) about the same (c) much more complex (d) there is so much variation that there is little basis for comparison.

____88. One of the most evolutionarily significant features of the clubmosses is (a) the development of an aquatic habit (b) production of true roots (c) development of heterospory (d) development of an independent gametophyte.

____89. In pine, and indeed many other plants, the liberated microspores are usually spoken of as (a) embryo sacs (b) ovules (c) pollen grains (d) zygotes.

____90. In Lycopodium the leaflike structure to which the sporangium is attached is best referred to as (a) a microsporophyll (b) a megasporophyll (c) a sporophyll (d) a sporophyte.

____91. The homologue in the flowering plants of the microsporophyll in vascular cryptogams is the (a) stigma (b) calyx (c) ovary (d) stamen.

____92. In angiosperms pollination differs from that in gymnosperms in that (a) pollen grains cannot be transported to the ovule (b) there is no ovule in gymnosperms (c) there is no pollen movement in gymnosperms (d) there is no ovule in angiosperms.

II. Each of the following lists is made up of characteristics and/or lack of characteristics which could be ascribed to a single plant. In each case place that plant in one of the following groups:

(a) angiosperms	(f) fungi
(b) gymnosperms	(g) green algae
(c) club mosses	(h) blue-green algae
(d) ferns	(i) bacteria
(e) bryophytes	

____ 1. Heterogamy, archegonium, heterospory, antheridium.

____ 2. No archegonium, photosynthetic, gametes produced, green gametophyte.

____ 3. Independent gametophyte, photosynthetic, archegonium, sporophyte predominant, not heterosporous.

____ 4. Nongreen gametophyte, heterosporous, pollen tube, no archegonium.

____ 5. Photosynthetic, independent gametophyte, no sporophyte generation, no gametes.

____ 6. Heterogamy, photosynthetic, heterospory, reduced but independent male gametophyte.

____ 7. Heterogamy, homosporous, reduced sporophyte, no archegonium, nonphotosynthetic.

____ 8. Archegonium, homosporous, independent gametophyte, dependent sporophyte.

____ 9. Homosporous, green gametophyte, gametophyte reduced, no microsporophylls.

____10. Heterogamy, antheridium, gametophyte, predominant, no archegonium, gametophyte green.

APPENDIX C

OPINION SURVEY QUESTIONNAIRE

Course Evaluation

The regular evaluation forms are directed mainly toward the instructor. This evaluation is concerned with the course itself. Inasmuch as possible, disregard the instructor's effect on your answer to each question. Mark your answer anywhere on the line between 1 and 9. The numbers and words immediately below each question are to serve as guides only. You need not select from only those numbers.

Example -- How would you rate the value of belonging to Science Club?
1. Of no value
5. Some value
9. Extremely valuable

1 ——————————— 5 ——————————— 9

1. How would you rate the type of learning required by this course?
   1. Completely rote memory work
   5. About half memory work and half understanding
   9. No directed memory work -- based entirely on understanding

1 ——————————— 5 ——————————— 9

2. Compared to other courses, Botany has been
   1. Much easier
   5. About the same
   9. Much more difficult

1 ——————————— 5 ——————————— 9

3. How did you like General Botany?
   1. I hated it.
   5. There was about as much that I liked as there was that I disliked.
   9. I loved it.

1 ——————————— 5 ——————————— 9

4. Did you like this type of learning situation?
   1. No
   9. Yes

1 ——— 5 ——— 9

5. How much have you been stimulated intellectually by this course?
   1. Very little
   5. An average amount
   9. A great deal

1 ——— 5 ——— 9

6. How does your attitude toward Botany at the present time compare to your attitude at the beginning of the semester?
   1. Thought I would like it but now I dislike it.
   5. No change in attitude.
   9. Thought I would dislike it but now I like it.

1 ——— 5 ——— 9

7. If you were enrolling in a course next fall with two sections, section A being taught by the discovery method and section B being taught by the lecture method, which section would you choose?
   1. Section A -- discovery method
   5. Whichever section would give me the best schedule
   9. Section B -- lecture method

1 ——— 5 ——— 9

8. The level of the course material was:
   1. Always below my level
   3. Generally at my level, about 40% below my level
   5. Almost always at my level
   7. Generally at my level, about 40% above my level
   9. Always above my head

1 ——— 5 ——— 9

9. If you were to teach this course, would you use the method that was used this semester?
   1. No
   5. Undecided
   9. Yes

1 ——————————— 5 ——————————— 9

10. From the standpoint of promoting learning, the poorest thing about the course was?

11. From the standpoint of promoting learning, the best thing about the course was?

12. Other comments.

APPENDIX D

TABULATION OF RESPONSES OF GROUP I (DISCOVERY METHOD) AND GROUP II (LECTURE METHOD) TO OPINION SURVEY

TABLE XVIII

TABULATION OF RESULTS OF THE OPINION SURVEY OF THE EXPERIMENTAL GROUP (GROUP I - DISCOVERY METHOD) AND THE MEAN FOR EACH ITEM

Student	Item Number								
	1	2	3	4	5	6	7	8	9
A	6.0	7.0	5.0	6.0	7.0	6.0	2.0	5.0	6.0
B	6.0	7.7	5.0	9.0	6.0	4.0	1.0	5.0	9.0
C	5.0	9.0	7.0	7.0	7.0	7.0	7.0	7.0	9.0
D	7.0	5.8	6.0	7.0	6.0	5.4	1.0	4.4	5.3
E	5.7	7.0	5.6	6.0	8.0	5.0	1.0	5.6	5.0
F	6.2	6.8	6.9	7.2	3.8	4.8	1.2	5.9	7.2
G	5.0	6.0	5.0	2.0	7.0	6.5	9.0	5.0	1.0
H	5.0	9.0	5.0	5.0	7.0	6.0	5.0	7.0	5.0
I	8.0	7.5	5.0	1.3	6.4	7.1	7.0	6.8	4.0
J	6.8	6.8	5.0	2.0	4.3	5.0	9.0	2.0	1.0
K	6.0	9.0	2.0	5.0	8.8	5.9	8.0	7.3	2.0
L	7.1	6.4	5.6	6.3	5.7	4.8	5.0	7.0	5.2
M	5.0	5.0	7.0	7.0	6.0	7.0	5.0	5.0	5.0
N	5.8	6.0	7.0	5.2	7.6	5.2	8.2	5.7	---
$\bar{x}$	6.0	7.1	5.5	5.4	6.5	5.7	5.0	5.6	5.0

TABLE XIX

TABULATION OF RESULTS OF THE OPINION SURVEY OF THE CONTROL GROUP (GROUP II - LECTURE METHOD) AND THE MEAN FOR EACH ITEM

Student	Item Number								
	1	2	3	4	5	6	7	8	9
A	7.0	5.0	5.0	6.0	5.0	6.0	9.0	6.0	8.0
B	6.5	8.0	3.7	2.0	1.0	4.8	8.7	8.0	1.0
C	5.0	8.0	4.0	7.0	5.0	5.6	9.0	6.0	6.0
D	5.0	6.3	6.7	8.0	5.0	6.3	8.1	5.0	7.0
E	5.8	6.6	7.3	8.6	5.0	5.7	8.8	5.1	8.0
F	6.9	6.6	5.0	9.0	6.7	5.0	9.0	7.1	5.0
G	9.0	1.0	1.0	1.0	1.0	1.0	9.0	7.0	1.0
H	7.0	4.0	9.0	9.0	8.0	7.0	9.0	5.0	9.0
I	5.0	6.5	4.0	3.5	4.3	5.0	8.7	5.0	5.0
J	6.0	9.0	5.0	1.0	2.4	4.3	5.5	6.5	1.0
K	2.8	9.0	4.0	4.2	4.0	4.0	6.5	7.3	5.0
L	5.0	9.0	6.0	9.0	9.0	8.0	9.0	5.0	9.0
M	6.6	6.1	7.1	6.4	7.8	7.2	2.2	6.0	6.3
N	7.0	8.0	8.0	8.0	9.0	5.0	1.0	5.0	5.0
$\bar{x}$	6.0	6.7	5.4	5.9	5.2	5.4	7.4	6.0	5.5

APPENDIX E

RESPONSES TO ESSAY QUESTIONS ON OPINION SURVEY

10. FROM THE STANDPOINT OF PROMOTING LEARNING, THE POOREST THING ABOUT THE COURSE WAS?

Group I (experimental):

A. The instructor wasn't always available when he was needed. Sometimes if we couldn't find things out we just sat around doing nothing.

B. Lack of organization in the laboratory periods. Poor labs lead to lectures which became stale and ordinary. Better promotion of discussion and survey in lab would have made the course more interesting, leading to more initiative on the part of the students. Could have developed better discussions and understanding if the divisions were studied evolutionary from algae up to angiosperms.

C. Not enough up to date charts. More plastic projections needed to cover all life cycles of plants, more natural materials.

D. Lack of a clear cut program of work. Course rambled a great deal. Although a course of this type tends to be that way, this course could have been more organized.

E. You were more or less on your own and it was up to you to either make it or flunk the course. Also, it was hard to get adjusted to this type of course.

F. Towards the last part of the semester interest in what we did in our labs dropped off and the material seemed dull.

G. I don't believe research works in a classroom situation. Learn more through lecture.

H. No really regular assignments. We were on our own.

I. Discovering things but not knowing all the names for the parts.

J. Too much work on finding material (in different books). Lecture would help point out aspects (characteristics) of plants, also the instructor being gone is not good.

K. The use of unscheduled class assignments, no use of book, the whole class discussions.

L. Toward the end it got to be too much of a good thing. It would have been nice to have some lecture.

M. ---

N. Hard for me to get down and get something done in lab.

Group II (control):

A. ---

B. It seemed so uninteresting almost all of the time.

C. ?

D. Poor labs, due to equipment.

E. Some of the unorganized labs.

F. ---

G. ---

H. ---

I. Lab

J. The lack of correlation between laboratory work and text assignments.

K. The lab work had little value to me. It was always looking at the same slides and getting nothing out of it.

L. Class participation.

M. Can't think of anything offhand.

N. 1. the rate we had to cover the material. 2. Lack of good microscopes to see material. 3. the text book was boring.

11. FROM THE STANDPOINT OF PROMOTING LEARNING, THE BEST THING ABOUT THE COURSE WAS?

Group I (experimental):

A. The excitement of discovering things for yourself. It was more interesting this way.

B. It gave you the chance to say what you knew. Through verbalization one learns the best. One had to know the material to present it to others and discuss it. Enjoyed the difference, and if the course weren't graded except on participation basis only, grades taken only from one final exam of knowledge one knew, results would be much different.

C. Intellectual ability of each student was challenged fairly except for the tests which should not be given at all. Pass-fail system should be used in this course.

D. The best part was working with other students and sharing your knowledge and understandings. It made the material much easier to grasp.

E. It really made you study the material! If you didn't you were up a creek without a paddle. I felt like I had accomplished something when I did it on my own.

F. It was not entirely lecture and most of the labs were interesting.

G. Recognize more plants in nature.

H. Everything that we got from the course we got ourselves.

I. Learning for ourselves.

J. Learning to dig material from observance.

K. The labs.

L. We were able to procede and work on our own to an extent.

M. ---

N. Worked with the material studied.

Group II (control):

A. The tests required understanding the material and not just memorizing it.

B. It showed me that there was more to learn about plants than I really thought there was.

C. ?

D. Well informed instructor.

E. Lectures on new material.

F. ---

G. ---

H. We took the plant kingdom step by step and only learned about the main plant in each step.

I. ?

J. Gives something to think about.

K. Lectures and the summary at the end of the chapter.

L. Lecture method.

M. More competition between the sections than would normally have been true.

N. 1. That it made one take notice of the plants around you.

12. OTHER COMMENTS.

Group I (Experimental):

A. ---

B. May have worked better if some students hadn't known it was an experiment. This developed negative attitudes in some cases.

C. Field trips to find natural habitat would be important. This was a good course but some things need a little touching up.

D. ---

E. This course was very stimulating, although it made me work my but off!

F. The instructor should not do all the discussing, but I feel he should not drop out of the picture all together but develop conversation and guide the students a little in what they should be looking for and not leave them totally blank to themselves.

G. None.

H. ---

I. To much finding for ourselves and then tests that are out of the book.

J. ---

K. More emphasis should be put on individual work rather than group work. In a group the bossier student will take over, the shy or less intelligent student will slough off. Projects should be given to two people but no more than two.

L. I liked the opportunity to participate in this type of learning experience.

M. ---

N. ---

Group II (Control):

A. ---

B. ---

C. ---

D. ---

E. By beginning with the Angiosperms and working downard, the students begin with something they know and can understand. It would be a lot harder, in my opinion, to begin with the different types of algae and each of their types of reproduction.

F. ---

G. Bleah!

H. At the beginning of this semester I hated Botany but since you have taught me, to me botany is a very interesting subject. Thank you Dr. Brashier for the enjoyable semester. See you next year.

I. ----

J. The course was hard. Not really too interesting for the average to poor student. Hard to correlate facts to common knowledge.

K. ----

L. See you this summer.

M. ----

N. I enjoyed the course very much. This may change me into a Biology Major.

VITA

Vincent Allen Hall

Candidate for the Degree of

Doctor of Education

Thesis: A COMPARISON OF THE DISCOVERY APPROACH WITH THE LECTURE APPROACH IN TEACHING GENERAL BOTANY

Major Field: Higher Education

Biographical:

Personal Data: Born at Elk Point, South Dakota, January 22, 1934, the son of Ellwood H. and Alma C. Hall. Married DeAnna D. Oleson, August 20, 1966; four children, LeAnn Lynn, Carolyn Marie, David Vincent, and Charis Lynette.

Education: Attended grade school in Jefferson, South Dakota, and Elk Point, South Dakota, Rural District Number 6; graduated from Elk Point High School in 1952; graduated from South Dakota State University at Brookings with the Degree of Bachelor of Science in Agriculture in 1956; received the Degree of Master of Science from South Dakota State University in 1957. Graduate study in Physiology at Michigan State University, 1958-1960.

Professional Experience: Taught Anatomy and Physiology and General Science at Lansing Community College in Lansing, Michigan, 1958-1960. Taught Physiology of Exercise at Michigan State University, 1961. Taught Anatomy and Physiology at South Dakota State University, 1962-1965. From 1968 to present have taught General Biology, Bacteriology, Anatomy and Physiology, Biological Science Curriculum Study (BSCS), and Special Methods of Teaching Biology in Secondary Schools at Dakota State College, Madison, South Dakota.

Professional Organizations: South Dakota Higher Education Faculty Association, American Institute of Biological Sciences, South Dakota Academy of Sciences.