THE RELATIVE EFFECTIVENESS OF THE INDUCTIVE-DEDUCTIVE
AND THE DEDUCTIVE-DESCRIPTIVE METHODS IN
THE TEACHING OF COLLEGE ZOOLOGY

APPROVED:

Graduate Committee:

C. W. Clark
Major Professor

Russell G. Sherman
Minor Professor

J. L. Marquardt
Committee Member

Earl W. Hofer
Committee Member

Dean of the School of Education

Dean of the Graduate School
THE RELATIVE EFFECTIVENESS OF THE INDUCTIVE-DEDUCTIVE
AND THE DEDUCTIVE-DESCRIPTIVE METHODS IN
THE TEACHING OF COLLEGE ZOOLOGY

DISSERTATION

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF EDUCATION

By

Eva Lee Craite, B. S., M. Ed.
Denton, Texas
August, 1966
# TABLE OF CONTENTS

| LIST OF TABLES | v |

<table>
<thead>
<tr>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. INTRODUCTION</strong></td>
</tr>
<tr>
<td>Statement of the Problem</td>
</tr>
<tr>
<td>Hypotheses</td>
</tr>
<tr>
<td>Background and Significance of the Study</td>
</tr>
<tr>
<td>Definition of Terms</td>
</tr>
<tr>
<td>Organization of Remainder of the Study</td>
</tr>
<tr>
<td><strong>II. SURVEY OF THE LITERATURE</strong></td>
</tr>
<tr>
<td>Historical Background of the Problem</td>
</tr>
<tr>
<td>Research with Reference to Methods</td>
</tr>
<tr>
<td>Research Referring to Student Maturity</td>
</tr>
<tr>
<td>Basic Psychological Considerations</td>
</tr>
<tr>
<td>Implications for Methodology in Science</td>
</tr>
<tr>
<td><strong>III. RESEARCH PROCEDURES</strong></td>
</tr>
<tr>
<td>Design of the Experiment</td>
</tr>
<tr>
<td>The Teaching Situation</td>
</tr>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Method of Assignment</td>
</tr>
<tr>
<td>Procedure in Matching Groups</td>
</tr>
<tr>
<td>Criterion Measures</td>
</tr>
<tr>
<td>Teaching Methods</td>
</tr>
<tr>
<td>Basic Assumptions</td>
</tr>
<tr>
<td>Limitations of the Study</td>
</tr>
<tr>
<td>Procedures for Analysis of Data</td>
</tr>
<tr>
<td><strong>IV. THE TEACHING METHODS</strong></td>
</tr>
<tr>
<td>Objectives</td>
</tr>
<tr>
<td>Conceptual Framework</td>
</tr>
<tr>
<td>Textbooks</td>
</tr>
<tr>
<td>Student-Teacher Relationships</td>
</tr>
<tr>
<td>The Deductive-Descriptive Method</td>
</tr>
<tr>
<td>The Inductive-Deductive Method</td>
</tr>
<tr>
<td>Chapter</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Laboratory Observations</td>
</tr>
<tr>
<td>Laboratory Investigation</td>
</tr>
<tr>
<td>Vicarious Participation in Research</td>
</tr>
<tr>
<td>Discussion</td>
</tr>
<tr>
<td>Testing</td>
</tr>
<tr>
<td>The Role of the Teacher</td>
</tr>
<tr>
<td>V. PRESENTATION OF FINDINGS</td>
</tr>
<tr>
<td>Assumptions for Use of the T Test</td>
</tr>
<tr>
<td>Zoology Achievement</td>
</tr>
<tr>
<td>Science Reasoning and Understanding</td>
</tr>
<tr>
<td>Critical Thinking</td>
</tr>
<tr>
<td>Summary of Mean Gains</td>
</tr>
<tr>
<td>Student Evaluation of the Course</td>
</tr>
<tr>
<td>Most Characteristic Feature</td>
</tr>
<tr>
<td>Class Goals</td>
</tr>
<tr>
<td>Study Habits</td>
</tr>
<tr>
<td>Tangible Effects of the Course</td>
</tr>
<tr>
<td>Most Helpful Features</td>
</tr>
<tr>
<td>Least Helpful Features</td>
</tr>
<tr>
<td>Choice of Course</td>
</tr>
<tr>
<td>VI. SUMMARY AND CONCLUSIONS</td>
</tr>
<tr>
<td>Summary</td>
</tr>
<tr>
<td>Conclusions and Recommendations for Further Research</td>
</tr>
<tr>
<td>The Criterion Measures</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Interaction of Classroom Variables</td>
</tr>
<tr>
<td>Values of the Method</td>
</tr>
<tr>
<td>APPENDIX</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Comparative Data on External Characteristics of the Matched Groups</td>
<td>44</td>
</tr>
<tr>
<td>II. Comparative Mean Scores and Standard Deviations onAll Criteria Used in Matching Groups</td>
<td>46</td>
</tr>
<tr>
<td>III. t Values of the Mean Difference Between the Several Groups on the Performance Scores Used in Matching Groups</td>
<td>47</td>
</tr>
<tr>
<td>IV. Distribution of Scores on the Zoology End-of-Term Achievement Test for the Inductive-Deductive and the Deductive-Descriptive Groups</td>
<td>84</td>
</tr>
<tr>
<td>V. Standard Deviations of the Experimental and Control Groups on Pretest and Retest of Three Criterion Measures</td>
<td>85</td>
</tr>
<tr>
<td>VI. Comparative Data Showing Means and Standard Deviations on the Zoology Achievement Pretest and Retest</td>
<td>86</td>
</tr>
<tr>
<td>VII. Mean Gains on the Zoology Achievement Test by Method and by Semester</td>
<td>87</td>
</tr>
<tr>
<td>VIII. Results of an Analysis of Variance of Mean Gains on the Zoology Achievement Test by Method and by Semester</td>
<td>87</td>
</tr>
<tr>
<td>IX. Comparative Data Showing Pretest and Retest Means and Standard Deviations on A Test of Science Reasoning and Understanding</td>
<td>90</td>
</tr>
<tr>
<td>X. Mean Gains on A Test of Science Reasoning and Understanding by Method and by Semester</td>
<td>91</td>
</tr>
<tr>
<td>XI. Results of an Analysis of Variance of Mean Gains on A Test of Science Reasoning and Understanding by Method and by Semester</td>
<td>91</td>
</tr>
</tbody>
</table>
Table IX.

XII. Comparative Data Showing Pretest and Retest Means and Standard Deviations on the Watson-Glaser Critical Thinking Appraisal . . 94

XIII. Mean Gains on the Watson-Glaser Critical Thinking Appraisal by Method and by Semester . . . . . . . . . . . 95

XIV. Results of an Analysis of Variance of Mean Gains on the Watson-Glaser Critical Thinking Appraisal by Method and by Semester . . . . 95

XV. Summary of Mean Gains for All Groups on All Criterion Measures . . . . . . . . . . . . . . 98

XVI. Differences Between Matched Pairs on the Several Criterion Measures Used in Matching Groups . . . . . . . . . . . . . . 133

XVII. Distribution of Retest Scores on A Test of Science Reasoning and Understanding for the Inductive-Deductive and the Deductive-Descriptive Groups . . . . . . . . . . . . . . 134

XVIII. Distribution of Retest Scores on the Watson-Glaser Critical Thinking Appraisal For the Inductive-Deductive and the Deductive-Descriptive Groups . . . . . . . . . . . . . . 135
CHAPTER I

INTRODUCTION

Today's demand for increased emphasis on science has resulted in a renewed interest in science teaching at all levels. During the last decade the National Science Foundation and other federal agencies have poured many millions of dollars into financial support for the improvement of science education. Much of the work to date has gone into a curricular program for the development of improved course materials for new science courses at the high school and elementary levels. Leading research scientists, assisted by teachers, have identified the significant concepts in their disciplines and have prepared, tested, and published textbooks and laboratory activities which are now in use in many high schools and elementary schools over the nation. Hurd and Rowe reported that though the NSF curriculum group for each discipline worked independently, there had been a progressive convergence of purposes, educational ideas, and processes. The purpose of instruction as conceived in these efforts has been "to develop an understanding of current scientific knowledge—its concepts and methods of inquiry" (17, p. 237). Textbooks have been built around
large conceptual themes or principles of science, and laboratory activities have tended "to be less illustrative and more investigative . . . to stimulate questions rather than simply to answer them" (17, p. 287). Tests have been devised which "required students to interpret data, to apply concepts in new contexts, and to demonstrate an ability to use the techniques and procedures of scientific inquiry" (17, p. 287). Hurd and Rowe also reported the realization that "the new movement in science instruction is as much a matter of improved teaching methods as of new goals and up-to-date content. Understanding rather than memorization was sought. Concepts were to be taught in depth to increase their meaning, retention, and intellectual usefulness" (17, p. 287).

Despite the challenge presented by the progress made at the high school level, college biologists have been slow to make radical changes. Van Deventer stated in his review of research on "The Teaching of Science at the College and University Level" for the 1964 Review of Educational Research that

whereas the physicists have been quite cognizant of the need for curricular change, and the chemists have been moderately active, college biologists have so far done little to meet the challenge posed by the rapid advances of biological knowledge and of new curricular development in the high schools (21, p. 334).
Grobman (13) in 1961 called attention to the problem posed for planners of college biology programs by the success of the BSCS high school biology course. Van Deventer (21) pointed out that college campuses will be receiving increasing numbers of students who have experienced these newly developed courses not only in biology but also in chemistry, physics, and mathematics, and that the standard biology courses now offered at the college level will no longer be sufficient. Grant and Saul cited (a) deficiencies in college biology teaching due to the ultra-conservatism of professors and their failure to keep up with recent trends and (b) the need for revision of undergraduate courses by "resynthesizing them according to newly developed conceptual templates" (12, p. 15).

Somewhat tardily, with the establishment of the Commission on Undergraduate Education in the Biological Sciences (CUEBS), biologists have made a start toward remedying what Hanson called the "gap between the present frontiers of biology and what is all too often taught in the college laboratory and classroom as representative of biology" (14, p. 1). In an address to a CUEBS sponsored Conference on Biology in the Junior College, Hanson who is chairman of the Commission, stated that "teaching in introductory courses is the most difficult of all college teaching and probably the most important, for here attitudes are shaped and
intellectual appetites whetted or dulled" (14, p. 2). In the same address he emphasized the need for innovative teaching and for developing a tradition of exploring for new ideas in teaching. Only seven years ago Solinger (20), after completing a survey of 131 introductory biology courses in fifty colleges, indicated evidence of a distressing lack of concern about beginning courses. It is heartening that some biologists have now become aware of the need for research in instructional methods at the college level.

Statement of the Problem

This study was concerned with making a comparative analysis of the relative effectiveness of two teaching methods in increasing students' (a) knowledge and understanding of principles, (b) ability in critical thinking, and (c) science reasoning and understanding in an introductory college zoology course. The two methods were (a) a laboratory-centered inductive-deductive method and (b) the more commonly found deductive-descriptive method organized as a large lecture section with smaller laboratory sections. The inductive-deductive method as conceived in this study was built around and conducted in a laboratory situation in which analysis and inquiry into meaningful problems were used to introduce general principles which serve in turn as bases for further generalization. The deductive-descriptive method is the more
usual approach, in which a principle, a generalization, or a concept is discussed at the outset, followed by its illustration, rationalization, and demonstration or proof in the laboratory. The purpose of the study was the comparison of these two instructional methods to determine the effect of the method on achievement in areas which are often listed (2, 18, 20) among the objectives of science education. The criteria used in determining the relative effectiveness of the two methods were differences in mean gains from pretest to retest on three measures: (1) a teacher-constructed zoology achievement test, (2) a Test of Science Reasoning and Understanding, Biological Sciences, Form A, and (3) the Watson-Glaser Critical Thinking Appraisal, Form A. A questionnaire seeking student evaluation of the course was employed as a basis for comparing the apparent effects upon student reactions of the two methods under study.

A secondary problem was also investigated. Since the experiment was carried through two semesters in order to obtain a population of significant size, and since those in the second semester had the opportunity for increased maturity as well as increased college experience, including a course in botany, an effort was made to determine what effect such factors had on student achievement as indicated by the several criterion measures mentioned above.
Hypotheses

In order to compare the relative effectiveness of the inductive-deductive and the deductive-descriptive approaches, the following hypotheses were tested:

1. There will be no significant difference in mean gains in achievement in general zoology as measured by a teacher-constructed end-of-the-term test between a group of students instructed with an inductive-deductive method and a group of students instructed with a deductive-descriptive method.

2. The inductive-deductive method in general zoology will be significantly more effective than the deductive-descriptive method in increasing mean gains in science reasoning and understanding as measured by A Test of Science Reasoning and Understanding, Biological Sciences, Form A.

3. The inductive-deductive method in general zoology will be significantly more effective than the deductive-descriptive method in increasing mean gains in critical thinking as measured by the Watson-Glaser Critical Thinking Appraisal, Form YM.

4. Students taking general zoology during the second semester, and consequently with increased college experience, will have a significantly higher mean gain on the end-of-the-term achievement test than those taking the course during the first semester.
5. Students taking general zoology the second semester will not have a significantly different mean gain on A Test of Science Reasoning and Understanding and the Watson-Glaser Critical Thinking Appraisal from those taking the course during the first semester.

6. The semester in which general zoology is taught will not affect significantly the relative effectiveness of the two methods with regard to any of the criterion measures.

Background and Significance of the Study

Hurd and Rowe (17) made the point that there can be no basis for evaluation of methods of instruction until the objectives are made explicit. As applied to zoology the objectives of science education most often emphasized are (a) the development and retention of knowledge and understanding of facts, principles, and concepts of zoology, and (b) the appreciation and understanding of the methods of science employed in solving problems, arriving at inferences and conclusions warranted by a set of data, and (c) the acquisition of scientific attitudes (1, 5, 7). Blanc (4) in his "Review of General Goals in Science Teaching" also noted a synthesis in objectives. But if there is general agreement on the objectives of science instruction, there is a definite lack of agreement on how to accomplish these goals. There is little experimental evidence to justify a preference for one
method over another. Apparently much thought has gone into formulating objectives, but Smith and Anderson in the Encyclopedia of Educational Research (19, p. 1220) reported that very little effort has been made to relate these defined objectives to actual classroom practice.

Several other authorities attest to this gap between objectives and practice. Aylesworth (3) compared the expressed attitude of high school teachers with actual classroom methodology and concluded that science teachers had been taught the importance of science as process but either did not truly understand the desirability of teaching the process directly or else had not learned the technique of teaching the method directly. According to Bullington (6) the subject-matter survey was the most common type of teaching approach used in general education science courses. This was true despite the fact that as long ago as 1945, the Harvard Committee on Objectives of General Education, in discussing the characteristics of courses in biological science and physics, did not conceive either course as a factual survey but stated rather that the purpose should be to communicate by discussion and example the methods by which scientific knowledge has advanced in the past four hundred years and should illustrate the combination of logical analysis, careful observation and experimentation, and imaginative insight, which has characterized the great scientific advances of the past (15, p. 1227).
Hurd (16), in a talk which he has presented at more than thirty science teacher conferences throughout the United States and Canada, reviewed the scientific events of the past few decades which have resulted in today's "explosion in knowledge" and opined that the problem of increasing knowledge could not be solved through the "coverage" of subject matter. He felt that the essentials could be grasped by a student only when he comprehended a framework of principles to which facts could be related and their cause-effect relations examined. The main emphasis must be upon methods of getting knowledge and its reorganization into comprehensive frameworks rather than upon hoarding stores of static information. Whether such principles can best be acquired by means of an organized presentation by the professor or by the investigative efforts of the student is one of the subjects of inquiry in this study.

Though statements of educational objectives in science invariably show a concern for cultivating the ability to think, there is little evidence in practice of a consistent effort toward this end. Dressel (10) pointed out several reasons for this state of affairs. For one thing, thinking is an intangible operation which is not well understood; also the means for provoking and cultivating thinking are not entirely clear. The seeming necessity for "covering" large masses of material leaves little time to reflect on meaning, interrelationships, and applicability of knowledge. There is a
tendency to associate an emphasis on the importance of thinking with a de-emphasis on the importance of knowledge. Many share the impression that such a goal can be achieved only at the expense of achievement in factual knowledge and that it would therefore be better to concentrate on adding to the store of knowledge in introductory courses and at some later date concentrate on thinking. Dressel (10) concluded that the delusion that thinking is triggered by an accumulation of facts is still very prevalent.

There seems to be a very definite need for structuring the type of course which will foster gains in critical thinking without sacrificing gains in knowledge. To test whether a course in which students are provided with the opportunity to analyze, to organize, to discover relationships within the subject largely on their own, and to practice skills in the processes and methods of science can improve their ability to think critically is the other chief subject for investigation in this study.

Definition of Terms

Deductive-descriptive method.—The Dictionary of Education (11, p. 158) defines the deductive method as a method of teaching which proceeds from rules or generalizations to examples and subsequently to conclusions or to the applications of generalization. Much material of a descriptive
nature is used to illustrate the general principles. A more detailed description of this method as used in this experiment is presented in Chapter IV of this report.

Inductive-deductive method.—The inductive method is defined (11, p. 285) as a method of teaching based on the presentation to the learner of a sufficient number of specific examples to enable him to arrive at a definite rule, principle, or fact. It proceeds from the particular case or cases at hand or from known data to a generalization, such as a theory or hypothesis that will explain the evidence at hand. In the inductive-deductive method such derived theories or principles are then used as bases for making wider applications to related problems. This method is also described in greater detail in Chapter IV.

Critical thinking.—The Dictionary of Education (11, p. 570) defines critical thinking as thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions as objectively as possible through the consideration of all pertinent factors and the use of valid procedures from logic. Watson's and Glaser's (22) concept of critical thinking included the comprehension and use of language for accurate and discriminating communication of thought, recognition of the existence (or nonexistence) of logical relationships between propositions, interpretation of data leading to warranted conclusions and generalizations, appraisal of the adequacy and weight of alleged
evidence, recognition of unstated assumptions and evaluation of arguments, discerning observation, and insightful interpretation of cues.

**Science reasoning and understanding.**—As defined in the manual accompanying *A Test of Science Reasoning and Understanding*, this factor can be measured by the extent to which students can

1. apply science knowledge to new problems and situations,
2. read and evaluate news articles and popular writings on scientific developments,
3. understand the point of view with which a scientist approaches his problems, and the kind of things he does (8, p. 4).

These three objectives were in turn translated into descriptions of specific abilities on the part of students to:

1. recognize and state problems;
2. select, evaluate, and apply information in relation to problems;
3. recognize, state, and test hypotheses;
4. recognize and evaluate conclusions, assumptions, and generalizations;
5. recognize and formulate attitudes, and take action after critical consideration (8, p. 5).

**Majors.**—Reference to majors is to students who were taking either a major or minor in some field of science. Non-majors, as used in this paper, are students who were taking the zoology course only to meet the science requirement for graduation rather than as a prerequisite for more advanced science courses.
Organization of Remainder of the Study

Chapter II traces the historical background of the problem, with specific attention given to the lecture-laboratory controversy. The small amount of experimental research on teaching methods for biology at the college level is examined, and those few studies which have been related to teaching methods in science are noted, particular emphasis being given to those concerned with the inductive-deductive method or with a problem-solving approach.

An attempt has been made to examine the relevance of educational psychology to science teaching. Scientific thinking and the teaching and learning of science are discussed in the light of pertinent psychological theory and previous research findings.

In Chapter III the research procedures followed in the development of a two-factor (method by semester) design having repeated measures on each of three criteria are reported. The teaching situation, research population, and the teaching methods are delineated; the criterion measures are described; basic assumptions are reviewed; limitations of the study are discussed; and the procedure for the analysis of data is outlined.

A detailed description of the teaching procedures used with the inductive-deductive method and the deductive-descriptive method is given in Chapter IV. The general
organization of the course is indicated, as well as typical unit plans for the two methods. The various types of student experiences used are described in some detail in this chapter.

Chapter V reports the results of the experiment together with an indication of the level of statistical significance for every finding that involves a comparison between groups or a relationship between variables. Where possible, the data are recorded in table form. A discussion of the implications derivable from the data is included with the presentation of the data.

A summary of the study, conclusions, and recommendations for additional research are presented in Chapter VI.
CHAPTER BIBLIOGRAPHY


CHAPTER II

SURVEY OF THE LITERATURE

Historical Background of the Problem

The dearth of experimental investigation of methods of science teaching is particularly apparent at the college level and especially so in the biological sciences. Those studies which are available have concerned themselves with the relative effectiveness of the lecture-demonstration and the laboratory phase of science work, have applied the inductive-deductive method only to the laboratory, or have compared the lecture approach with a problem-solving approach. Almost nothing has been done in the area of the organizational pattern of biology courses.

Most of the earlier studies were involved with the lecture versus laboratory controversy. However, Smith and Anderson (17) stated that most of the research which has been done in this area contained serious flaws in experimental design or analytical treatment. Cunningham (4), in reviewing thirty-seven investigations relative to lecture versus laboratory methods, reported that many of the studies were now outdated and that modern experimental design and statistical techniques could be employed to provide more
satisfactory insight into all aspects of the problem. This lack of definitive research is probably due, as Watson (20) suggested, to the orientation of those few individuals who might be expected to carry it out. Their commitment to natural science and its teaching leaves little time to become competent in aspects of behavioral science research needed to study teaching methods and their consequences.

Krauskopf (11), in surveying the progress of science in general education over the last half century, concluded that there is general agreement that the laboratory is very desirable but that it is not universally considered indispensable. The advantage of laboratory work most often pointed out is that it enables the student to understand the scientific method and make it a part of his intellectual equipment.

Kruglak (12) cited laboratory work as one of the most important of the many intellectual and practical activities of the scientist. He felt that without the continuous interaction of experimental facts and theoretical ideas, modern science would soon lapse into a sterile discipline. The student who struggles with an experimental problem, no matter how elementary, is caused to experience what every scientist goes through in his work.

However, there are many critics of the laboratory as it is practiced today. Kruglak (12) cited as typical shortcomings
the cookbook directions, tedious verification of already known facts, and the lack of integration with other parts of the course. Students often complain that the lecture and laboratory are so poorly correlated that it is like taking two different courses. Kahn (10) also pointed out the inadequacy of the laboratory, judged by its comparatively poor results in imparting essential knowledge, and some of its misuses, such as the prevalence of copying and duplications and the "fixing" of laboratory work in order to fit the requirements of the guide.

Research With Reference to Methods

The inductive-deductive approach in laboratory instruction has been introduced in an attempt to use the laboratory more effectively. Two excellent studies of this problem are those of Boeck (3) and Lahti (13). Boeck worked with high school chemistry students in the University of Minnesota High School, whereas Lahti's experiment was conducted with college students in the physical science laboratory at the University of Minnesota. The primary concern of Boeck's study was to compare the learning of students instructed with a deductive-descriptive approach as it was reflected in their knowledge of, and ability to use, the scientific method and its accompanying scientific attitudes. His findings showed a significant difference in favor of the inductive-deductive
group in mean achievement in both the knowledge and application of principles and the scientific method and attitude. As a result of the experiment the method is now in use in Minnesota University High School.

Lahti (13) explored the effect of various approaches in the physical science laboratory. Among these were the individual or small group efforts by an inductive-deductive or problem-solving approach. Though he found no statistically significant differences, this approach scored higher than the case history, theme, or standard—get-the-right-answer—approaches on performance tests and tests for interpretation of data and for designing an experiment. He suggested that similar studies should be made with other criteria of accomplishment.

No studies were found in which the inductive-deductive approach was used in the complete course. Barnard (1) compared the lecture-demonstration method with the problem-solving method in the biology portion of an orientation science course and Dawson (5) compared the lecture method with a problem-solving approach in a college course in elementary soil science. Both attempted to find which method achieved more effective learning as measured by achievement in specific information, ability to make generalizations, ability in problem solving, and scientific attitudes. Though neither reported any statistically significant differences,
the lecture was found to have some advantage in the acquisition of specific information and the problem-solving method in developing scientific attitude. Neither method appeared to have a significant advantage in forming generalizations.

That the traditional lecture-laboratory is by far the most common type of organization in introductory college biology courses is confirmed by a survey of 131 courses in fifty colleges completed by Solinger (19) in 1959. He found a discussion approach used in only nine classes and what he called a discovery-discussion method in only four classes. His description of the latter method as one involving a communal investigation of problems and materials by both teacher and students indicates a similarity to the inductive-deductive method. He also described it as an extremely arduous type of instruction but one which generated much enthusiasm among those using it. In most cases these courses were given in five one-hour class periods per week.

The integrated type of organization which was used in the inductive-deductive method in this study is not often found in the introductory course in college biology. This may be due to the fact that these classes often have a large enrollment and that the large lecture section is much more economical in terms of the instructor's time and effort. Van Deventer, Kruglak, and Berry (19) reported that the biological
science course in the general education program at Western Michigan College was organized as a combined lecture and laboratory. The classes met six clock hours per week in either three two-hour periods or two three-hour periods. The time was used for lecture, laboratory, demonstrations, or field work as was considered desirable, but the units were built around a core of laboratory work. A perusal of the following reviews revealed no studies evaluating this type of organization: Review of Educational Research, June, 1964; Handbook of Research on Teaching, edited by Gage; and the Encyclopedia of Educational Research, edited by Harris.

The early controversy over the relative merits of the lecture-demonstration and laboratory appears to have been resolved, at least to the extent that most science courses are now offered as a lecture series, with supposedly complementary laboratories. The shortcomings of the lecture method, however, as demonstrated by Barnard (1) and Dawson (5), and the failure of the laboratory, as presently conducted, pointed out by Kruglak (12) and Kahn (10), suggest the need for experimentation to find an improved approach to the teaching of science. The success of the inductive-deductive approach in accomplishing the objectives of science education in the laboratory, as reported by Boeck (3) and Lahti (13), suggests that this might be a fruitful direction for further experimentation and study.
Research Referring to Student Maturity

Lehmann (14) found some evidence that the majority of college students tend through their college years to become more rational, objective, and scientific in their thinking, to become less stereotypic in their beliefs, to become more flexible and open to new ideas, and to change their ideas as to what they consider important in life. He found that changes of this type were of greater magnitude during the freshman and sophomore years. He also found that students who were flexible, adaptive, and receptive to new ideas achieved higher grades in comprehensive exams than did students who were rigid, authoritarian, and set in their beliefs. If those changes are taking place, and if the examinations are of the type that would take advantage of those changes, it would seem reasonable that classes made up mostly of freshmen and sophomores would make better scores on their examinations in a science course in the spring than in the fall. If, in addition to maturation in this direction, the factor of experience in a related science course is present, there should be a significant difference in student performance on an examination related to general achievement in zoology.

Basic Psychological Considerations

During the last half of the nineteenth century the reason most often given for including science in the curriculum
was its disciplinary value. After research by Thorndike (9) disproved the faculty concept, more emphasis was placed on motivation, interest, attitudes, and individual needs. The twentieth century has seen the development of a large number of learning theories but little evidence, as Estes remarked, of a "harmonious and fruitful interplay" between education and the psychology of learning (7, p. 752).

Estes (7) in pointing out this lack of a fruitful interplay between the educator and the psychology of learning, likened the relationship between the two to that of physiology to medicine rather than that of medicine to the patient. At present there are no rational grounds for expecting direct transfer of laboratory findings or direct application of basic psychological theories to problems of the school room. He further stated that the only realistic contribution which can be expected is (a) a better understanding of school learning and (b) guidance in the planning and conduct of research.

It seems self evident that the fundamental basis for classroom procedure should be a knowledge of how individuals learn. But educators are far from agreement as to what constitutes the learning process (9). While there is considerable unanimity in recognizing that learning is essentially change due to experience, many different points of view have arisen regarding those aspects of learning which have the greatest theoretical and practical importance for the educator. The
teacher needs to know how and why changes in behavior occur in order to determine how to bring about these changes. The problems of the schools may be solved in accordance with psychological generalizations, but they will have to be tested in the school room. This emphasis upon practical procedures does not subordinate the role of psychology in education, for no educational philosophy is likely to be acceptable if it flies in the face of established psychological facts and principles.

However, Peel (16) called attention to the limited extent to which modern psychological theory has influenced instruction in science. He also noted that surprisingly little research on science teaching has been explicitly designed to test educational practice against psychological theory and experimental result.

Psychological theory offers two basic explanations of learning: the conditioning and the cognitive, both of which may have significance for the teacher of science. The larger portion of psychological research and theorizing on the topic of learning, at least in America, has been concerned with the matter of the acquisition of fixed meaning and a certain amount of this type of learning is necessary. On the other hand, much of the educational literature has dealt with the development of understanding and attitudes with no experimental background to back it up. It remained for the cognitive
theorists to provide the experimental background and theoretical interpretation for understanding, insight, and thinking (9).

However, despite their deficiencies in providing a useful vehicle for the obtaining of the higher objectives of comprehension, understanding, and critical thinking, conditioning theories do provide some useful implications for the school room. The importance of anticipatory adjustment is enormous because it provides the habitual foundation of all subsequent voluntary behavior. It defines the character of the active desires which set the goal toward which the organism strives in trial and error learning. It determines the mind-set and the readiness of the organism. Conditioned responses occur in the classroom whether or not they are deliberately and methodically induced and controlled. By becoming aware of their operation a teacher can use them to get the desired outcomes and to prevent undesirable conditioning.

Though a few behaviorists have attempted to explain the understanding, thinking, and problem solving processes within a S-R framework, most of the work in this area has been done by the cognitive theorists. Harlow (8) pointed out that the complex behavior of humans is to be understood in terms of the changes which are affected through multiple, though comparable, learning problems. He feels that the most
important learning is the formation of learning sets. This learning how to learn efficiently, in situations frequently encountered, changed monkeys who made their choices on discrimination problems in a trial and error fashion into creatures who adapted by carefully formed hypotheses and insight. Their hypotheses were the result of second order habits of observing and testing consequences, and they arose because these are the common features of behavior reinforced in a number of lower order habits. The emphasis was on the role of the experience variable. Harlow (6) has not found evidence of such phenomena outside of a gradual learning history. He reported that one-trial learning appeared only as the end result of orderly and progressive learning processes and felt that insight was to be understood only in terms of its historical perspective.

Birch (2) also highlighted the importance of previous experience to the development of insightful problem solving. He stated that insight depended on a background of simple instrumental habits and the probability of solution by insight was quite low if his animals had not learned these.

The gestalt view assumes an active learner busily giving meaning to all his experiences. He organizes the experiences to give as "good" a meaning as the conditions allow. So the pupil, when presented a problem, offers as good an explanation as his organization and restructuring
of his past experience will allow. The teacher's role is to improve upon this "insight" by discussion and questioning, incorporating similar experiences into the student's field.

Maier's (15) research into human reasoning led him to the conclusion that the way in which a problem is attacked depends upon the way in which it is seen. Even when the necessary experience was provided, obvious solutions were often missed because the problem was interpreted and attacked in a habitual way. He stressed the importance of "direction" in problem solution and showed that successful reasoning required that new "direction" be found when necessary. Direction is the way in which a problem is attacked, and it depends on the way the difficulty is seen. Only when past experience fits the "direction" will it aid in the solution of the problem. Otherwise, experiences called up by association will not help unless they can be restructured to fit the direction which has been taken.

The idea of productive thinking in humans is most often associated with the name Wertheimer (21). He stressed the processes of thinking and the nature of the operations essential to thinking, such as grouping, centering, and or reorganization. In keeping with the general gestalt theory, he believed that solutions arise not from blind recall of past experience or blind trial and error, but rather from the perceptual requirements of the problem. Understanding of the
structure of the problem, thinking out the gaps in the situation, the desire to get at the inner relatedness are much to be preferred to making associations blind to their specific function in the process, recall of previous knowledge, or rote learning of steps or formulas for solution of a problem.

There are many educational implications from Wertheimer's work. His thesis was that one cannot expect forceful, productive thinking in problem situations from people who are trained by blind rote methods. However, he did not specify how people can be taught to think. Some practical suggestions for teaching can be drawn from his ideas. The gestalt theory of "insight," "structure," and "active organization" is peculiarly appropriate for science teaching since it is essentially the way by which science has developed. The teacher's task is to start from the experience and concepts of the pupil and direct them appropriately to give them new meaning—actively widening the pupil's experience.

As previously noted, Maier (15) saw learning as the result of the learner's achieving a clearer, more realistic perception of the situation with which he is dealing. Duncker (6) agreed with this concept and outlined the following steps by which he thought that problem solving took place.

1. The learner becomes aware of a problem, obstacle, or objective.
2. The existence of the problem makes it necessary for him to perceive the situation.

3. He tries to solve the problem in terms of his perception of the situation.

4. This act has consequences. If the result achieves the goal or satisfies the need, there is closure and the process is complete.

5. If the result does not solve the problem to the learner's satisfaction, a reinterpretation of the situation takes place.

6. The second attack is appropriate as the learner now perceives the situation in his new interpretation.

7. The consequent result either brings the search to an end or leads to a new organization and reinterpretation. The process continues until the learner reaches his goal or perceives another as a more practical means of satisfying his need. Each repetition of the problem gives the pupil an opportunity to gain a clearer and more accurate perception of the situation and provides an opportunity to learn but does not guarantee that learning will take place. The student thus acquires a method of attacking problems which will help him to deal with problems.

Implications for Methodology in Science

The work of Duncker (6) as well as that of other cognitive theorists has a number of implications for the inductive-deductive
method. It indicates an advantage from allowing the correct solution or interpretation of experimental data to emerge organically from earlier attempts. The goals which influence perception are those chosen by the student rather than the teacher because they are appropriate to his own value system and his own concept of his ability. Students are proud of difficult achievement and value the opportunity to test themselves in a wide range of activities and to make original contributions to the solution of problems. Different students with the same goal will interpret the situation differently (since they approach it with different field organizations). Student and teacher can learn from each other. The teacher must not assume that his interpretation is the only one that is possible or useful but must recognize the validity of other ways of solving a problem. Not only do students need the opportunity to investigate and attempt to solve problems that are important to them, but they need a chance to test the validity of their perceptions and to discover their misconceptions. Laboratory experiences should be of significance to the student with results unknown and at least a part of the procedure devised by the student, rather than a stereotyped verification of already known facts. Otherwise verbal material exchanged may be perceived by the student as a means of passing examinations and quite devoid of any other relation to his life and behavior.
Because insight learning is largely a consequence of the student's solving problems, the teacher needs to present the problem as a whole rather than piecemeal or by cookbook-like steps leading to a solution. This helps the pupil to get insight into its essential structure. The teacher must make certain that the student has the necessary store of generalizations with which to approach a given problem. This may call for a larger stock of books, materials, and workspace. The teacher should not solve the problem for the student or supply him with ready answers but should make it possible for him to see the structural relations within the problem and to reach a successful solution. Insightful solutions are usually preceded by a period of exploration of the field. When a student gets "stuck," it may help to reformulate the problem so that he can see it in a new "field." The teacher can facilitate learning by having the relevant cues available and by giving "direction" in problem solving.

The science of learning can provide guidance if one has an understanding of its principles, an understanding of the learning to be managed, and enough ingenuity to make applications. However, one cannot expect an empirical translation from principle to practice. The relationship between psychology and education is more like that of the physical sciences and engineering. The development of the one does
not wait upon the other, but each should play a mutually supportive role. Psychology must organize our knowledge and understanding of the acquisition of attitudes, motives, affective and emotional responses, mental sets, simple and complex discriminative acts, serial verbal and motor acts, motor and perceptual skills, meanings, concepts, abstractions, and various cognitive capabilities that comprise such complex activities as ideational problem solving, thinking, reasoning, and creative inventiveness. Psychology should also point direction to educators in planning research at the level of practical problems. Education must confront psychology with its problems, review critically the advances made, and then design curricula and teaching methods that exploit that knowledge.

The science of learning is relevant to the teaching of science. It has substituted a conception of the whole for the earlier emphasis on parts, placed emphasis on the superiority of gaining insight and understanding over rote learning, focused attention on the importance of maturation and individual capability, and given us the conception of the learner as a purposive, striving personality, rather than a passive learner.

The conclusion seems justified that many, if not most, of the significant contributions of psychology to educational practice do not depend for their validity exclusively on
one or the other of the different schools of learning theory. While it is easier to construct the cognitive patterns most applicable to science teaching in the language of the gestalt psychologist, an educational theory does not flow automatically from gestalt psychology. Many of these practices could also be formulated in the language of the behaviorists and many of the most significant contributions have been made by those who do not identify strictly with either group. All of the theories have stimulated research which has lead to principles useful to the teacher as well as answers to specific problems. In this respect gestalt psychology has perhaps the weakest record. A theory of insight does not tell how to teach for an understanding of genetic principles, but it does provide some guide lines which the teacher can use in verifying the principles which govern his management of the learning process.

Educational practices are obviously modified by developments within psychology. Yet there is danger in giving our allegiance to one particular school of thought. There is more to be said for taking those principles that have stood the test of time and repeated investigation and using them in a creative fashion to design the methodology of the classroom, realizing that the precepts of science must be tested in the classroom at a level close to that at which applications are to be made.
Though psychology in its present stage of development cannot offer a prescription to increase learning in the classroom, a realistic appraisal of learning theory can provide a better understanding of school learning and give some direction to research. Learning theory offers two basic explanations of learning, the conditioning and the cognitive, both of which have implications concerning the hypotheses of this study. Although S-R theory is limited as an explanation of human learning, it can account for transfer of training by means of "stimulus generalization"—and it does point to the need for motivating the learner.

Too, the habit family hierarchy principle allows maximum utilization of past experience in solving present problems. However, most of the work in the area of explaining understanding, thinking and problem solving has been done by the cognitive theorists with their emphasis on insight, structure and active organization. Harlow (8) stressed the importance of "learning sets"—of building hypotheses as a result of second order habits of observing and testing consequences. Birch (2) and Maier (15) recognized the importance of previous experience and perceptual background to both the gradual analysis of problems and the sudden reorganization that characterizes insightful learning. In the gestalt view the learner is active in reorganizing his experiences and giving meaning to those experiences to reach as "good" an interpretation as
the conditions allow, but by widening his perceptual experiences, by questioning, and by discussion, the teacher can give the "direction" which Maier (15) suggests and can assist him in the reorganization thought necessary to productive thinking by Wertheimer (21). Also he can assist the student in attaining new insights by sequences similar to those suggested by Duncker (6). The presence of a problem sets up tensions because the "whole" is incomplete, causing the student to strive toward its completion. By involving the student in this active way the problem of motivation is also solved. The inductive-deductive method built around laboratory experiences with its emphasis on active participation and investigation seems to provide an ideal environment for the application of the view of learning propounded by the cognitive theorists. The deductive-descriptive method lends itself more readily to an illustration of the best in conditioning. Out of the understanding of learning developed by the cognitive theorists and to a lesser extent by the S-R theorists has come the specific design of the two methodologies being tested in this study.
CHAPTER BIBLIOGRAPHY


CHAPTER III
RESEARCH PROCEDURES

Design of the Experiment

The basic design of the experiment was a two factor (method by semester) experiment with matched pairs having repeated measures on each of three criteria. The experiment was conducted in the general zoology classes at Hardin-Simmons University during the school year 1965-66 with all students enrolled in the Monday-Wednesday-Friday class being taught by the inductive-deductive method and all students enrolled in the Tuesday-Thursday class being taught by the deductive-descriptive method. The inductive-deductive class was termed the experimental group and a matched group was picked from the larger deductive-descriptive class to serve as a control. The experiment was carried out in the fall semester and was replicated during the spring semester. Since most of the students in the spring classes had been enrolled in a related course in botany in the fall semester, it was felt that a new variable was being introduced, the effect of which should be investigated.

The Teaching Situation

The general zoology course is designed to be, along with botany, the prerequisite course for all other courses offered
in the biology department at Hardin-Simmons. It attracts mostly those students who intend to major or minor in one of the sciences, as well as majors in physical education, home economics, and speech and hearing therapy, who must have the course as a prerequisite to other courses required in their degree plans. A few upperclassmen from other fields are enrolled to complete their science requirement for graduation. The science requirement in general education is now satisfied for entering freshmen by enrollment in a science bloc tailored to the needs of the non-science major. Such an alternative arrangement tends to encourage the enrollment in general zoology of students who would be expected to have a fairly high level of motivation and interest in the subject. The course covers one semester and carries four semester hours of credit.

Both groups met for a total of five and one-half hours of actual class time per week. The inductive-deductive classes met each semester from eight to nine-fifty on Monday, Wednesday, and Friday in the zoology laboratory. This integration of class time with laboratory was felt to be an inherent part of the method. The deductive-descriptive classes met for lecture in a large classroom on Tuesday and Thursday from eight to nine-fifteen and were divided into two smaller groups for their laboratory sections, which met either on Monday or Wednesday afternoons from two to five o'clock in the zoology laboratory.
Population

All students enrolled in the general zoology classes at Hardin-Simmons were included in the experiment as it was felt that these would be representative of the population who would be taking the course in any given year. However, due to a curriculum change now in progress, there is a likelihood that the class will tend to be made up of a larger proportion of science majors as more of the non-majors are routed into a newly developed science bloc. Total enrollment in the course for 1965-1966 was 124, 52 per cent of whom were boys and 48 per cent girls, with an age range from seventeen to twenty-nine years.

Method of Assignment

Students were assigned to zoology class sections by regular procedures with every third person being assigned to the experimental group insofar as was possible. Scheduling of other classes or of outside work hours sometimes dictated the class to which a student would have to be assigned, but it was possible to keep the classes balanced at something near this ratio. This procedure resulted in almost twice as many students being assigned to the traditional lecture section as to the experimental class. According to the study made by Solinger (12), a large lecture section divided into smaller sections for laboratory is typical of the way zoology
is taught in many institutions. Each of the two laboratory sections formed was of approximately the same size as the experimental section, which met for all of its sessions in the laboratory.

**Procedure in Matching Groups**

The experimental inductive-deductive class was composed of twenty-four students in the fall and twenty students in the spring. For purposes of comparison in testing the hypotheses a matched group was selected from the larger lecture sections on which comparable data were recorded. The groups were matched on the basis of (1) sex, (2) classification, (3) initial science interest as revealed by their ACT natural science scores and by whether they were majoring or minoring in some field of science, (4) academic ability as revealed by the ACT composite score, and (5) the results of the pretests on each of the three criterion measures used in the study. As close a match as possible was made for each member of the experimental classes to make twenty-four matched pairs in the fall and twenty matched pairs in the spring. (See Table XVI, page 133, for extent of differences in matched pairs on the several measures.) The entire experimental class, which had been chosen by random means, was made the basis for matching. Comparative data on sex, classification, and science interest for the inductive-deductive and the deductive-descriptive groups for each semester as well as the total of both semesters
are given in Table I. The symbols I-D for the inductive-deductive group and D-D for the deductive-descriptive group will be used in the tables throughout this report.

**TABLE I**

**COMPARATIVE DATA ON EXTERNAL CHARACTERISTICS OF THE MATCHED GROUPS**

<table>
<thead>
<tr>
<th>External Characteristic</th>
<th>Fall I-D</th>
<th>Spring I-D</th>
<th>Both Semesters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students enrolled</td>
<td>24</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>Students included in data</td>
<td>24</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>Males</td>
<td>14</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Females</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Majors</td>
<td>13</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Non-majors</td>
<td>11</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Freshmen</td>
<td>12</td>
<td>11</td>
<td>21</td>
</tr>
<tr>
<td>Sophomores</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Juniors</td>
<td>5</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Seniors</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

A perfect match was made each semester on the basis of sex and upon the number of majors and non-majors. The proportion of freshmen to upperclassmen was also the same. However, it was not possible to match the groups on the number of outside hours worked as the experimental class hour seemed to attract more students who worked in the afternoon. Total outside work hours per week for the respective groups were as follows:

**Fall I-D group**—147 hours—7 students

**Spring I-D group**—262 hours—9 students
Fall D-D group—53 hours—3 students

Spring D-D group—107 hours—5 students

More students worked longer hours in the inductive-deductive groups than in the deductive-descriptive groups and in the spring semester as contrasted with the fall semester. Although Lahti (8) found some evidence that work schedules and the time of day that students prefer a laboratory did not significantly alter their mean scores on his tests, it seems possible that such a factor could have militated against the experimental group and against the spring semester.

Differences between fall and spring groups varied by chance election of students as there was no requirement which dictated whether they should take botany or zoology first. Reference to Table I shows that there was a difference of four in the number enrolled and a difference of eight in the number of majors between semesters. The reason there were more students taking zoology in the fall was that only one lecture section was scheduled in botany, and that was closed after fifty students had registered, causing all of the students who registered in the last few alphabetical groups to be routed into the zoology classes. It was due to chance that more of these happened to be science majors.

The mean scores for each of the other criteria which were used as bases for matching are given in Table II.
<table>
<thead>
<tr>
<th>Criterion Measure by Group</th>
<th>Fall Mean</th>
<th>S. D.</th>
<th>Spring Mean</th>
<th>S. D.</th>
<th>Combined Group Mean</th>
<th>S. D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT Natural Science Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive-Deductive group</td>
<td>21.33</td>
<td>5.34</td>
<td>20.05</td>
<td>3.97</td>
<td>20.75</td>
<td>4.91</td>
</tr>
<tr>
<td>Deductive-Descriptive group</td>
<td>22.21</td>
<td>5.27</td>
<td>19.80</td>
<td>5.26</td>
<td>21.11</td>
<td>5.40</td>
</tr>
<tr>
<td>ACT Composite Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive-Deductive group</td>
<td>20.54</td>
<td>4.15</td>
<td>19.55</td>
<td>3.28</td>
<td>20.09</td>
<td>3.81</td>
</tr>
<tr>
<td>Deductive-Descriptive group</td>
<td>20.63</td>
<td>4.74</td>
<td>19.60</td>
<td>4.19</td>
<td>20.16</td>
<td>4.53</td>
</tr>
<tr>
<td>Zoology Achievement Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive-Deductive group</td>
<td>62.00</td>
<td>15.30</td>
<td>56.50</td>
<td>14.07</td>
<td>59.50</td>
<td>15.00</td>
</tr>
<tr>
<td>Deductive-Descriptive group</td>
<td>61.00</td>
<td>17.65</td>
<td>55.60</td>
<td>11.35</td>
<td>59.18</td>
<td>15.43</td>
</tr>
<tr>
<td>A. C. E. Test of Science Reasoning and Understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive-Deductive group</td>
<td>28.29</td>
<td>5.53</td>
<td>29.80</td>
<td>5.28</td>
<td>28.98</td>
<td>5.47</td>
</tr>
<tr>
<td>Deductive-Descriptive group</td>
<td>27.13</td>
<td>4.72</td>
<td>29.45</td>
<td>6.73</td>
<td>28.18</td>
<td>5.84</td>
</tr>
<tr>
<td>Watson-Glaser Critical Thinking Appraisal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inductive-Deductive group</td>
<td>71.79</td>
<td>7.90</td>
<td>71.50</td>
<td>8.36</td>
<td>71.65</td>
<td>8.11</td>
</tr>
<tr>
<td>Deductive-Descriptive group</td>
<td>68.88</td>
<td>7.98</td>
<td>71.50</td>
<td>10.12</td>
<td>70.07</td>
<td>9.11</td>
</tr>
</tbody>
</table>
The means of both groups for the ACT scores were slightly higher for the fall as compared to the spring, while the means on the A. C. T. Test of Science Reasoning and Understanding and the Watson-Glaser Critical Thinking Appraisal were slightly higher in the spring than in the fall groups.

There was a mean difference of five to six points on the zoology achievement test, with the fall group scoring higher. This was somewhat surprising in view of the fact that most of the spring group had just completed a course in botany.

The results of the $t$ test of the significance of the difference between both the matched groups and the groups from each semester are reported in Table III. The fall experimental group is referred to as $E_f$, the spring as $E_s$, the fall control group as $C_f$, and the spring as $C_s$.

**TABLE III**

<table>
<thead>
<tr>
<th>Between Groups</th>
<th>ACT Natural Science</th>
<th>ACT Composite</th>
<th>Zoology Pretest</th>
<th>Test of Science Reasoning</th>
<th>Watson-Glaser CTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_f$ and $C_f$</td>
<td>-.560</td>
<td>-.063</td>
<td>.000</td>
<td>.769</td>
<td>1.246</td>
</tr>
<tr>
<td>$E_s$ and $C_s$</td>
<td>.165</td>
<td>-.041</td>
<td>.169</td>
<td>.178</td>
<td>.000</td>
</tr>
<tr>
<td>$E_f$ and $E_s$</td>
<td>-.330</td>
<td>-.076</td>
<td>.097</td>
<td>.652</td>
<td>.855</td>
</tr>
<tr>
<td>$E_s$ and $C_s$</td>
<td>.869</td>
<td>.864</td>
<td>1.207</td>
<td>-.898</td>
<td>.116</td>
</tr>
<tr>
<td>$C_f$ and $C_s$</td>
<td>1.476</td>
<td>.735</td>
<td>1.323</td>
<td>-1.312</td>
<td>.940</td>
</tr>
<tr>
<td>$E_f$ and $C_f$</td>
<td>1.694</td>
<td>1.121</td>
<td>1.808</td>
<td>-1.583</td>
<td>.623</td>
</tr>
<tr>
<td>$E_s$ and $C_s$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As might be expected, there was a larger difference between groups for each semester, which were not matched, than between the matched groups which were taught by different methods. In no case, however, did the difference reach the .05 level of significance which was chosen during the design of the experiment as the significance level to be used in comparing groups. The largest $t$ found here was the difference between the fall and spring classes on the zoology pretest, and a difference this large could be expected to occur 7 per cent of the time due to sampling error. The null hypothesis that there was no significant difference in the groups was therefore accepted at better than the 5 per cent level of confidence.

Criterion Measures

Each group was given pretests and retests on each of three criterion measures, which were considered to be the dependent variables. Independent variables were the teaching approaches and the times of year at which the classes were offered. Controlled variables were the physical facilities, the length of instruction, the teacher, and the principles emphasized. The three criterion measures used were (1) a teacher-constructed zoology achievement test, (2) the Watson-Glaser Critical Thinking Appraisal, Form YM (15), and (3) A Test of Science Reasoning and Understanding (3).
The instrument used to measure knowledge and understanding of zoological facts and principles was a teacher-constructed zoology achievement test which was developed during a pilot study a full year previous to the beginning of the experiment. The examination contained 135 items of both a matching form and a best answer variety of the multiple choice form. This test had a split half reliability coefficient of .86 when adjusted with the Spearman-Brown formula. A copy of the test is included in the Appendix, page 136. Support for use of this type of locally constructed test was suggested by Travers (13), who indicated his belief that standardized tests for the measurement of knowledge have limited value and that it should be left to the teacher to measure this outcome.

The instrument used in measuring ability in critical thinking was the Watson-Glaser Critical Thinking Appraisal (15). Form YM of this test was used for both pretest and retest as reliability data given in the manual (14) indicate that the total score has adequate statistical reliability for use with groups when one form is used. Practice effects have proven relatively slight. Hovland, in his review of the test in The Fifth Mental Measurements Yearbook, stated that the test is a "conscientious, imaginative effort to provide appraisal in a most difficult area" (6, p. 700). He called it a very promising test for use on an experimental
basis in research on the effects of instructional procedures on critical thinking. He concluded that it is not possible to have as precise a test in this area as in mental and scholastic ability, but that it is nevertheless a good test for comparing the effects of teaching methods on ability in scientific reasoning.

The Watson-Glaser Critical Thinking Appraisal contains 100 items divided into five sub-tests as follows: (a) inference (twenty items), (b) recognition of assumptions (sixteen items), (c) deduction (twenty-five items), (d) interpretation (twenty-four items), and (e) evaluation of arguments (fifteen items). These are clearly related to most definitions of critical thinking and are therefore considered pertinent to one objective of this study. The keyed answers represent the unanimous judgment of a jury of thirty-five people selected because they were trained in logic and the scientific method. To assess the validity of the test several high school teachers were asked to identify students in their classes who appeared markedly able or markedly poor in ability to reason accurately and to think logically. The test distinguished significantly between these two groups. Coefficients of from .33 to .52 for four different classes are reported between teacher ratings and total scores on the test. Hovland (6) stated that the test is not sufficiently standardized to permit the use of scores on it in any absolute
way for determining adequacy of testees' skill in critical thinking, but that it was very promising for use on an experimental basis for research on effects of instructional procedure on critical thinking.

The other instrument for measuring thinking skill was *A Test of Science Reasoning and Understanding, Biological Sciences, Form A*. This test was published by the American Council on Education as an outgrowth of the Cooperative Study of Evaluation in General Education following the Eight Year Study. This test was chosen because it measures thinking skill in relation to content area in contrast to the Watson-Glaser Critical Thinking Appraisal, which is not related to a specific content area.

According to the instructor's manual (2) the test was designed to measure the extent to which students can apply science knowledge to new problems and situations, read and evaluate articles on scientific developments, and understand the scientific attitude.

In addition to data furnished through the three criterion measures described above, students were asked to respond to an inquiry regarding their own role in, and perception of, the course, along the lines suggested by Dressel (4). They were asked what they saw as the most characteristic feature of the course; what they perceived to be the goals of the class; what they perceived to be the relationship between the
course experiences which were provided and the goals which they saw in the course; what habits of study they used in preparation; what tangible effect the course had on them; and what specific suggestions they would make for the improvement of the course. A copy of the instrument used to elicit these responses is appended on page 131.

Records of several types were kept and were used in writing the descriptions of the experimental methods in Chapter IV. An outline of the lectures and of the laboratory assignments was kept for the deductive-descriptive classes. Unit plans and instructions for laboratory investigations together with a daily evaluation of what was done were recorded for the inductive-deductive approach. Evaluation instruments used as an inherent part of the teaching method were kept for both groups.

Teaching Methods

The deductive-descriptive method used was that prevalent in many college zoology classes in which the lecture periods are used by the instructor to give an organized statement of principles and an explanation of data supporting those principles. The direction of attention is from the general to the specific, with emphasis upon the students' acquisition of factual information. The laboratory period is used to describe principles, to illustrate applications of the general principles already
discussed, to permit the observation of phenomena, and to verify known relationships. Laboratory exercises used in this study were those developed by Wodehouse (18), a well-illustrated college laboratory manual which stresses recognition and identification of structures in the morphology of the various phyla. Evaluation resulted primarily from objective tests covering the material studied and laboratory tests of the students' ability to identify slides and structures in the animals studied. The method involved the use of the same text, the same laboratory facilities, the same length of instruction, and it emphasized the same principles as did the inductive-deductive method described below. The general plan for organization of the course is outlined in the Appendix, page 123. A unit typical of the deductive-descriptive method also is outlined in the Appendix, page 124.

The inductive-deductive method as conceived in this investigation emphasized student investigation and inquiry as a means of acquiring an understanding of zoological principles. The method was built around a laboratory core of a selected group of problems in biology which represent opportunities for the development of general principles. Such principles were then used as bases for making wider applications. The laboratory was used to obtain data for use in the formulation and testing of hypotheses directed
toward the solution of the problems. Generalizations drawn from solution of the problems were applied to related problems. The order of study was from the particular to the general, making use of careful observation, classification of data, hypothesis formation, experimentation, and generalization. Students were taught to recognize assumptions and the limitations of their data, to seek additional sources, and to value experimental controls and careful record keeping. The units were built around the laboratory experience, reaching after fundamental ideas. Facts were used as tools to get at ideas rather than as ends in themselves. Students were provided with study guides and bibliographies so that they could acquire most of the required information by reading, thereby freeing more class time for cooperative group analytical activities. The emphasis of the course was upon the method of acquiring answers to significant questions and the process of arriving at conclusions. Evaluation was conducted through structured unit reports and tests which stressed understanding of relationships and principles rather than memorization of facts.

A typical unit is described in Chapter IV, with illustrative examples given for the various types of experiences planned. Since no zoology laboratory manual was available which used this approach, it was necessary for the experimenter to make plans for laboratory investigations. These were
duplicated and handed to the students at the period before the study was to be undertaken. Two examples of the laboratory plans used are appended on pages 129-130. This material was selected and adapted from various laboratory manuals such as Laboratory Guide for Biological Principles, by A. M. Winchester (16), Investigations Into Biology, by Robert W. Korn and Ellen J. Korn (7), and the B. S. C. S. Yellow Version Laboratory Guide (1). The chief adaptation used was the elimination of some of the descriptive material which could be determined by the student's own observation when directed by means of pertinent questions.

Basic Assumptions

All classes were taught by the experimenter. Having the same teacher for all classes is assumed to eliminate what Landsman has called "the most prevalent pitfall in methods studies" (9, p. 16). When different teachers are assigned to different methods, the possibility of separating the effects of the teacher from the effects of the method is diminished.

Since the experimenter was aware of the bias which could result from greater teacher interest in one method over another, the same careful preparation and effort was made to teach each course in a manner consistent with the objectives and procedures inherent in that approach. It is necessary to assume, however, that the experience of the two groups was consistent
with the characteristics described under the definition of the two approaches and with those objectives and procedures described in the chapter on the experimental method, and that any difference in teacher effect between the two approaches did not influence significantly the findings of the study.

The size of the lecture groups was almost twice the size of the experimental group, though the laboratories were of similar size. Since this is typical of the traditional method of teaching, the size of the lecture group is assumed not to be significant in determining the effect of the deductive-descriptive method of teaching for the control group.

In selecting a matched group from the larger lecture class for comparison with the experimental group an attempt was made to equate such factors as the students' ages, sex, classification, and vocational interests insofar as was possible. Such other differences as could not be equated are assumed to vary by chance among the groups and to have no significant effect on the results.

As far as possible students were assigned to the various sections by random means with two students being assigned to the lecture session for every one assigned to the experimental group. However, schedule conflicts often made such an assignment impossible. It is assumed that such conflicts varied by chance among the sections and did not significantly affect
the results of the experiment. One factor which may have militated against the experimental group, however, was that students who had longer outside work hours were attracted to this schedule.

**Limitations of the Study**

It is not assumed that these methods would have the same result if the experiment were to be conducted by another teacher. McKeachie (10) has pointed out that the effectiveness of a method depends on the competence and enthusiasm of the teacher, that the teacher's enjoyment of a method is a critical variable. Hartman maintained that "there is strong reason to believe that a 'poor' method (psychological and statistical grounds) in the hands of a 'good' instructor is a better teaching risk than a demonstrated 'good' method employed by a 'poor' instructor" (5, p. 268). Ray (11), who studied pupil discovery and direct instruction methods, concluded that teaching skills will largely determine which method should be used. Therefore, the findings of this study, while providing some evidence of the relative effectiveness of the two methods tested when taught by a particular teacher, cannot be expected to be applicable in the hands of a teacher who does not have the interest or the teaching skill to work with either of these methods.
Procedure for Analysis of Data

The plan of this experimental design, which was a two-factor design with matched pairs, permitted the use of the Lindquist Type I analysis of variance as the basic statistical technique. Winer (17) listed as an advantage of the factorial experiment that it allows the experimenter to make an evaluation of the combined effect of two or more experimental variables used simultaneously, as well as of the interactive effects. In this experiment the two variables compared were the teaching method and the semester in which the course was given. It was planned to use a t-test for the significance of the difference between groups if any interaction was found. A significance level of 5 per cent was selected at the time of the design of the experiment for determining the acceptance or rejection of the several null hypotheses under examination.

A compilation of student answers on the evaluation sheets was made for both groups. These were used both as evidence of the more intangible gains not measurable by the three criterion measures and as an aid in interpretation of the results.


CHAPTER IV

THE TEACHING METHODS

The purpose of this chapter is to bring structure and definition into what might otherwise remain vaguely defined methods. A general description of the rationale of both the inductive-deductive and the deductive-descriptive methods was presented in Chapter III. What is proposed here is a description of the specific way in which these methods were developed in the general zoology classes used in the experiment.

Objectives

Basic to any course is the selection of meaningful objectives which will give direction in the selection of the methods and materials of the course. The following statements were set down as the broad objectives of the course.

1. Knowledge: a substantial foundation of concept and principles which can be integrated into an understanding of modern zoology.

2. Skills.
   a. Ability to think critically.
   b. New ways of approaching problems.
3. Appreciations.
   a. Appreciation of the role of science in daily life.
   b. Appreciation of the orderliness of nature.
   c. Appreciation of the interrelations of science with religion, economics, politics.
   d. The ever changing nature of the universe and the adjustments necessary for the preservation of life.
   e. Science as inquiry.

4. Attitudes.
   a. Curiosity about the world we live in.
   b. Suspended judgment.
   c. Open mindedness.
   d. Healthy skepticism.
   e. Weighing evidence before drawing conclusions.
   f. Belief in cause-effect relationship.

5. New interests.

In the deductive-descriptive class these objectives were enumerated as a part of the introductory lecture. In the inductive-deductive class students were asked what they wanted to get out of the class besides four hours of credit. In the ensuing discussion many of these things were mentioned; others they seemed not to be aware of. The list was not completed at the time, but for the time being remained the objectives of the teacher. However, at the end of the course when the students
of both groups were asked, without any structuring, to respond to the evaluation questionnaire, the experimental group had a much more inclusive perception of the goals of the class than did the traditional group. In addition to knowledge, and understanding of relationships, and appreciations mentioned by both groups, they listed such things as acquiring a desire to seek and find answers not provided, learning to reason, learning to think and to draw their own conclusions, evaluating material, developing awareness of the scientific method, and examining the why's.

Conceptual Framework

One of the first tasks confronting the teacher following acknowledgement of the goals of the course is the selection of the emphases of the course. With the explosion of scientific knowledge that shows no signs of abating, it is no longer possible to teach more than a small portion of any field during any one course. It seems that the only logical way to meet the problem is to select those facts which will contribute to the development of concepts and the formulation of principles which can be organized around a few broad integrated themes. Such a conceptual scheme has been recommended by a conference of recognized scientists convened by the National Science Teachers Association in November, 1963. It is contained in the report of the Curriculum Committee of
N. S. T. A. (8). From a conference of leading science educators sponsored by the Pennsylvania Academy of Science on April 29-30, 1964, comes a recommendation relative to such a set of conceptual schemes. The recommendation of the discussion group led by Novak, as reported in Guidelines for Improving College Science Programs, read, "Both the selection of facts and the manner in which they are used should be determined by their potential contribution to an understanding of these conceptual schemes" (3, p. 36). In accordance with this philosophy the course was organized around four broad themes—(1) science as inquiry, (2) the unity of pattern in living things, (3) the origin and continuity of life, and (4) the diversity of animal life—through which this basic set of concepts could be developed. An outline of the organization of the course is given in the Appendix, page 123.

The first unit was devoted to an understanding of the process by which much of the knowledge in this particular discipline has been produced—the scientific method. Not only is there a constant accretion of new facts and discovery of new phenomena, but as these new data are unfolded, the reformation of the older body of knowledge is necessary. It must be reorganized to allow for the new and to put the old and the new in connection with one another. To convey to the student a realistic and understandable view of science and scientists, the perception of the role of science as inquiry is essential.
The second unit sought to develop an understanding of the basic unity of pattern in living things both structurally and functionally, with attention given to the striking similarity which is evident at all levels of organization. The virtually universal role of ATP as the vehicle for energy transfer, DNA and RNA as the materials of hereditary control, glucose as the fuel of the life processes, enzymes as the initiators of cell activity, and mitosis as the means of cell division, all evidence this remarkable unity. The protozoa were studied as a manifestation of these processes within the confines of a single cell. An outline of plans for this unit for both groups is given in the Appendix, the deductive-descriptive on page 124 and the inductive-deductive on page 127.

The next unit sought to provide a basis for an understanding of the diversity and complexity of structure and function found in the multicellular animals. It is no longer possible to give a coherent account of living things without the story of evolution, both because many of the most striking characteristics of living things are best explained as products of the selective forces at work in the evolutionary process and because evolution appears in organisms as a present phenomenon as meiosis, fertilization, and mutations provide the mechanism by which it takes place. Genetics provides an explanation of the continuity of life as well as its discontinuity. The occasional error in replication of the genes
is responsible for the variability and diversity basic to
the process by which life has spread over so much of the
world.

This extraordinary diversity of living organisms and
their adaptation to widely differing environmental conditions
formed the subject matter of the fourth unit. The morphology,
physiology, and ecology of both invertebrates and vertebrates
were studied to illustrate the complementarity of organism
and environment and of structure and function, and the
biological roots of behavior.

Textbooks

An attempt was made to correlate the latest research
findings with an understanding of classic biology. The text-
book used was General Zoology, by Nagler and Stiles (4), which
was organized along classic lines with an introductory chapter
on the field of zoology followed by a study of protoplasm,
cells, and tissues. Chapters on the various invertebrate
phyla are followed by material on the vertebrate classes and
the systems. Scientific American reprints were the chief
source of recent research findings. The deductive-descriptive
classes also used an illustrated laboratory manual, by Wodsedalek
(9). The inductive-deductive classes were given mimeographed
handouts similar to the two examples in the Appendix, pages 144
and 146, previous to the study of each phylum. These were
teacher-made, using suggestions from several new biology laboratory manuals (1, 5, 9) which use the investigative approach. Both groups were given an assignment sheet at the beginning of the semester, listing the page references in the text where related material could be found on each of the units and suggesting supplementary sources in the _Scientific American_ and library books. A bibliography list of current articles related to the field of study was kept on the chalkboard in one corner of the laboratory and students from both classes were encouraged to add any articles which they thought would be of interest to the class. Newspaper and magazine clippings of biological interest were placed on the bulletin board by teacher and students from time to time.

**Student-Teacher Relations**

Since teacher-student relationships are important in any kind of teaching, some attention was given to developing the necessary rapport and a warm friendly atmosphere free from any emotional tension that might interfere with learning. In both groups on the first day an attempt was made to establish a face to face relationship between teacher and student by directing remarks to each student who showed an interested response. This type of rapport seems to be more readily built in the laboratory setting than in the formality of the lecture room. The once-a-week laboratory periods of the
deductive-descriptive class were taught by the experimenter rather than by the student assistants and thus provided an appropriate opportunity for getting to know this group. It is very difficult to become well acquainted with students in a lecture situation where the instructor does most of the talking, and the students' contributions are confined to asking occasional questions. Sturgis (7) reported an experiment in which students of physics teachers who were given increased knowledge of the students' personal background made significantly greater gain in achievement and voted their instructors as being more effective. In order to assist the teacher in acquiring this type of information the students of both groups were asked to complete a questionnaire concerning their high school and college background in the sciences, the high school from which they had graduated, their vocational aspirations, major and minor fields of concentration, outside employment, marital status, and address (on or off campus). The information obtained from these questionnaires, the pre-tests, and the ACT scores served to make the instructor aware of the individual differences in past experience and capability and made the process of getting acquainted more rapid. Despite these precautions, the smaller class size, the laboratory setting three times each week, and the class participation inherent in the inductive-deductive method made the getting acquainted process much faster and more effective in that class.
The objectives, the conceptual framework and the general field of subject matter covered, the textbook, and the attempt to know the students was the same for both groups. It was in the method of presentation and study that they differed.

The Deductive-Descriptive Method

As already mentioned the deductive-descriptive class was conducted in the traditional manner with a large lecture section which was divided into two smaller groups for laboratory.

The lecture period was used by the instructor for the statement and elaboration of the general principles and concepts within each of the four broad themes around which the course was organized. Most of the material covered could be found in the textbook but it was supplemented with information obtained from research that had been carried out since publication of the text. Stressed in connection with all units was the change of living things through time, the complementarity of structure and function and of the organism and its environment, regulation of process and homeostasis. Students were encouraged to ask question whenever they did not understand, but their role was largely a passive one of listening and notetaking. The majority of the students indicated on the evaluation sheet that they found it easy to take good notes and many indicated that they used their notes as the chief means of preparation for tests. Weekly fifteen minute quizzes
of a rather factual nature provided some motivation for continuous study. Immediate feedback was supplied by going over the answers immediately after the quiz. This procedure was useful for correcting any misconceptions and for locating weaknesses in their understanding before major tests were given.

Lectures were illustrated by drawing diagrams and writing unfamiliar terms on the chalkboard, by anatomical charts, models, plastic mounts and preserved specimens, colored slides, and one moving picture reel. Electron photomicrographs were presented with the opaque projector. A plastic take-apart model of the DNA molecule and teacher-constructed flannelgraphs were used in the study of genetics. In addition to these visual aids an attempt was made to keep the lectures interesting by narration of unique research findings, current events of biological significance, application of principles to their own bodies, health and activities, and interpretation of the social significance of biological advances. Observations which they would make, or had made, in the laboratory were constantly alluded to as an attempt was made to relate the activities in the laboratory to the material being studied in the lecture.

The laboratory sections met in the same laboratory as did the experimental class and used the same equipment, slides, and specimens for dissection. The laboratory exercises in
the manual by Wodsedalek were followed rather closely, beginning with the study of the microscope, cells and tissues, through representative animals for each invertebrate phylum, and culminating with the study of the frog and fetal pig as representative vertebrates. The emphasis was upon the identification of various anatomical structures in the slides and the animals studied. Students made the drawings and did the labeling called for in the manual. In most instances discussion in the lecture period preceded the illustrative laboratory.

The Inductive-Deductive Method

The inductive-deductive class met for two hours three times a week in the laboratory. The physical setting was not ideal as it meant sitting on a stool with no back rest for two hours, with one-half of the class seated with their backs to the demonstration table and the chalkboard. However, with the integration of classwork and laboratory work which was characteristic of the class, there was enough activity to relieve the fatigue of sitting on the stools. The work was quite varied and a number of different types of experiences were used.

Laboratory Observation

Where possible the course was built around laboratory investigation, observation, and experimentation. The laboratory
work was organized to convey a sense of science as inquiry, to treat problems for which answers could not always be found in the textbook. Some of it was necessarily illustrative aimed at providing the sensory perceptions and experiences necessary to the formation of a concept. Even here students were not told what to expect but the responsibility for the observation was placed on them. Given a mimeographed laboratory sheet which consisted mainly of questions, they were expected to display some initiative in seeking answers. Dissections and observations were made of parts of animals which were not outlined in any laboratory manual and problems were investigated which were not outlined for them (as when a student wanted to know how the cheliped of the crayfish worked). Some became so interested that they came back to the laboratory at night to work on their specimens. No laboratory manual was used. Prior to each new laboratory experience the students were handed a mimeographed sheet which suggested observations to be made and raised questions which required careful observation, some thought, and sometimes recourse to the text or to library sources. Two examples of these are included in the Appendix, page 130.

The teacher gave whatever instruction or demonstration was necessary to enable the students to dissect an unfamiliar animal without loss of time and mutilation of specimens. After that students worked in pairs to make the observations and to
find answers to the problems on their laboratory sheets. They consulted diagrams in their text, wall charts in the laboratory, each other, and the teacher as she moved from table to table. Her job at this time was to give encouragement to the quest, express approval of a good dissection, answer questions, help the student to see gaps, additional problems, or inconsistencies in his work, to confirm an uncertain identification, and to give new direction and impetus when students seemed "stuck." Students were encouraged to differentiate between relevant and irrelevant data, to see the limitations of their methods and their data, and to develop intellectual honesty rather than a search for the right answers. It was hoped that this direct study of material would not only provide the precepts for the formation of new concepts and generalizations but also make the student aware that this was the original source from which came the facts that led to interpretations, concepts and theories that yielded the fundamental laws and basic truths by which humanity has advanced.

Regardless of whether the laboratory materials being used at the time were inorganic materials, living animals, or preserved specimens, the use made of them was to stress that these are the raw materials from which have come the planned observations and the experimentation that have formed the basis of the concepts and the principles of science, that the body
of knowledge thus forged is a temporary codex continuously being restructured as better means of observation and experimentation force reinterpretation of old data and the formation of new conclusions.

Cronback stated that "Experience ought to lead toward verbal knowledge. A well-formulated principle packs the residue of experience into a small capsule, easily remembered and easily applied" (2, p. 377). This was the philosophy behind the plan used in the inductive-deductive class. Discussion followed experimentation and observation. Students were asked to face the scientists' problem of describing observations in a way that communicates, to put an interpretation on what they saw, to formulate concepts and to make generalizations, to draw conclusions and to make applications. Concepts were not handed over ready-made to the students, but they were encouraged to work them out for themselves. However, this was not carried to the extreme; they were given aid when the give and take of discussion revealed deficiencies in their comprehension. The teacher tried not to assume that what she said was always clear to the learner. A provocative question was often used to reveal what had been left vague in the student's mind and to give the teacher a chance to clear up misconceptions.
Laboratory Investigation

To gain some insight into the nature of the scientific method, two very simple problems were investigated, one in which the hypothesis could be tested by observation and the other in which it had to be tested by experimentation. This active involvement in the process replaced the enumeration and illustration of the steps of the scientific method used in the other class. The students became participants as they moved through the process. They were given the background information and encouraged to formulate a statement of the problem, and on the basis of casual observation to state a hypothesis, to devise some way of testing their hypothesis, to collect and record data, and then to draw conclusions. It was hoped that, as a result of this experience, students would be able to set up several criteria for testing a hypothesis, to see the need of controls, to realize the necessity of qualifying conclusions, to begin to develop some scientific attitudes, to set up some characteristics of a good experiment, to see how knowledge arises from the interpretation of data and how the interpretation of data proceeds on the basis of concepts and assumptions. It was hoped that by personal participation in scientific processes, the student would come to know and respect them and also to recognize their limitations.
Students were also allowed to discover relationships for themselves through laboratory experience. Instead of the teacher's explaining the basis of classification, a large number of specimens belonging to the Phylum Mollusca were placed on the tables and the students asked to place those animals which seemed to have the most common characteristics into groups. As a result of this experience the basis for classification as well as the differences which exist between classes of this particular phylum became apparent. They saw the relation of a particular class to the phylum and were able to list those characteristics which were common to all classes and could be said to characterize the phylum.

Other experiments of the investigative type were performed to provide a more meaningful perceptual basis for such processes as diffusion and osmosis or such terms as hypertonic and hypotonic. It is not possible to observe such phenomena as cell metabolism, but a better basis for understanding how things get into cells is provided when students actually see evidence of Brownian movement as carmine particles are set in motion before their eyes under the microscope and as they are able to see what happens to that movement as the temperature is raised or lowered. To be able to make such observations just before discussion of a process adds a new vividness, creates interest, and makes possible a more concrete
understanding. Moreover the students learned to develop confidence in their own efforts and learned to account for their errors. Knowledge gained in such a manner may not be new knowledge, but if it is new to the student it will not be forgotten. They know because they have been convinced by observation.

Vicarious Participation in Research

Some concepts cannot be developed through direct experience. A historical narrative showing the sequence of development of a certain concept was a device sometimes used. The narrative was broken as it was stopped and the student allowed to grapple with the intellectual problems involved. He was asked to cope with the problems faced by the actual researchers. At times he was asked to develop a hypothesis, to suggest a means of testing a given hypothesis, or to draw conclusions. These were compared with those of the actual experimenter. The student was involved in the process by vicarious means.

Discussion

Students were encouraged to raise question and if the question was relevant and worthwhile, the class was led into an exploration of its ramifications, into a cooperative effort to use facts and principles in the solution of the problem. The discussion was a period of testing facts, proposing
solutions, or presenting divergent points of view on a problem. Some of the most thought-provoking questions were raised by students during the brief recess sometimes taken to break the long period. These students were encouraged to present such problems to the class.

It was sometimes necessary for the teacher to raise philosophical or social questions, to encourage discussion and argument, to raise problems in preparation for later topics, and to ask leading questions. Teacher-student planning for discussion periods helped to make them more worthwhile so they did not result in just pooled ignorance. The students were briefed on what was expected and prepared themselves for the discussion by acquiring the relevant facts. They had opportunity to observe how people could form different opinions from the same facts, to encounter uncertainty of information and the need for checking on their sources, to become aware of prejudice and the realistic conflict of interests, and to learn the importance of defining their terms with care. It gave them an opportunity to think, to organize their own ideas, and to evaluate findings in the light of known theory. Conclusions drawn had to be connected with other generalizations and theoretical structures so that the implications could be seen.

Testing

Once each week students were given an opportunity to write. Questions asked were of the type that would not permit
a parroting back of memorized material but would require some degree of understanding. They were asked to make generalizations, to interpret concepts, to make judgments, to reveal understanding of a principle, to make applications, to trace sequences which required a grasp of principles, and to explain an unfamiliar phenomenon or a set of relationships which displayed theoretical knowledge. These weekly quizzes also provided an opportunity for the student to catch any deficiencies in his understanding or any misconceptions which he may have entertained. Major tests were both multiple-choice and essay.

The Role of the Teacher

It was necessary for the successful operation of the inductive-deductive method to provide an atmosphere of freedom and spontaneity that would invite inquiry, an assurance of respect for the individual so the students would feel free to contribute, to differ, and even to suggest new directions. The role of the teacher is extremely important in such a class. Schwab (6), in the Biology Teacher's Handbook, which was prepared for the Biology Sciences Curriculum Study, listed three necessary attributes of the teacher in his role as teacher which would be a valuable asset to any teacher but would be particularly important in the employment of the inductive-deductive method. He stated that, first of all,
the teacher must be competent, possess a mastery of the content and structure of his subject matter field and an awareness of its interconnections with other fields, manifest an enthusiasm for learning, be unashamed to present materials which tax his own abilities, and be a model for his students of what the educated person should be. Secondly, he should present tasks that are "real" to the student, difficult enough to challenge but not so difficult that he becomes lost before he starts. Some of them should be difficult enough to require the teacher's participation in solving them. The third attribute which he mentions is that the teacher should be the students' ally, one who shows the students his methods and resources and helps and encourages them in developing their own problem-solving competencies. At the same time he must avoid "taking over."
CHAPTER BIBLIOGRAPHY


3. Eiss, Albert F., director, Guidelines for Improving College Science Programs, Harrisburg, Pennsylvania, The Pennsylvania Academy of Science and the Pennsylvania Department of Public Instruction, with the cooperation of the National Science Teachers Association, 1964.


7. Sturgis, Horace W., "The Relationship of the Teacher's Knowledge of the Student's Background to the Effectiveness of Teaching: A Study of the Extent to Which the Effectiveness of Teaching is Related to the Teacher's Knowledge of the Student's Personal Background," Dissertation Abstracts, XIX, No. 11 (1959), 2884.


CHAPTER V

PRESENTATION OF FINDINGS

The research hypotheses concerned the differences between the two methods being tested, between semester groups, and the interaction effect of method with semester on three criterion measures. The basic statistical technique used in the analysis of the results was a variation of the analysis of variance—the Lindquist Type I design for controlling individual differences. This is a two factor (AxB) design in which each of the A treatments (method) in combination with any one of the B treatments (semester) is administered to the same or to matched pairs of subjects but with each B treatment administered to a different group of subjects (2, p. 307). The inductive-deductive and the deductive-descriptive methods (Treatment A) were administered to matched groups in the fall semester and again in the spring semester. The semester groups were randomly assigned and were a different group of subjects (Treatment B). The design permits control of individual differences in a two factor design where one group is matched and the other is not.

Two intact classes were used in the experiment in both the fall and the spring semesters. Students were placed in
the lecture and the experimental sections in a two-to-one ratio by as random a procedure as scheduling conflicts would admit. During the first week of classes students were given pretests of each of the three criterion measures used in testing the hypothesis relative to the effectiveness of the inductive-deductive and the deductive-descriptive methods. These scores, along with their scores on the natural science portion of the ACT and the ACT composite scores and such external characteristics as sex, classification, and vocational interest, were used in choosing a matched group from the large lecture section to serve as control. Procedures used in matching groups and comparative data on the groups were presented in Chapter III and in the Appendix, Table XVI, page 133. Retests on all criterion measures were given during the last week of the semester.

Assumptions for Use of the F Test

The use of the analysis of variance involves certain assumptions in order to derive the F values required for significance. They are the assumption of normality of distribution of scores and the assumption of homogeneity of certain variances. However, McNemar reported that

there is ample evidence that marked skewness, departures from normal kurtosis, and extreme differences in variance (of the order one to four to nine)—it is not the numerical differences
but the relative sizes of the variances that are pertinent do not greatly disrupt the \( F \) test as a basis for judging significance in the analysis of variance (3, p. 252).

As evidence of the degree to which the experimental and control groups approach normality, Table IV presents the frequency distribution of scores of the students from all classes on the zoology achievement test given at the end of the term. Frequency distributions of the retests for the other two criterion measures are presented in Tables XVII and XVIII in the Appendix.

### TABLE IV

**DISTRIBUTION OF SCORES ON THE ZOOLOGY END-OF-TERM ACHIEVEMENT TEST FOR THE INDUCTIVE-DEDUCTIVE AND THE DEDUCTIVE-DESCRIPITIVE GROUPS**

<table>
<thead>
<tr>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>130-139</td>
<td>1</td>
<td>100.0</td>
<td>130-139</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>120-129</td>
<td>2</td>
<td>97.8</td>
<td>120-129</td>
<td>3</td>
<td>93.2</td>
</tr>
<tr>
<td>110-119</td>
<td>5</td>
<td>93.2</td>
<td>110-119</td>
<td>10</td>
<td>70.5</td>
</tr>
<tr>
<td>100-109</td>
<td>9</td>
<td>81.8</td>
<td>100-109</td>
<td>7</td>
<td>61.4</td>
</tr>
<tr>
<td>90-99</td>
<td>10</td>
<td>61.4</td>
<td>90-99</td>
<td>9</td>
<td>54.5</td>
</tr>
<tr>
<td>80-89</td>
<td>12</td>
<td>38.6</td>
<td>80-89</td>
<td>4</td>
<td>34.1</td>
</tr>
<tr>
<td>70-79</td>
<td>2</td>
<td>11.4</td>
<td>70-79</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td>60-69</td>
<td>3</td>
<td>6.8</td>
<td>60-69</td>
<td>4</td>
<td>11.4</td>
</tr>
<tr>
<td>50-59</td>
<td>0</td>
<td>2.1</td>
<td>50-59</td>
<td>1</td>
<td>2.1</td>
</tr>
</tbody>
</table>

The mean achievement score for the inductive- deductive groups on this test was 95.64 with a standard deviation of 15.80. For the deductive- descriptive groups the mean achievement score was 95.43 with a standard deviation of 18.18. This
was the largest difference in variability found on any of the tests. A comparison of the standard deviation of the experimental and the control groups on all three criterion measures is presented in Table V.

TABLE V

STANDARD DEVIATIONS OF THE EXPERIMENTAL AND CONTROL GROUPS ON PRETEST AND RETEST OF THREE CRITERION MEASURES

<table>
<thead>
<tr>
<th>Criterion Measure</th>
<th>I-D Groups</th>
<th>D-D Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoology Achievement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>15.00</td>
<td>15.43</td>
</tr>
<tr>
<td>Retest</td>
<td>15.80</td>
<td>18.18</td>
</tr>
<tr>
<td>Science Reasoning &amp; Understanding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>5.47</td>
<td>5.84</td>
</tr>
<tr>
<td>Retest</td>
<td>7.50</td>
<td>6.97</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>8.11</td>
<td>9.11</td>
</tr>
<tr>
<td>Retest</td>
<td>7.82</td>
<td>8.95</td>
</tr>
</tbody>
</table>

The small difference in variability shown by the groups and the near normality of the distribution scores indicate that the F test could be used for judging the significance of the difference in the mean gains on the three criterion measures used.

Zoology Achievement

A teacher-constructed zoology achievement test was given as both pretest and retest to measure understanding of principles and concepts in zoology. A compilation of the means and standard deviations of each class for both pretest and retest is presented in Table VI.
A comparison of the means shown in Table VI reveals a mean increase of 33.71 points for the inductive-deductive against a mean increase of 37.42 for the deductive-descriptive group in the fall. In the spring the direction was reversed, with the inductive-deductive group showing the larger mean increase, 39.05 points, as opposed to 34.85 for the deductive-descriptive class. For the combined groups for both semesters the mean increase of the experimental group was 36.14 points and that of the control group was 36.25 points. A graphic presentation of mean gains by method and by semester is given in Table VII.

The difference in mean gains between the two methods was extremely small, only .11. The difference between the semester groups was very little more, 1.38 points. An
### TABLE VII

**MEAN GAINS ON THE ZOOLOGY ACHIEVEMENT TEST**
**BY METHOD AND BY SEMESTER**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Methods</th>
<th>Mean Gain By Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-D</td>
<td>D-D</td>
</tr>
<tr>
<td>Fall</td>
<td>33.71</td>
<td>37.42</td>
</tr>
<tr>
<td>Spring</td>
<td>39.05</td>
<td>34.85</td>
</tr>
<tr>
<td>Mean gain by method</td>
<td>36.14</td>
<td>36.25</td>
</tr>
</tbody>
</table>

Analysis of variance showed neither difference to be significant. The sums of squares and the resulting mean squares needed to perform the F test of significance for differences in mean gains in methods, in semesters, and interaction between the two are presented in Table VIII.

### TABLE VIII

**RESULTS OF AN ANALYSIS OF VARIANCE OF MEAN GAINS**
**ON THE ZOOLOGY ACHIEVEMENT TEST BY METHOD AND BY SEMESTER**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sums of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subject</td>
<td>8204.22</td>
<td>43</td>
<td>42.00</td>
<td>.2161</td>
</tr>
<tr>
<td>B—semester</td>
<td>42.00</td>
<td>1</td>
<td>42.00</td>
<td></td>
</tr>
<tr>
<td>Error B</td>
<td>8162.22</td>
<td>42</td>
<td>194.34</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>10155.50</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A—method</td>
<td>.28</td>
<td>1</td>
<td>.28</td>
<td>.0012</td>
</tr>
<tr>
<td>AB—interaction</td>
<td>341.14</td>
<td>1</td>
<td>341.14</td>
<td>1.4599</td>
</tr>
<tr>
<td>Error W</td>
<td>9814.08</td>
<td>42</td>
<td>233.67</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8359.72</td>
<td>87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In checking for interaction, the F equals $341.14/233.67$, or $1.4599$, which falls far short of the $4.08$ needed for the .05 level of significance. This means that the apparent failure of the four cells to be consistent can be attributed to chance fluctuation and that there was no interaction between method and semester on the zoology achievement test. For the difference between methods the F equals $0.28/238.67$, or $0.0012$. Any effect of the method which may exist is therefore not large enough to be demonstrated in the number of cases used. The fact that the interaction is not significant leads to the conclusion that the increase in achievement from the time of the pretest to the retest was not affected by one method more than the other. Therefore the research hypothesis that there will be no significant mean differences in achievement in general zoology as measured by a teacher constructed end-of-the-term zoology achievement test between a group of students instructed with an inductive-deductive method and a group of students instructed with a deductive-descriptive method can be accepted.

The F for the difference in semesters was $42.00/194.34$, or $0.2161$, which is not significant at the .05 level and leads to the acceptance of the null hypothesis that there was no significant difference in the semester effect. It is therefore necessary to reject the research hypothesis that students
taking general zoology the second semester will have a significantly higher mean gain on the zoology achievement test. Table VII showed that the average gain of the spring groups was 36.95 points, which was a gain of 1.38 points more than the average gain of 35.75 points for the fall group. However this gain was not statistically significant. It is possible that the gain would have been larger had it been possible to match the spring group more closely with the fall group in such characteristics as vocational science interest and outside work hours. It was noted in the description of the populations that only five in each spring section indicated that they planned to major or minor in some field of science, in contrast to thirteen from each class in the fall. It may be worthy of note that three people in the spring classes who were classified as non-majors indicated on the evaluation sheet that they were considering changing to a biology major or minor as a result of the interest aroused by the course. One of these was in the experimental class and the other two were in the lecture group.

Science Reasoning and Understanding

A Test of Science Reasoning and Understanding was used as pretest and retest as a criterion measure of development in this field. Comparative data showing means and standard
deviation on the pretest and retest are given in Table IX for both the inductive-deductive and the deductive-
descriptive groups.

**TABLE IX**

**COMPARATIVE DATA SHOWING PRETEST AND RETEST MEANS AND STANDARD DEVIATIONS ON A TEST OF SCIENCE REASONING AND UNDERSTANDING**

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest SD</th>
<th>Retest Mean</th>
<th>Retest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall semester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>24</td>
<td>28.29</td>
<td>5.53</td>
<td>34.50</td>
<td>8.01</td>
</tr>
<tr>
<td>D-D group</td>
<td>24</td>
<td>27.13</td>
<td>4.72</td>
<td>31.92</td>
<td>6.16</td>
</tr>
<tr>
<td>Spring semester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>20</td>
<td>29.80</td>
<td>5.28</td>
<td>31.70</td>
<td>6.52</td>
</tr>
<tr>
<td>D-D group</td>
<td>20</td>
<td>29.45</td>
<td>6.73</td>
<td>29.25</td>
<td>7.57</td>
</tr>
<tr>
<td>Both semesters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D groups</td>
<td>44</td>
<td>28.98</td>
<td>5.47</td>
<td>33.23</td>
<td>7.50</td>
</tr>
<tr>
<td>D-D groups</td>
<td>44</td>
<td>28.18</td>
<td>5.54</td>
<td>30.70</td>
<td>6.97</td>
</tr>
</tbody>
</table>

A comparison of the pretest and retest means reveals that there was an increase in all groups except the spring deductive-descriptive group. The experimental classes increased more than did the control classes, though the \( P \) test revealed that there was not a significant difference in the increase. A graphic comparison of mean gains by method and semester is presented in Table X.

The range of mean gains was from \(-.20\) to \(6.21\), but the range for individual gains was from \(-10.0\) to \(17.0\). Seventeen individuals (twelve from the experimental classes and five from the control classes) made gains of nine or more points.
and five (two experimental and three control) had losses of five or more points. As shown in Table X, there was a greater difference between mean gains by semester than by method. An analysis of variance showed this difference to be significant. Data for the analysis of variance on mean gains, together with the F scores, are recorded in Table XI.

### TABLE X

**MEAN GAINS ON A TEST OF SCIENCE REASONING AND UNDERSTANDING BY METHOD AND BY SEMESTER**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Methods</th>
<th>Mean Gain By Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-D</td>
<td>D-D</td>
</tr>
<tr>
<td>Fall</td>
<td>6.21</td>
<td>4.79</td>
</tr>
<tr>
<td>Spring</td>
<td>1.90</td>
<td>-.20</td>
</tr>
<tr>
<td>Mean gain by method</td>
<td>4.75</td>
<td>2.52</td>
</tr>
</tbody>
</table>

### TABLE XI

**RESULTS OF AN ANALYSIS OF VARIANCE OF MEAN GAINS ON A TEST OF SCIENCE REASONING AND UNDERSTANDING BY METHOD AND BY SEMESTER**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sums of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subject</td>
<td>1571.86</td>
<td>43</td>
<td>471.76</td>
<td>18.01</td>
</tr>
<tr>
<td>B—semester</td>
<td>471.76</td>
<td>1</td>
<td>471.76</td>
<td></td>
</tr>
<tr>
<td>Error B</td>
<td>1100.10</td>
<td>42</td>
<td>26.19</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>1475.00</td>
<td>44</td>
<td>65.64</td>
<td>1.96</td>
</tr>
<tr>
<td>A—method</td>
<td>65.64</td>
<td>1</td>
<td>65.64</td>
<td></td>
</tr>
<tr>
<td>AB—interaction</td>
<td>2.55</td>
<td>1</td>
<td>2.55</td>
<td>.08</td>
</tr>
<tr>
<td>Error W</td>
<td>1406.82</td>
<td>42</td>
<td>33.50</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3046.87</td>
<td>87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The $F$ for interaction had a value of .08, which was not significant and revealed no interaction between the method and the semester. The value of $F$ for method was 1.96, which was not significant at the .05 level of 4.08. This means that the null hypothesis of no difference due to method would have to be accepted, and the research hypothesis that the inductive-deductive method would be significantly more effective than the deductive-descriptive method in increasing ability in science reasoning and understanding as measured by A Test of Science Reasoning and Understanding rejected. However the direction of gain favored the inductive-deductive method.

Determination of the $F$ for semester differences showed a value of 18.01, which is considerably higher than the 4.08 or the 7.31 required for acceptance of the null hypothesis at the .05 and the .01 levels of confidence. It would seem that there was a significant difference in the mean gain scores between the fall and spring semesters, with the fall semester making the larger gain. This indicates that the influence of the training in science reasoning and understanding was not the same for the spring groups as it was for the fall groups. It is rather difficult to account for this difference except on the basis of a difference in the external characteristics of the fall groups, since the methods used in the spring were as nearly as possible a replication of those
used in the fall, and a \( t \) test revealed no significant difference on ACT and pretest scores, though they were somewhat higher for the fall group on the ACT and the zoology pretest.

These data call for the rejection of both the null hypothesis of no significant difference in mean gains by semester and the research hypothesis that students taking general zoology the second semester will not have a significantly higher mean gain on *A Test of Science Reasoning and Understanding* from those taking the course during the first semester. Not only did they show a significant difference, but the direction of the higher mean gain was for the fall groups rather than the spring groups. (Refer to Table X, page 91.) The average mean gain in the fall semester was 5.50 points, as opposed to a gain of only .85 in the spring semester. A possible explanation for this difference could lie in the fact already noted that the fall groups apparently had more scientific aptitude and interest, and it may be that such students would profit more from science training. Another possible explanation is that having had a traditional botany course just prior to this course was a disadvantage rather than an advantage as far as this objective was concerned.

**Critical Thinking**

The *Watson-Glaser Critical Thinking Appraisal* was used as pretest and retest to measure gain in critical thinking
which was not related specifically to science. Comparative data showing means and standard deviations is presented for both the inductive-deductive and the deductive-descriptive groups in Table XII.

### TABLE XII

**COMPARATIVE DATA SHOWING PRETEST AND RETEST MEANS AND STANDARD DEVIATIONS ON THE WATSON-GLASER CRITICAL THINKING APPRAISAL**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>SD</th>
<th>Retest Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall semester</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>24</td>
<td>71.79</td>
<td>7.90</td>
<td>73.79</td>
<td>7.60</td>
</tr>
<tr>
<td>D-D group</td>
<td>24</td>
<td>68.88</td>
<td>7.98</td>
<td>70.08</td>
<td>8.54</td>
</tr>
<tr>
<td><strong>Spring semester</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>20</td>
<td>71.50</td>
<td>8.36</td>
<td>70.60</td>
<td>7.72</td>
</tr>
<tr>
<td>D-D group</td>
<td>20</td>
<td>71.50</td>
<td>10.12</td>
<td>70.35</td>
<td>9.42</td>
</tr>
<tr>
<td><strong>Both semesters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D groups</td>
<td>44</td>
<td>71.66</td>
<td>8.11</td>
<td>72.34</td>
<td>7.82</td>
</tr>
<tr>
<td>D-D groups</td>
<td>44</td>
<td>70.07</td>
<td>9.11</td>
<td>70.20</td>
<td>8.95</td>
</tr>
</tbody>
</table>

Mean gains for all groups were quite small and there was actually a loss in both spring groups. However, individual gains went as high as thirteen points and individual losses as high as seventeen points. There were twelve people who had losses of seven or more points and seventeen people who had gains of seven or more points. That the same direction of mean gains prevailed here as in *A Test of Science Reasoning and Understanding* is evident from the graphic comparison presented in Table XIII.
TABLE XIII
MEAN GAINS ON THE WATSON-GLASER CRITICAL THINKING APPRAISAL BY METHOD AND BY SEMESTER

<table>
<thead>
<tr>
<th>Semester</th>
<th>Methods</th>
<th>Mean Gain By Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-D</td>
<td>D-D</td>
</tr>
<tr>
<td>Fall</td>
<td>2.00</td>
<td>1.21</td>
</tr>
<tr>
<td>Spring</td>
<td>-.90</td>
<td>-1.15</td>
</tr>
<tr>
<td>Mean gain by method</td>
<td>.68</td>
<td>.13</td>
</tr>
</tbody>
</table>

An analysis of variance also revealed the same relation between methods and semesters as in A Test of Science Reasoning and Understanding, as shown by the F scores on the significance of the difference in mean gains in Table XIV.

TABLE XIV
RESULTS OF AN ANALYSIS OF VARIANCE OF MEAN GAINS ON THE WATSON-GLASER CRITICAL THINKING APPRAISAL BY METHOD AND BY SEMESTER

<table>
<thead>
<tr>
<th>Source</th>
<th>Sums of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subject</td>
<td>1824.95</td>
<td>43</td>
<td>165.50</td>
<td>4.16</td>
</tr>
<tr>
<td>B—semester</td>
<td>165.50</td>
<td>1</td>
<td>165.50</td>
<td></td>
</tr>
<tr>
<td>Error B</td>
<td>1659.45</td>
<td>42</td>
<td>39.51</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>1397.00</td>
<td>44</td>
<td>39.51</td>
<td></td>
</tr>
<tr>
<td>A—method</td>
<td>10.23</td>
<td>1</td>
<td>10.23</td>
<td>.34</td>
</tr>
<tr>
<td>AB—interaction</td>
<td>3.42</td>
<td>1</td>
<td>3.42</td>
<td>.10</td>
</tr>
<tr>
<td>Error W</td>
<td>1383.35</td>
<td>42</td>
<td>32.94</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3221.95</td>
<td>87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The very small F of .34 for method indicated an acceptance of the null hypothesis that the difference in mean gains of
the inductive-deductive group over the deductive-descriptive group was not significant. The research hypothesis of a significant difference in mean gains on the Watson-Glaser Critical Thinking Appraisal due to method would thus have to be rejected. That there was a significant difference between semesters is evidenced by the F of 4.16, which means that both the null hypothesis and the research hypothesis of no difference between semesters on the Watson-Glaser Critical Thinking Appraisal would have to be rejected. Not only was there a difference but the difference was in favor of the fall semester. Evidently the uncontrolled group differences of higher science interest and fewer outside work hours which favored the fall groups were of more importance on this criterion than any increased maturity or experience which the spring groups could have been presumed to have acquired.

The experimental class which was used as the basis for matching between methods groups contained thirteen science majors (six either pre-medical or pre-dental), with a mean ACT natural science score of 23.76, and only eleven non-majors. In matching this group it was necessary to use all of the students with high academic ranking from the lecture class in order to obtain a comparable group on which to record data. In the spring the experimental class contained only five science majors, none of whom were pre-medical. The mean ACT natural science score for the five was only 19.60. The better students
academically in the spring were non-science majors who did not have a vocational interest in the subject. Another difference which could not be controlled concerned the number of outside hours worked by the students. This was greater for the experimental class both semesters and greater for the spring semester than for the fall semester.

The F of .10 indicated almost no interaction between method and semester on the Watson-Glaser Critical Thinking Appraisal. This same lack of interaction was recorded on the other two criterion measures, an indication for the acceptance of the research hypothesis that the semester in which zoology was offered would have no effect upon the relative effectiveness of the inductive-deductive and the deductive-descriptive methods of teaching college zoology.

Summary of Mean Gains

A summary of the mean gains for all groups on all criterion measures is recorded in Table XV.

A comparison of the mean gains between methods groups showed almost no difference for the combined groups on zoology achievement, though the direction of gain favored the deductive-descriptive group in the fall and the inductive-deductive group in the spring. The direction of gain, though not significant at the .05 level, favored the inductive-deductive groups on those measures concerned with the objectives of science reasoning and understanding and critical thinking.
TABLE XV
SUMMARY OF MEAN GAINS FOR ALL GROUPS
ON ALL CRITERION MEASURES

<table>
<thead>
<tr>
<th>Criterion Method</th>
<th>Fall</th>
<th>Spring</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoology Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>33.71</td>
<td>39.05</td>
<td>36.14</td>
</tr>
<tr>
<td>D-D group</td>
<td>37.42</td>
<td>34.85</td>
<td>36.35</td>
</tr>
<tr>
<td>Science Reasoning and Understanding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>6.21</td>
<td>1.90</td>
<td>4.75</td>
</tr>
<tr>
<td>D-D group</td>
<td>4.79</td>
<td>-.20</td>
<td>2.52</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-D group</td>
<td>2.00</td>
<td>-.90</td>
<td>1.32</td>
</tr>
<tr>
<td>D-D group</td>
<td>1.21</td>
<td>1.15</td>
<td>.13</td>
</tr>
</tbody>
</table>

Student Evaluation of the Course

In order to obtain evidence of the basic difference in the two methods and of what was accomplished in the course from the student's point of view, a questionnaire titled "Course Evaluation," appended on page 131, was given to the students of all classes during the last week of the semester. They were asked not to identify themselves and to give a sincere and honest opinion on the questions asked. It was suggested that their straightforward frankness in answering the questions would be of value in improving the course for later classes. Dressel (1), whose suggestions for evaluation were incorporated into this questionnaire, felt that the big advantage of the method over the usual course appraisal check list lay in the fact that student reaction was directed toward the learning process. The student was asked to study his role
in, and perception of, the class rather than to engage himself with a judgment of the teacher's conduct of the class.

No structuring was given relative to how the students were to answer the questions. Interpretation of the meaning of the question was left up to the individual student. It is true that this procedure has its disadvantages in the wide diversity of replies, which makes tabulation and consensus somewhat difficult, the possibility of misdirection, and in the fact that the students, not being sure of what is wanted, may tend to answer in terms of what they feel is desired. However, it was felt that the spontaneity and personalization of reaction to be gained by not structuring would outweigh these disadvantages, particularly since the replies were to be anonymous. A summary of student reaction follows.

**Most Characteristic Feature**

To determine whether there had been a basic difference in the two methods which was obvious to the participating students, they were asked what they saw as the most characteristic feature of the course. Replies concerned method, material covered, attitudes, and interest. Comments from the traditional class relative to method were: "Good factual lectures, precise and to the point, presented so that you can get good notes," "Lectures followed the schedule given
and were well prepared," "Having something tangible (lab specimen) to relate and compare to what we were studying in lecture," "The teacher was also the lab instructor," "Each time the lecture and lab were related and made up part of a chain."

Almost all of the experimental class mentioned the laboratory combined with the discussion of the material but their comments revealed that they were also aware of the less obvious differences. They mentioned such things as a search for reasons behind facts normally memorized, learning experiences brought about largely by the student rather than the teacher, a more meaningful way of mastering facts, emphasis on really learning something and then being able to apply it in a different situation, and the atmosphere of intellectual activity and generally intelligent discussion. Some mentioned the class participation, the fact that everyone worked together to learn and seemed interested in what they were doing, or that the group worked together to accomplish common goals. Still others referred to the way the material was presented—-that they had to hunt for their observations in laboratory and try to formulate their own conclusions instead of being given all the information, that the student had to dig for answers, not given on a silver platter to be recited later, that they did laboratory work first and then discussed reasons and causes, making everyone think
more, or that they had the chance to observe and analyze and to see objects while they were being discussed.

The traditional class more often mentioned the course subject matter as the most characteristic feature; the comparison of the different levels of animal life, the study of the more complex systems of the higher animals, the memorization of names and characteristics, the comparison of the human with other animals. Some of the experimental class saw the course as a comparative study of the relationships among animals and their evolution and of how each form has its way of carrying out the same life processes. They mentioned the emphasis on understanding, on theory and interpretation rather than on facts. In both groups there was mention of the interest of students and enthusiasm of the teacher.

**Class Goals**

The majority of the traditional class saw the goals of the class in terms of the mastery of subject matter as a foundation for more advanced work. They put the emphasis upon developing an understanding of animal life and its development, its relationship with its environment, with other animals and with man, and an appreciation of the importance of life, its complexity, and the working of their own bodies. The experimental class also mentioned the development of these understandings and appreciation but saw
other goals as well. They mentioned such things as to instill a desire to seek and find answers not provided, to learn and to develop ability to reason, to stimulate thinking, to increase ability in reaching conclusions based on facts, to arouse curiosity and an interest in investigating for oneself, and to develop an awareness of the scientific method. Of course there were those in both groups whose goals did not rise above the completion of a required course.

**Study Habits**

The most significant difference revealed by the questions on habits of study used in preparation was that the traditional classes more often put the emphasis on study of notes, memorizing definitions, reading the text to supplement notes, and intensive review before tests. Most made good use of the text in studying diagrams and glossary, though a few admitted that they seldom used it, depending entirely upon their class notes. One person said that he tried to learn instead of memorize. The experimental class, in contrast, thought of the class period as a learning experience. They were apt to read the text in preparation for class discussion and to seek outside sources of information. They used the text as a reference, made good use of the diagrams and glossary, and read in reviewing for tests. They were not as dependent upon class notes. They also noted that they discussed problems or items
which had interested them outside of class with each other and with others who had science interests.

**Tangible Effects of the Course**

In answer to the query as to what tangible effects the course had on them, both groups ascribed to it an increased interest in animal life and in science. One of the experimental group said, "First time I ever enjoyed being in a biology class. I was never bored or uninterested." Several from both groups indicated a new interest in science as a vocation. Both groups spoke of what they had learned, of a better understanding of their own bodies, of the life processes, and of relationships among animals. Several attributed to it a broadened appreciation of science and an increased awareness of the world around them. Both groups also mentioned that they had been helped in their study habits.

In addition to these effects which were named by members of both groups, the experimental group listed a number of others. One said that he had become more analytical, weighed arguments and facts more closely before arriving at conclusions; another that he now enjoyed reading articles about zoology; still others mentioned such things as critical thinking, a scientific approach to problems, a strengthened faith in God and His creative powers, a new inquisitiveness, and a realization of the part the scientific method has played in
finding the knowledge we have today. Another said that he now had some facts which he thought would stay with him because he had seen how and why they worked. Another replied that he had made many good friends due to the type of association in the class. There were two who said that they were not used to this type of course and found it difficult to correlate material and draw conclusions.

**Most Helpful Features**

Both groups listed the use of visual aids such as the chalk board, living animals, preserved specimens, models, flannel board, and charts as helpful experiences. The dissection of animals, though unpleasant to some, was thought to be very helpful; also named was the weekly test. In addition the experimental group listed such things as the chance to apply what has been learned immediately, the combination of laboratory with classwork so that the objects being discussed can be seen, the discussion with each other and with instructor while examining the specimens, the experiments, the actual doing and seeing for oneself, class discussion.

**Least Helpful Features**

Features mentioned as least helpful by the traditional group were the drawing in laboratory, the instructions in the laboratory manual, and the lack of discussion. Most of
the features which were enumerated as least helpful in
the experimental class had to do with the physical facilities
such as sitting on stools for two hours, and the fact that half
the desks faced away from the instructor and the chalk board.
These discomforts will be eliminated as soon as the new
science building is finished, as the architect has worked with
the instructor to design a classroom particularly suited to
this method of teaching. One student complained that time
always ran out just when he was most interested and suggested
that the class be scheduled at a time when those who were
interested could stay on if they so desired. Others felt
that the class period was a little too long. There were a
few students who said they missed having the instructor list
the materials they should memorize; yet they said they wanted
to keep the present method. Such students felt a little lost
and insecure without previous instruction of exactly what
they were to do in laboratory and an explanation of the sig-
nificance of it. The suggestions which were given for im-
provement of the course were related to the features which
they had noted as most or least helpful.

Choice of Course

In addition to the questions on the evaluation sheet
the experimental class was asked, "If you had it to do again,
would you enroll in this type of class or would you choose
the more traditional lecture and laboratory course?" All but two of the fall group said that they would definitely choose this type of course. One said that he wished botany could be taught this way. Of the two who said they would choose the other class, one said that he thought that he could make a better grade in the other type course though he would recommend it because it was different and interesting. The other said that he was used to the other type course, that it was easier to study for it, and that he liked to have organized notes that he could study. The spring group, most of whom had completed the traditional botany course, were unanimous in their choice of this type of course. They gave as their reasons that it was much more interesting, that one loses many of the facts given in lecture before laboratory time, that one's mind doesn't have a chance to wander as it does in lecture, that they could see more and understand it better, that they learned more and learned faster and that what one learned would stay with one. Or as one student put it, not very grammatically but nevertheless quite graphically, "It is easier for the student to learn and stay learned." Several expressed the wish that all science courses would be given in this manner.
CHAPTER BIBLIOGRAPHY


SUMMARY AND CONCLUSIONS

Summary

In order to test the relative effectiveness of a laboratory centered, inductive-deductive method and of a deductive-descriptive method conducted in the traditional lecture and laboratory sessions in the teaching of college zoology, an experiment was conducted in the fall of 1965 and replicated in the spring of 1966 with the zoology classes as Hardin-Simmons University. Subjects were students assigned by as random a means as schedule conflicts would admit to the lecture section or to the experimental combined class on a two-to-one ratio. A matched group was picked from the larger lecture section on the basis of pretest scores on three criterion measures, their ACT composite and natural science scores, and such external characteristics as sex, classification, and their science interest as expressed in their choice of a major or minor field. Though a t-test showed no significance in mean difference between the matched method groups and the unmatched semester groups on ACT or protest scores, there were uncontrollable differences in these external characteristics between semester groups, which favored the fall group.
The criterion measures of the effectiveness of the compared procedures were a teacher-constructed zoology achievement test, A Test of Science Reasoning and Understanding, Biological Sciences, Form A., and the Watson-Glaser Critical Thinking Appraisal, Form YM. It was assumed that these tests would give an adequate measure of the more commonly sought objectives in science education.

The experimental class met from eight to nine-fifty A. M. Mondays, Wednesdays, and Fridays in the zoology laboratory. The traditional lecture section met from eight to nine-fifteen on Tuesdays and Thursdays in the lecture room and was divided into two equal sections for a three-hour laboratory on either Monday or Wednesday afternoons. All classes were taught by the experimenter, had the same principles emphasized, used the same textbook, and had access to the same facilities. The difference was in the organizational pattern and in the method of teaching.

The deductive-descriptive method used with the separate lecture and laboratory class is the traditional method prevalent in many college zoology classes in which the lecturer gives an organized exposition of the important principles of the discipline, followed by their elaboration, illustration, and application. Although students were encouraged to ask questions whenever they did not understand, their role in the lecture class was largely passive, confined primarily to
listening, taking notes, asking occasionally for clarification, and taking weekly quizzes designed to check on their mastery of subject matter. In the laboratory students followed a well illustrated laboratory manual giving detailed description of the morphology of the various phyla. They were told what to do and what to observe. Their activity was confined to microscopic examination of slides, to observations of living cultures, projected slides, preserved specimens and models, and to dissection of type animals. No provision was made for student planning, and there was little call upon the student to develop or use generalizing ability. The emphasis was upon identification of parts of the internal anatomy of the various animals studied, and testing was largely in the form of practicals in which students were asked to identify the organ or structure of the actual specimen. Insofar as possible, the laboratory was planned to be illustrative of the principles which had been discussed in the lecture during the previous week. Perfect correlation was not always possible, however. It should be noted that this instructional approach had a presumed advantage in that the same instructor taught both the lecture and laboratory phases of the course. To this extent it was not representative of many introductory zoology courses.

The experimental section was conducted entirely in the laboratory, with the students participating in the process of
working from specific examples through the interpretation of data to the generalization and its application to other problems. As it was used in this experiment, it was an attempt to put the scientific method into operation in a learning situation. Students were given an opportunity to make careful observations and conduct controlled experiments in the laboratory, to analyze problems, examine assumptions, collect and organize data and test hypotheses. Generalizations were drawn from data that were "discovered" in the laboratory or in the students' reading. Though not to be equated with a pure discovery method, the inductive-deductive method aimed at using laboratory experience as a basis for developing meaning. It was more like the directed discovery described by Craig (2), as learning was accelerated by giving appropriate explanations and by helping the student to formulate in words what he had observed. Applications were then made to other related problems. Tests were designed not simply for recall but required some degree of understanding, interpretation, and application. The inductive-deductive method was intended to put a premium not just on the knowledge of facts and principles but upon their use and the ability to reorganize them to suit the problem; that is, to reason and think critically.

Retests of all the criterion measures were given to all classes during the last week of the semester as a means of
determining gains made since the pretests. Differences in mean gains were computed for testing the several research hypotheses related to the effect of method and semester as measured by the three criterion measures. A course evaluation questionnaire was used as an added measure of what was accomplished in the course. The basic statistical technique used in the testing of the hypotheses was the Lindquist type I analysis of variance, which permits the control of individual difference where one group is matched and the other is not, in a two-factor design. Mean gains on the zoology achievement test were almost identical for the inductive-deductive and the deductive-descriptive classes, with the traditional class leading slightly in the fall and the experimental class in the spring. These differences were not significant at the .05 level, which led to the acceptance of the research hypothesis that there would be no difference in mean gain between methods and a rejection of the research hypothesis that the spring group would show a significantly higher mean gain than the fall group in zoology achievement as measured by improvement on the teacher-constructed end-of-term test.

The difference in mean gains on A Test of Science Reasoning and Understanding and the Watson-Glaser Critical Thinking Appraisal, though not statistically significant favored the inductive-deductive groups. This led to the rejection of the research hypothesis that mean gains on the two tests
would be significantly greater for the inductive-deductive groups. The direction of gain was that proposed by the hypotheses, but it was not of sufficient magnitude to be statistically significant.

The F scores of the analysis of variance were significant for the difference between semesters. The research hypotheses that there would be no significant difference in mean gains on A Test of Science Reasoning and Understanding and the Watson-Glaser Critical Thinking Appraisal was therefore rejected. The total fall semester group exceeded the total spring semester group in mean gains on both tests.

Evidence from the student evaluation questionnaire seemed to favor the inductive-deductive method as to increased motivation and interest, development of scientific attitude, and understanding of the scientific method. Students also felt that they would have better retention of the material because of their active participation and better understanding of the "whys" behind the facts. Though no study of retention was made, it is possible that it would have made a contribution to the evaluation of the two methods under study.

Conclusions and Recommendations for Further Research

Because of the fact that the inductive-deductive classes did as well as or better than the matched deductive-descriptive classes on the three criterion measures used, plus the rather
intangible but nonetheless demonstrated benefits of increased student interest, motivation, scientific attitude and understanding, the decision to continue the use of the inductive-deductive method in all zoology classes at Hardin-Simmons University seems justified.

No statistical evidence was found of a significant advantage of either method in improving ability in science reasoning and understanding and critical thinking, but the direction of gain tended to favor the inductive-deductive method. The students' feeling that the inductive-deductive method built around the laboratory activities would be an aid in retention deserves further investigation.

The refrain of "no significant difference" seems to be a rather constant accompaniment in studies of classroom methodology. There are a number of contributing factors to this state of affairs. One has to do with the limitations imposed by the still primitive state of instruments for measurement of accomplishment in education. Another concerns the limited time devoted to most studies, and a third factor is related to the extreme difficulty of controlling and evaluating all of the variables in an active classroom situation. This study was no exception in suffering from these limitations.
The Criterion Measures

The first question that comes to mind concerns the validity of the instruments used. It is possible that the tests did not measure what they were intended to measure. Dressel and Mayhew (5) have suggested that test results may reflect familiarity or unfamiliarity with terminology and concepts. This is particularly true of tests of cognitive abilities. These authors noted the tendency of students with low pretest scores to make large gains and that of those with high pretest scores to make small gains and theorized that the large gain might be at least partly a gain in knowledge rather than in the ability which was supposedly being measured. So many factors influence test scores that it is difficult for the effect of a methodological change alone to be detected at a level that would be statistically significant.

It is also possible that there were features of both methods which could have made some contribution to this ability, and that the method which was optimal for some students could be detrimental for others. This possibility acquires some probability from the fact that though the mean gains on the critical thinking test ranged from -1.15 to +2.00, the range for individual gains was from -17 to +13. The same thing was true of the test of science reasoning, with a range for mean gain of -1.20 to 6.21 and a range for
individual gain of -10 to +17. If the tests have any validity, some individuals taught by both methods had a significant improvement, while others regressed. Such a wide variance among the individuals who made up the group is one reason, as McKeachie (8) noted, that experimental comparisons so often show no significant differences.

Still another possibility suggested is that what appears to be "general" ability in critical thinking is so complicated and involves such a large number of unique abilities and items of knowledge that it cannot be adequately measured by a written test. Cunningham (4) pointed out that written tests cannot be used to measure all desired outcomes. Other difficulties arise, however, when such devices as the student evaluation questionnaire are used, chiefly having to do with the objectifying and quantifying of such evidence. Yet who is a better judge of what is happening to him educationally than the student himself? If it is true as Schueler suggested that "learning succeeds to the degree that the learner feels that what he is learning matters to him," (10, p. 91) such a method may provide more insight into what is actually being accomplished than any other way. Still there is a pressing need for the development of tests which are designed to go beyond recall into more general behaviors in the cognitive domain. These shortcomings of the criterion measures used and the fact that the direction of gain favored the
inductive-deductive method encourage the making of similar studies with other criteria of accomplishment.

Time

It may be expecting too much to think that the influence of method in one course over as short a period as one semester could make a real difference in anything as complex as critical thinking ability. Bloom (1) suggested that some objectives require learning experiences in several sectors of the curriculum or a sequence of learning experiences over a period of several semesters if growth toward that objective is to be significant. He also stated that a research worker should not expect to obtain significant evidence of growth toward a new objective in a single study carried over a one-year period. He reported that observations and unpublished studies made by the Examiner's Office of the University of Chicago indicated that it was usually not possible to secure evidence that students had grown toward a particular objective until the second or third attempt and after repeated modifications in the learning experiences. The essential nature of the difficulty is probably due, as he suggested, to the fact that breaking away from habitual teaching practices takes much time, effort, and involvement from the teacher. This suggests the need to plan for a prolonged period of research. It seems quite possible that, as the instructor becomes more skilled in adapting learning
experiences in the application of the inductive-deductive method, significant student growth would be evidenced.

Interaction of Classroom Variables

In relation to the problem of evaluating research done in the classroom Mouly made this statement:

... problem situations are invariably so complex that attempting to reduce them to the operation of a single variable simply defeats the purpose of the experiment by seeking a partial answer out of the context of reality. In fact, the unwarranted transfer of the law of the single variable from the physical sciences—where it might conceivably be used—to education where it is essentially inappropriate, is responsible to a large degree for the relative unproductivity of educational experimentation to date. The present interpretation is that experimentation must operate in the context of the complex multivariate interaction which characterizes phenomena as they actually exist (7, pp. 327-328).

The method used is but one factor in the classroom situation; its relative merit varies with the subject of instruction, the mental levels and other pertinent traits of the students, and the teacher. Hartman (6) stated his opinion that this method-subject-student-teacher configuration may be the new dynamic organization to be introduced into studies of classroom technique.

Subject.—Science seems to be a subject peculiarly suited to the use of the inductive-deductive method, since this process is essentially that of what has come to be known as the scientific method. Yet as noted, there has been a big gap between
precept and practice. This has been especially true of laboratory experience. Another line for additional research is manifest by the obvious need of college laboratory manuals with an investigatory approach. Crooks (3) also pointed up this paradox of science instruction. Most of our present laboratory manuals do not have exercises to demonstrate the methods scientists use. It is as if science teachers expected their students to pick up scientific methods by osmosis. It is not safe to assume, however, that the characteristic qualities of the discipline will be automatically transferred to the learner. There is a need to devise laboratory exercises that will deliberately illustrate scientific methods. This has been done in the B. S. C. S. materials at the high school level, strangely enough with the help of college research personnel, but very little has been reported on the undergraduate college level. Winchester (11) and Korn (7) have made a start in this direction in the field of biology.

Student.—Another possibility for further research would be a study of the interaction of the method with the intellectual ability, science interest, and other traits in students which might be expected to influence response to different teaching methods. Differences which showed up in the fall group, which contained more students with a real science interest and with higher academic ability, suggest that this
might be a fruitful line of research. These differences seemed to be of more importance in achievement of the objectives than did the degree of past experience or the level of maturity.

Teacher.—It is not safe to assume that these methods would have the same results when carried out by another teacher. The experimental method described in this study is a difficult one to carry out; and for a teacher not convinced of its merit and not willing to spend his time and energy at a job that is both physically and mentally demanding, it would likely result in a fiasco. Hartman (6) has stated that the major analytical error which one is likely to commit in educational research is the assumption that the merits of any teaching method are independent of the caliber of the person using it. Other differences among teachers may also exert significant influences upon the effectiveness of their use of different approaches to teaching.

Values of the Method

Granted that teaching skill will largely determine the effectiveness of any method used, the inductive-deductive method built around a laboratory core as it was conducted in the general zoology classes at Hardin-Simmons University does have much to recommend it. The primary advantage is that it enables the student to learn from the material directly, to
understand that this direct study of material was the original source from which came our present-day knowledge, and to understand the scientific method and to make it a part of his intellectual equipment. It has become impossible to keep up with the factual information coming out of the explosion of knowledge. Students must be taught thinking processes, problem-solving techniques, broad concepts and generalization, and open-mindedness. It will take creative, dynamic teachers who are aware of the new discoveries and research findings in both the subject field and in the manner in which learning goals in the field are achievable, who are willing to experiment to find the best methods by which they can teach their students how to think, and who are convinced that science is a particularly effective area for learning these desired skills. Perhaps one big bonus will be, since people tend to teach as they were taught, that more teachers will be going out into classrooms who have experienced this type of learning environment in their college classrooms.
CHAPTER BIBLIOGRAPHY


APPENDIX

Organization of Course

Unit I  Introduction—Science as inquiry

Unit II  The Unity of Pattern in Living Things

1. Nature of life
   a. Basic structural organization—protoplasm, cells, tissues, organs, systems
   b. Basic functional organization—metabolism, responsiveness, reproduction

2. The Animal Way of Life as Revealed in the Protozoa

Unit III  The Origin and Continuity of Life (genetics and evolution)

Unit IV  The Diversity of Animal Life

1. Morphological, physiological, and ecological principles of animal life as revealed by various multi-cellular phyla—Complementarity of structure and function

2. Morphological, physiological, and ecological principles of animal life as revealed in vertebrate life and organization
   a. Energy utilization—transport, respiration, digestion, excretion
   b. Movement, support, and protection
   c. Integrative systems—nervous, endocrine
   d. Development of new individuals—reproduction and development
Deductive-Descriptive Approach

Unit II The Unity of Pattern in Living Things

Time: Two weeks, 4 1/2-hour class periods, 2 3-hour laboratories.

Objective: To obtain an understanding of the basic unity which characterizes all living organisms.

Experiences: 1. Lectures based on the following principles and concepts with elaboration giving information, illustrations, and explanations.

2. Laboratory


Evaluation: Objective test—short answer and multiple choice questions over information covered in the unit.

Principles and Concepts

I. Life is a complex series of dynamic interacting processes (metabolism, growth, responsiveness, reproduction) taking place within a highly organized system in interaction with its environment.

II. All organisms come from preexisting organisms. Biogenesis.
III. All organisms are fundamentally alike.

A. All organisms are composed of protoplasm, which is the physical basis of life.

1. Physical and Chemical organization.

Protoplasm has a unique physical and chemical organization, which varies to produce the potentialities of each particular group of organisms—accounts for the functional and morphological differences between organisms.

a. Physical characteristics

b. Chemical properties

2. Physiological Aspects.

All protoplasm has certain general properties which are the basic expressions of life—metabolism, growth, reproduction, responsiveness.


a. In all protoplasmic systems the ground-substance is differentiated into a superficial region (ectoplasm) and inner region (endoplasm). The ectoplasm serves as a boundary between the external environment and the inner part of the protoplasmic system and is specialized to perform many roles.

b. Protoplasmic systems are differentiated and organized into compartment units.
B. All organisms are composed of units with coordinated interactions.

1. The cell is the basic unit of organization both structural and functional.
   a. Cell theory
   b. How cells are studied
   c. Complementarity of structures and function

2. An animal is an organization of units differentiated and integrated for carrying on the life processes and this organization goes from one level to another as life becomes more complex.
   a. Grades of organization
   b. Tissues and their functions

C. In the protozoa all the life activities are carried on within the limits of a single plasma membrane—thus a complete organism and functionally and structurally not the same as metazoan cell.

1. Structure, basis of classification
2. Specialization for carrying on basic activities
3. Responsiveness
4. Reproduction
5. Relation to environment
6. Relation to metazoans
7. Relation to man
8. Position in the animal kingdom

Inductive-Deductive Approach

Unit II The Unity of Pattern in Living Things

Time: Two weeks, 6 2-hour class periods meeting in the laboratory.

Objectives: To develop the ability to make careful observations and to interpret data and to deduce appropriate conclusions.

To develop an understanding of the basic unity which characterizes all living organisms.

Experiences: Discussion, observation of slides, electron photomicrographs, living protozoa, case histories of famous experiments, and laboratory investigations used to explore the following problems.

1. What is life? What is the fundamental difference in that which is living and non-living? Is the gulf between the living and non-living really absolute? Can the same matter be alive, then dead, then alive again?

Discussion: Develop a definition of the word life that can apply to man or amoeba. Draw from experience the observable qualities of life—energy transformation, growth, reproduction, responsiveness. Give an example of each of these processes occurring in inanimate objects. Lead to conclusion that living things must have all—the whole
series of complex processes. What is different about these processes as they occur in living organisms? (Dynamic, originating within the organism, self initiated, interacting.)

Conclusion: Life is a complex series of dynamic interacting processes taking place within a highly organized system in interaction with its environment.

2. Where do living things come from? (Other living things) Cats always come from cats, or do they?

Discussion: Answer accepted for less than a century. Historical examples of drawing wrong conclusions; giraffe from camel and leopard; of poor observation; barnacle goose, worms in rotten wood; of wrong interpretation of data; fish in a pond that had been dry, eels that were full grown with never any young, flies that came out of rotting meat.

Case history of Redi's experiments to refute the theory of spontaneous generation. If you had made the same observations, what idea would suggest itself? What would be your hypothesis? How could you set up an experiment that would test such an hypothesis? What conclusions would you be justified in drawing? Had he shown that spontaneous generation was impossible?

Three hundred years of debate—reopened by Leeuwenhoek's discovery of the microscopic world.
Laboratory investigation. Take a few pieces of hay or grass, chop up and place in two cups of water and boil. Pour half into open container and half into closed container. After several days make a temporary mount. How do you interpret your results? How would the abiogenesist explain these results? the biogenesist? Suggest an experiment that would prove who was right. (Control)

Case history of the controversy—Needham, Spallanzani, Pouchet, Pasteur.

What principles concerning scientific investigation could you formulate from the previous discussion?

3. In what ways are all living things alike? Is there a basic unity of pattern? What is the physical basis of life? the chemical basis?


Observation of living amoeba.

Demonstration of properties of a colloid.

Discussion leading to the generalization that protoplasm has a unique physical and chemical organization which varies to produce the potentialities of each particular group of organisms, accounts for the functional and morphological differences between organisms.
4. We are not just one blob of protoplasm like a slime mold. How are protoplasmic systems structured so that they can function?

Laboratory investigations:


Examination of electron photomicrographs.


Discussion: Interpretation of results and conclusions.

5. How can all the life activities be carried on within the limits of a single plasma membrane?

Laboratory investigations:


Evaluation: Reports of laboratory investigations.

Test designed to test objectives.
Course Evaluation

Science major or minor  Non-science major  Male  Female  
Fr.  So.  Jr.  Sr.  

1. What did you see as the most characteristic feature of this course?

2. What did you perceive to be the goals of the class?

3. What were the relationships between the course experiences which were provided and the goals which you see in the course?

4. What habits of study have you used in preparation?

5. In what way did you make use of your text?

6. Did you seek to find answers to problems from sources other than your text and class experiences?
7. What tangible effects has the course had on you?

8. What features or experiences in the class were most helpful to you?

9. Which features were least helpful?

10. What specific suggestions would you make for the improvement of the course?


<table>
<thead>
<tr>
<th>Score Point Difference Between Matched Pairs</th>
<th>Number of Students Showing Differences</th>
<th>Score Point Difference Between Matched Pairs</th>
<th>Number of Students Showing Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Science Test</td>
<td>ACT</td>
<td>Composite Test</td>
<td>ACT</td>
</tr>
<tr>
<td>0-1</td>
<td>23</td>
<td>19</td>
<td>0-2</td>
</tr>
<tr>
<td>2-3</td>
<td>9</td>
<td>10</td>
<td>3-5</td>
</tr>
<tr>
<td>4-5</td>
<td>8</td>
<td>12</td>
<td>6-8</td>
</tr>
<tr>
<td>6-7</td>
<td>3</td>
<td>3</td>
<td>9-11</td>
</tr>
<tr>
<td>8-9</td>
<td>0</td>
<td>12-14</td>
<td>4</td>
</tr>
<tr>
<td>10-11</td>
<td>2</td>
<td>15-17</td>
<td>0</td>
</tr>
<tr>
<td>12-20</td>
<td>0</td>
<td>18-20</td>
<td>1</td>
</tr>
<tr>
<td>21-23</td>
<td>3</td>
<td>24-26</td>
<td>1</td>
</tr>
<tr>
<td>27-29</td>
<td>1</td>
<td>30-32</td>
<td>2</td>
</tr>
<tr>
<td>33-35</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE XVI

Differences Between Matched Pairs on the Several Criterion Measures Used in Matching Groups
TABLE XVII

DISTRIBUTION OF RETEST SCORES ON A TEST OF SCIENCE REASONING AND UNDERSTANDING FOR THE INDUCTIVE-DEDUCTIVE AND THE DEDUCTIVE-DESCRIPTIVE GROUPS

<table>
<thead>
<tr>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>52-54</td>
<td>1</td>
<td>100.0</td>
<td>52-54</td>
<td>5</td>
<td>100.0</td>
</tr>
<tr>
<td>49-51</td>
<td>0</td>
<td>97.8</td>
<td>49-51</td>
<td>4</td>
<td>97.8</td>
</tr>
<tr>
<td>46-48</td>
<td>1</td>
<td>97.8</td>
<td>46-48</td>
<td>3</td>
<td>97.8</td>
</tr>
<tr>
<td>43-45</td>
<td>3</td>
<td>95.5</td>
<td>43-45</td>
<td>2</td>
<td>95.5</td>
</tr>
<tr>
<td>40-42</td>
<td>2</td>
<td>93.2</td>
<td>40-42</td>
<td>2</td>
<td>93.2</td>
</tr>
<tr>
<td>37-39</td>
<td>7</td>
<td>90.7</td>
<td>37-39</td>
<td>3</td>
<td>90.7</td>
</tr>
<tr>
<td>34-36</td>
<td>7</td>
<td>88.6</td>
<td>34-36</td>
<td>10</td>
<td>88.6</td>
</tr>
<tr>
<td>31-33</td>
<td>7</td>
<td>86.4</td>
<td>31-33</td>
<td>6</td>
<td>86.4</td>
</tr>
<tr>
<td>28-30</td>
<td>6</td>
<td>84.1</td>
<td>28-30</td>
<td>4</td>
<td>84.1</td>
</tr>
<tr>
<td>25-27</td>
<td>5</td>
<td>81.8</td>
<td>25-27</td>
<td>7</td>
<td>81.8</td>
</tr>
<tr>
<td>22-24</td>
<td>3</td>
<td>79.5</td>
<td>22-24</td>
<td>6</td>
<td>79.5</td>
</tr>
<tr>
<td>19-21</td>
<td>1</td>
<td>77.3</td>
<td>19-21</td>
<td>2</td>
<td>77.3</td>
</tr>
<tr>
<td>16-18</td>
<td>0</td>
<td>75.0</td>
<td>16-18</td>
<td>2</td>
<td>75.0</td>
</tr>
<tr>
<td>13-15</td>
<td>1</td>
<td>72.7</td>
<td>13-15</td>
<td></td>
<td>72.7</td>
</tr>
</tbody>
</table>
TABLE XVIII
DISTRIBUTION OF RETEST SCORES ON THE WATSON–GLASER
CRITICAL THINKING APPRAISAL FOR THE INDUCTIVE–
DEDUCTIVE AND THE DEDUCTIVE–
DESCRIPTIVE GROUPS

<table>
<thead>
<tr>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
<th>Class Interval</th>
<th>Frequency</th>
<th>Cumulative Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>91-93</td>
<td>2</td>
<td>100.0</td>
<td>91-93</td>
<td>1</td>
<td>100.0</td>
</tr>
<tr>
<td>88-90</td>
<td>2</td>
<td>95.5</td>
<td>88-90</td>
<td>0</td>
<td>97.8</td>
</tr>
<tr>
<td>85-87</td>
<td>2</td>
<td>90.9</td>
<td>85-87</td>
<td>1</td>
<td>97.8</td>
</tr>
<tr>
<td>82-84</td>
<td>2</td>
<td>86.4</td>
<td>82-84</td>
<td>0</td>
<td>95.5</td>
</tr>
<tr>
<td>79-81</td>
<td>5</td>
<td>81.0</td>
<td>79-81</td>
<td>6</td>
<td>95.5</td>
</tr>
<tr>
<td>76-78</td>
<td>4</td>
<td>75.0</td>
<td>76-78</td>
<td>6</td>
<td>81.8</td>
</tr>
<tr>
<td>73-75</td>
<td>3</td>
<td>69.9</td>
<td>73-75</td>
<td>4</td>
<td>68.1</td>
</tr>
<tr>
<td>70-72</td>
<td>9</td>
<td>65.2</td>
<td>70-72</td>
<td>8</td>
<td>59.2</td>
</tr>
<tr>
<td>67-69</td>
<td>7</td>
<td>59.6</td>
<td>67-69</td>
<td>4</td>
<td>49.0</td>
</tr>
<tr>
<td>64-66</td>
<td>4</td>
<td>42.7</td>
<td>64-66</td>
<td>5</td>
<td>31.7</td>
</tr>
<tr>
<td>61-63</td>
<td>4</td>
<td>33.6</td>
<td>61-63</td>
<td>3</td>
<td>20.5</td>
</tr>
<tr>
<td>58-60</td>
<td>2</td>
<td>22.7</td>
<td>58-60</td>
<td>2</td>
<td>13.6</td>
</tr>
<tr>
<td>55-57</td>
<td></td>
<td></td>
<td>55-57</td>
<td>1</td>
<td>9.1</td>
</tr>
<tr>
<td>52-54</td>
<td></td>
<td></td>
<td>52-54</td>
<td>2</td>
<td>6.6</td>
</tr>
<tr>
<td>49-51</td>
<td></td>
<td></td>
<td>49-51</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>46-48</td>
<td></td>
<td></td>
<td>46-48</td>
<td>1</td>
<td>2.2</td>
</tr>
</tbody>
</table>
I. Multiple Choice: On the answer sheet circle the letter corresponding to the correct answer.

1. The vessels which carry the blood away from the heart to all parts of the body are (a) arteries (b) capillaries (c) veins (d) bronchioles.

2. The blood cells which transport oxygen in the form of oxyhemoglobin are (a) erythrocytes (b) leucocytes (c) platelets (d) plasma.

3. The part of the heart which receives blood directly from the rest of the body is (a) left ventricle (b) right atrium (c) right ventricle (d) aorta.

4. The food material which is absorbed through the walls of the villi is transported first by (a) carotid arteries (b) jugular vein (c) coronary arteries (d) hepatic portal vein.

5. All of the following statements about arteries are true except (a) they are thick-walled (b) they are elastic (c) they pulsate (d) they contain valves.

6. All of the following arteries carry oxygenated blood except (a) aorta (b) pulmonary artery (c) carotid (d) subclavian.

7. In the pulmonary circulation the blood flows through (a) liver (b) lungs (c) skin (d) entire body.

8. The liquid that bathes all the cells of the body is (a) blood (b) tissue fluid (c) plasma (d) fibrinogen.

9. All of the following are found in plasma except (a) fibrinogen (b) antibodies (c) hormones (d) starch.

10. Iron is needed for (a) formation of red blood cells (b) formation of white blood cells (c) prevention of goiter (d) prevention of diabetes.

11. An organ which acts as a reservoir of excess blood is (a) spleen (b) pancreas (c) heart (d) kidney.

12. An inherited disease in which blood does not clot is (a) thrombosis (b) hemophilia (c) anemia (d) diabetes.

13. The blood type which is known as the universal recipient is (a) 0 negative (b) AB positive (c) AB negative (d) 0 positive.

14. The protective substance which is produced in the blood in response to an invading antigen is (a) antibody (b) fibrin (c) leucocyte (d) platelet.

15. Most people are (a) Rh positive (b) Rh negative.

16. The passageway of the trachea is kept open by rings of (a) striated muscle (b) cartilage (c) ligaments (d) smooth muscle.
17. Inhalation is caused by all of the following except (a) lowering of
diaphragm (b) amount of oxygen in the air (c) level of CO₂ in the blood
(d) raising of the ribs.

18. Internal respiration takes place in the (a) nasal passages (b) lungs
(c) cells (d) arteries.

19. The functional unit of external respiration is (a) alveolus (b) bronchial
tubes (c) cells (d) nasal passages.

20. The respiratory center which controls the rate of respiration is located
in (a) lungs (b) trachea (c) medulla (d) cerebellum.

II. The six lettered headings below are followed by a list of numbered state-
ments. For each numbered statement choose the one lettered heading which
is most closely related to it.

A. Thyroid gland
B. Parathyroid gland
C. Islets of Langerhans
D. Pituitary gland
E. Suprarenals or adrenal gland
F. Gonads—ovary or testes

1. The hormone secreted by this gland regulates male secondary sexual
characteristics.

2. Injury to the cortex of this gland results in addisons disease which ends in
death if not treated.

3. The function of this gland is to regulate the calcium content of the blood.

4. These glands secrete the hormone insulin.

5. This gland is a bilobed gland lying in front of the trachea below the larynx.

6. Cretinism may result from an undersecretion of this gland in infants.

7. This gland is sometimes called the "master" gland because of its influence
on the other glands.

8. This gland is located at the base of the brain in a depression of the
sphenoid bone.

9. This gland is located in the pancreas.

10. Injections of the hormone secreted by this gland are used to control sugar
diabetes.

III. The five lettered headings below are followed by a list of numbered
statements. For each numbered statement choose the one lettered heading
which is most closely related to it.

A. Cerebrum
B. Cerebellum
C. Medulla
D. Spinal cord
E. Autonomic nervous system
1. The center for thought, reasoning, memory.
2. Regulates diameter of blood vessels.
3. Center of reflex reactions.
4. Coordination of muscles
5. Respiratory center located here
6. Sensory area for sight
7. Increasing size is coordinated with increasing intelligence
8. Regulates peristalsis.
9. Pathway for impulses to and from brain.
10. Originates voluntary acts.

IV. Choose the best answer from the numbered list and place it in the blank after the corresponding letter on the answer sheet.

a. Structures in the inner ear which govern balance
b. The tough white outer covering of the eye.
c. A small bone in the middle ear which transmits sound vibrations.
d. A part of the eye which controls the amount of light admitted.
e. The inner coat of the eye which contains the sense receptors, the rods and cones.
f. The passageway from the middle ear to the pharynx which equalizes pressure on the ear drum.
g. A jelly like material found in the space between the back of the eyeball and the lens.
h. A biconvex, transparent structure which bends the light rays as they enter the eye.
i. A structure in the inner ear which helps to orient you to your position in relation to gravity.
j. Sense receptors located on the tongue.
V. Matching. Next to each letter write the number of the specific structure most closely related to it.

1. Esophagus       6. Vermiform appendix
2. Stomach         7. Duodenum
3. Liver           8. Gall bladder
5. Colon           10. Villi

a. Reabsorption of water takes place here.
b. Stores glycogen.
c. Produces hydrochloric acid.
d. A vestigial organ serving no known purpose.
e. Contains capillaries and lymph vessels to absorb amino acids, glucose, and fats.
f. Produces enzymes which are used in the duodenum to digest proteins, starches, and fats.
g. Stores bile to be used in emulsifying fats.
h. Serves as a passageway for food from the mouth to the stomach.
i. Receives the concentrated, indigestible remains of food for elimination.
j. Most of chemical digestion takes place here.

VI. Select the correct choice for each of the following statements.

1. The animal which is not included in the same phylum as the others is a
   (a) amoeba    (b) paramecium   (c) euglena   (d) termite   (e) trypanosome.

2. Two warm blooded groups of vertebrates are (a) mammals and sharks (b) birds and amphibia (c) mammals and birds (d) amphibia and reptiles (e) mammals and amphibia.

3. An animal that is not an invertebrate is (a) jellyfish (b) starfish (c) goldfish (d) sponge (e) plasmodium.

4. All of the following phyla are worms except (a) Coelenterata (b) Nemathelmintes (c) Platyhelminthes (d) Annelida.

5. All of the following are parasitic worms except (a) leech (b) sheep liver fluke (c) hookworm (d) ringworm (e) tapeworm.

6. Animals with backbones are classified as (a) invertebrates (b) vertebrates (c) protozoa (d) mollusks (e) echinoderms.

7. A phylum that is characterized by radial symmetry is (a) Chordata (b) Aves (c) Echinodermata (d) Arthropoda (e) Crustacea.

8. The octopus, clam, and snail are alike in (a) having a backbone (b) having jointed legs (c) being classified as mollusks (d) being classified as arthropods (e) having a three chambered heart.

9. Animals having a chitinous exoskeleton and jointed legs are classified as (a) Aves (b) Arthropods (c) Coelenterates (d) Chordates (e) Echinoderms.

10. Spiders may be distinguished from insects because they have (a) two antennae (b) jointed legs (c) eight legs (d) a separate head, thorax, and abdomen (e) biting mouth parts.
11. Animals that possess a notochord are classified as (a) Crustacea (b) Coelenterates (c) Chordates (d) Notobrates (e) Chilopoda.

12. All of the following are classes of vertebrates except (a) Amphibia (b) Osteichthyes (c) Agnatha (d) Mammalia (e) Arthropoda.

13. An animal with a four-chambered heart is a (a) lungfish (b) whale (c) codfish (d) shark (e) eel.

14. The characteristic that makes an opossum a mammal is that it (a) produces milk (b) has a dorsal hollow nerve cord (c) has a backbone (d) has a closed circulatory system (e) has external development of its young.

15. The definite changes through which insects pass in development are due to (a) metamorphosis (b) cephalization (c) symmetry (d) metamerism (e) acidosis.

VII. Select the correct choice for each of the following statements.

1. A group of similar cells performing the same function is known as a(n) (A) organ (B) tissue (C) system (D) layer.

2. An axon is part of a (A) nerve cell (B) muscle cell (C) bone cell (D) cartilage cell.

3. A tissue which contains an inorganic matrix is (A) epithelium (B) bone (C) muscle (D) vascular.

4. A tissue specialized for contraction is (A) nerve (B) bone (C) muscle (D) adipose.

5. The germ layer from which the skeleton develops is (A) ectoderm (B) mesoderm (C) endoderm.

6. The germ layer from which the nervous system develops is (A) ectoderm (B) mesoderm (C) endoderm.

7. The germ layer from which the lining of the intestinal tract develops is (A) ectoderm (B) mesoderm (C) endoderm.

8. All of the following are part of a cell except (A) nucleus (B) mitochondria (C) chromatin (D) tissue fluid.

9. Homologous structures (A) always have same function (B) develop from different structures embryologically (C) are similar in structure (D) none of these.

10. All of the following animals show metamerism except (A) sponges (B) earthworms (C) grasshoppers (D) man.

11. The scientific name for man should be written (A) homo sapiens (B) Homo sapiens (C) Homo sapiens (D) Homo sapiens.

12. All of the following are physical properties of protoplasm except (A) exists as a colloid (B) translucent (C) viscous (D) contains C, H, O, and N.
13. The telophase of mitotic cell division is the stage in which (A) the chromosomes duplicate themselves (B) the chromosomes pull apart and migrate toward the ends of the cell (C) the cytoplasm divides forming 2 daughter cells (D) the chromosomes line up on the equatorial plane of the cell.

14. Bilateral symmetry is exhibited by the (A) Porifera (B) Protozoa (C) Cnidaria (D) Chordates.

15. A somatic cell may be any of the following except (A) ovum (B) smooth muscle cell (C) squamous cell (D) neuron.

16. The ability to cast off an injured part in order to replace it with a new one is called (A) autotomy (B) gametogenesis (C) biogenesis (D) cleavage.

17. Animals which live in the same environment in a mutually helpful relationship are said to practice (A) parasitism (B) symbiosis (C) commensalism (D) regeneration.

18. All of the following are stages in embryological development except (A) blastula (B) morula (C) gastrula (D) trophozoite.

19. A true coelom is possessed by (A) flat worms (B) hydra (C) round worms (D) earthworms.

20. The theory of biogenesis states that (A) all living things come from other living things (B) it is possible for life to arise from non-living things (C) spontaneous generation occurs in bacteria (D) every form of life that is now on the earth was created in its present form at the beginning.

VIII. Each of the following is followed by five suggested answers. Select the one answer which is best in each case.

1. All of the following terms apply to sexual reproduction except (a) maturation (b) fission (c) polar bodies (d) zygote (e) gametogenesis.

2. When a red bull is mated with a white cow producing a spotted calf, the gene for red color (a) is dominant (b) is recessive (c) lacks dominance (d) is sex-linked (e) is a mutation.

3. Fertilization functions in all of the following except (a) initiating embryonic development (b) restoring the diploid no. of chromosomes (c) producing a zygote (d) uniting two distinct lines of heredity (e) producing a sperm.

4. The criss-cross pattern of inheritance in hemophilia, the bleeder's disease, is due to the fact that (a) it is a sex-linked characteristic (b) it is a recessive trait (c) it is a dominant trait (d) only men can have it (e) it is due to a mutation.

5. The structure within the uterus where the actual exchange of O₂ and CO₂ takes place is (a) amniotic sac (B) umbilical cord (c) uterine wall (d) placenta (e) umbilical artery.

6. All of the following are a part of the female reproductive system except (a) vas deferens (b) Fallopian tube (c) Graffian follicle (d) vagina (e) clitoris.

7. A gamete is most closely related to (a) testis (b) ovum (c) zygote (d) morula (e) gonad.
8. Of the following, the term that includes all the others is (a) mitosis (b) reduction division (c) oogenesis (d) maturation (e) spermatogenesis.

9. Development of an organism from an unfertilized egg is known as (a) fertilization (b) conjugation (c) parthenogenesis (d) maturation (e) oogenesis.

10. The species number of chromosomes is restored in a new individual by the process of (a) regeneration (b) fertilization (c) reduction-division (d) parthenogenesis (e) metamorphosis.

11. An animal that develops a placenta is a (a) goldfish (b) bird (c) lizard (d) salamander (e) cow.

12. Color blindness in humans is a (a) sex-linked trait (b) dominant trait (c) blended trait (d) hybrid trait (e) pure trait.

13. Chromatin is to chromosomes as DNA is to (a) daughter cells (b) mitosis (c) genes (d) maturation (e) electron microscope.

14. The chromosome number of human gametes is (a) 12 (b) 23 (c) 46 (d) higher for eggs than sperms, (e) higher for sperms than eggs.

15. Of the following cells the only one to have the haploid number is (a) skin (b) muscle (c) nerve (d) bone (e) ovum.

16. Polar bodies are formed during (a) regeneration (b) oogenesis (c) prophase (d) spermatogenesis (e) fertilization.

17. When hybrids are crossed (Bb x Bb), the genotypic ratio of the offspring would be (a) 1:1 (b) 1:2:1 (c) 3:1 (d) 4:1 (e) 3:2.

18. If a pair of hybrid blacks are mated and there are four offspring, we would expect their appearance or phenotype to be (a) all black (b) 3 black, 1 white (c) 1 black, 3 white (d) 2 black, 2 white (e) all white.

19. If two parents who are heterozygous for brown eyes have four children, the eye colors of the children may be (a) all brown (b) 3 brown, 1 blue (c) 2 brown, 2 blue (d) 1 brown, 3 blues (e) any of the above combinations.

20. If a man who is colorblind marries a woman who is pure normal for color vision the chances of their sons being colorblind is (a) 0 (b) 100% (c) 50:50 (d) 75:25 (e) 25:50:25.

II. Select the correct choice to complete each of the following statements.

1. The gland which functions to help regulate body temperature is (A) sebaceous (B) sweat (C) lacrimal (D) pancreas.

2. New cells to replace those being worn away on the surface of the skin are produced by the (A) dermis (B) stratum germinativum (C) papilla in hair follicle (D) cuticle.

3. All of the following are functions of the skeletal system except (A) production of red blood cells (B) calcium storage (C) support and form (D) contraction.
4. The tough white connective tissue sheet which covers the outside of a bone (A) produces white blood cells (B) provides an attachment for muscle and tendons (C) gives the bone its shape (D) stores calcium.

5. The liquid which is enclosed in a membrane between joints to serve as a cushion is (A) tissue fluid (B) synovial fluid (C) blood (D) plasma.

6. The bones are supplied with food and O₂ through blood vessels contained in (A) Haversian canals (B) the marrow (C) osteoblasts (D) the epiphyseal line.

7. The all or none principle applies to the contractions of (A) a single muscle fiber (B) the entire skeletal muscle (C) all the muscles in an appendage (D) the bending of a joint.

8. A muscle which straightens a joint exhibits the type of action known as (A) flexion (B) extension (C) depression (D) adduction.

9. A person needs to breathe hard after violent exercise in order to (A) relax (B) pay the O₂ debt built up in the muscles (C) speed up circulation (D) get rid of excess body water.

10. The ribs which articulate with the thoracic vertebrae but are not attached to the sternum are called (A) true ribs (B) false ribs (C) floating ribs (D) none of these.

X. Select the correct choice for each of the following statements.

1. Two waste materials resulting from metabolism are (a) oxygen and water (b) CO₂ and urea (c) oxygen and urea (d) ATP and carbon dioxide.

2. Urea is removed from the blood by (a) lungs (b) liver (c) kidneys (d) spleen.

3. The functional unit in the kidney is (a) nephron (b) neuron (c) alveolus (d) capillary.

4. The part of the skin which acts as an excretory organ is (a) pores (b) sebaceous glands (c) sweat glands (d) stratum germinativum.

5. The structure through which protocox escrete waste is (a) cell membrane (b) trichocyst (c) oral groove (d) cilia.

6. The tuft of capillaries known as the glomerulus functions (a) as a filter (b) to reabsorb useful products into the blood (c) to concentrate the urine (d) to get rid of protein in the blood.

7. Urine leaves the bladder through the (a) glomerulus (b) nephron (c) ureter (d) urethra.

8. All of the following are organs of excretion except (a) skin (b) lungs (c) liver (d) colon.

9. According to Darwin's thesis the struggle for existence results in natural selection which means (a) the survival of the fittest (b) all animals have an equal opportunity to survive and produce offspring (c) the weak tend to be protected by nature (d) animals tend to reproduce in numbers that match their food supply.

10. Evolution means (a) that man descended from apes (b) that man came from a monkey (c) a mutation of the apes became man (d) the process by which organisms have changed through time, both structurally and functionally, to make possible the change of organisms from simple to more complex forms.
Protozoa and the Animal Way of Life

Purpose: To come to a better understanding of how animals meet the problems of living by closely examining the way in which Paramecium performs its life functions, since all the reproductive and metabolic functions are carried out within the confines of a single cell.

Structure and Movement: With a pipette make a ring of methyl cellulose solution about the diameter of a lead pencil in the center of a clean slide. Place one drop of Paramecium culture inside the ring and add a cover slip, examine under low power. What is the general shape? Do they move slowly or rapidly? When the methyl cellulose begins to diffuse into the water and slow down your paramecium, switch to high power to observe motion in detail. Is the same end usually in front as the paramecium moves? Which is the anterior end? Does the shape vary as the animal moves? Is there a definite top and bottom?

Add a few cotton fibers to your slide and note the reaction when the paramecium bumps into one of them. What do the reactions of the paramecium to an obstacle suggest about its behavior?

Add a small drop of carmine solution to your slide. Under high power observe the surface of the animal. What seems to be the function of the cilia? Notice carefully the passage of the carmine particles along the surface. What does their pattern of movement suggest about the activities of the cilia? In higher animals the cilia do not move the entire animal but are found localized in the respiratory passages or the sperm ducts. What function might they possibly serve in these areas?

Functions: Make an outline drawing including all the parts that you can observe. What structures are included in the diagram in your text that you cannot see?

Suppose that you are a biologist examining this organism for the first time. Number the structures which you see and write below your hypothesis as to what function you think that structure might possibly perform. Try to identify structures which could (1) serve for food intake, (2) be concerned with digestion of food, (3) discharge undigested food remains, (4) serve for O₂ and CO₂ exchange, (5) move the animal from place to place, (6) excrete fluid wastes, (7) serve as a hydrostatic organ.

Try to locate the contractile vacuole at either end of the animal. Do you see both of them at the same time? Is the fluid inside the vacuole clear or granular? Can you see the radiating canals which seem to empty into the contractile vacuoles? How many contractions does it make in one minute?

From the biological literature we learn (1) Urea (an end product of nitrogen metabolism) has not been found in any significant amount in the fluid of the contractile vacuole. (2) When vacuoles do not function, the body of the paramecium swells. (3) Amoeba also have contractile vacuoles. The injection of distilled water results in increased contraction of the vacuole.

On the basis of this information and your observations, what is the most likely function of the contractile vacuole?

Kitching found that water intake with food vacuoles is only a fraction of what is expelled in the food vacuole. That does this indicate to you about the major method of water entry into the body of the paramecium?

Add a drop of iodine or methylene blue to the slide. What structures can you see now which you did not see previously? Add these to your diagram. Have any of the structures you saw previously disappeared?
Ingestion and Digestion: Prepare a fresh ring of methyl cellulose and add a drop of Paramecium culture. Add a drop of yeast suspension which has been colored with Congo red. Add cover slip.

Watch the colored yeast cells being ingested. Where do they enter the body of the Paramecium? Notice that they are enclosed in a tiny droplet to form a food vacuole. Where does this form? After 2 or 3 minutes, what change do you observe in the position and color of the vacuole? Are there further color changes as you continue to watch? Congo red is an indicator which changes color as the pH changes. What change is apparently taking place in the food vacuoles?

Trace the path of the food vacuole as it moves through the cytoplasm. Are there any undigested residues being discarded and ejected to the outside of the animal? Is there a particular locus where this takes place?

Behavior: Observe two test tubes full of Paramecium. Place one upright under even illumination. Stopper the second tube, and wrap the top half in foil and illuminate the bottom half.

What response do paramecium make to gravity? Are they positively or negatively geotactic?

What response did they make to light? Are they positively or negatively phototactic? Why was it necessary to turn the test tube on its side? Of what value to the organism is this response to light?

Check the chemotactic response to acetic acid, sugar, and salt by dipping a thread in various solution and laying them across your culture.

Amoeba and Euglena—Examine living cultures and stained slides.

How does the amoeba compare in structure with a single somatic cell? What is its method of locomotion? How does it take in food material? How does it maintain homoeostasis with regard to water content? What device does it have for digestion? How would you assume that its respiratory needs are met? In what ways is it similar to the paramecia? to euglena? In what ways is it different from paramecium or euglena?
Phylum Annelida

Class Oligochaeta — The Earthworm—

Lumbricus terrestris

Materials needed:

Living earthworms, Petri dishes, preserved earthworms, paraffin lined dissecting tray, straight pins, scissors, scalpel, prepared slides of earthworm cross sections, microscope, hand lens, light, red cellophane.

I. Observe living earthworms for movement, external features, dorsal blood vessel, reaction to a dark cover over one side of dish, on moist sand, to sound, to vibrations, to strong light, to red light.

1. What do you observe about the length and girth of the earthworm as it moves?
2. What reaction does the earthworm make to touch on the anterior end? Posterior end?
3. In which direction does the blood flow in the dorsal blood vessel?
4. Describe the changes in the dorsal blood vessel which occur as the blood is forced along.
5. Describe the earthworm's response to light and dark environments. What structures are responsible for this response? How does this correlate with what you know about the habits of the earthworm?
6. Describe the earthworm's response to moist sand.
7. Is there any difference in the response to strong white light and that to red light?

External features:

II. 1. Observe the external features on your preserved specimen. Count the segments and compare with the number obtained by others.
2. Identify the prostomium, mouth, clitellum, on segment 15 the two openings to the vasa deferentia surrounded by swollen lips, the seminal groove which conducts the semen during copulation, on segment 14 the two openings of the oviduct, the four openings to the seminal receptacles, one pair between segments 9 and 10 and the other between 10 and 11, the two nephridiopores on the lateral-ventral surface of each segment except the first three and the last one (Use low power on microscope).
3. Locate the setae by pulling the worm through your fingers. Examine with a hand lens. Note how they are attached to the body and the direction in which they point.
4. Locate the anus near the posterior end of the body.
5. Observe the cuticle which covers the entire body.
6. How many segments are included in the clitellum? Is it always at the same distance from the anterior end—Which segment does it start on—What is the function of the clitellum?
7. In which direction do the setae point? Do they arise from elevations or depressions? How are they moved? Is there a difference in the setae on segment 36?
III. Internal Anatomy

1. To dissect the earthworm make an incision with fine pointed scissors through the dorsal body wall about one inch posterior to the clitellum and extend it anteriorly to the prostomium. Hold the lower blade almost parallel to the dorsal body wall and lift as you cut to avoid injury to the soft body parts within the body cavity. Place the worm, dorsal side up, in a paraffin-lined dissecting tray. Carefully spread the body wall by cutting the internal partitions septa away from the dorsal and lateral surface with a sharp scalpel and expose the internal organs. Use straight pins to attach the body wall to the paraffin on either side. Note the perforations in the septa which permit a free flow of fluids in the coelom from one segment to another. Are the septa found as continuations of the external indentations of the body wall or are they at some other location?

2. Trace the digestive system from the mouth through the large muscular pharynx (to segment 5), the esophagus (to segment 15), the crop, the thick-walled gizzard, the intestine, and the anus. Note the irregular brownish mass of cells covering the intestine, the chloragogue layer.

3. Trace the dorsal blood vessel forward along the dorsal surface of the intestine over the crop and gizzard to the esophagus. Note the 5 pairs of hearts which encircle the esophagus in segments 7, 8, 9, 10, and 11.

4. Observe the paired seminal vesicles with their three large lobes alongside the esophagus (9-15), the two pairs of seminal receptacles (9-10), the testes (in the seminal vesicles, require very difficult dissection.) Ovaries and oviducts are too small to be seen clearly. What is the function of these organs?

5. The nephridia can usually be seen most clearly as coiled tubes in the segments behind the gizzard. (Use stereo-microscope.) What is the function?

6. Expose the brain at the anterior region of the pharynx. Remove a small section of the intestine in order to see the nerve cord on the ventral body wall. Note the enlarged ganglion in the center of each segment. Is there a nerve ganglion in each body segment? Do any segments have more than one ganglion? How many nerves arise from a single ganglion? Is this number constant in each of the segments? Draw a short length of the nerve cord including five or six ganglia and the connecting nerves.

Conclusions:

1. What parts of the earthworm are derived from the ectoderm, mesoderm, endoderm?
2. What is the relation of the coelom to these layers?
3. What advances does the earthworm show over the previous phylum in the circulatory system?
4. What advantage to the earthworm is the typhlosole?
5. How is reproduction accomplished in the earthworm?
6. What evidence did you find of sense organs?

Class Hirudinea

Observe the plastic mount of the leech.

What adaptations have been made for parasitic existence.
BIBLIOGRAPHY

Books


Lindquist, Everet Franklin, Design and Analysis of Experiments in Psychology and Education, Boston, Houghton Mifflin, 1953.


Articles


Hanson, Earl D., "Teaching and Research--the Gap and Its Cure," CUES News, II (April, 1966), 1-5.


Sturgis, Horace W., "The Relationship of the Teacher's Knowledge of the Student's Background to the Effectiveness of Teaching: A Study of the Extent to Which the Effectiveness of Teaching is Related to the Teacher's Knowledge of the Student's Personal Background," Dissertation Abstracts, XIX, No. 11 (1959), 2884.


Reports

Eiss, Albert F., director, Guidelines for Improving College Science Programs, Harrisburg, Pennsylvania, The Pennsylvania Academy of Science and the Pennsylvania Department of Public Instruction with the cooperation of the National Science Teachers Association, 1964.

Publications of Learned Organizations


Encyclopedia Articles


Unpublished Materials


Tests and Test Manuals

