Implications of literature for and comparison of two laboratory teaching methods in general college biology for non-biology students : demonstration method and the individual laboratory method
by Charles Richard King

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF EDUCATION
Montana State University

Abstract:
The study resulted from the belief that the demonstration teaching method in biology laboratory teaching could be.as effective as the individual teaching method. The investigation was two-directional. Literature was reviewed to determine the validity of the belief and to substantiate the kinds of experiences and materials that would characterize an experimental demonstration teaching method which emphasized the use of multi-sensory aids in developing effective learning of principles of biology. Literature provided this, and made possible the experimental part of the study - the effectiveness of the demonstration method.

The experimental study was conducted in a one semester course of 18 weeks in one university with the selection of 154 non-biology students in 7 sections of general college biology. All laboratory sections were scheduled in two two-hour periods. The 77 students forming the control group were taught by four instructors each teaching one laboratory section for two two-hour periods per week by the individual laboratory teaching method; the experimental group of 77 students was taught by the author for the required time of two one-hour periods per week by the demonstration teaching method that made extensive use of multi-sensory aids. The second hour of each scheduled laboratory period was made optional for self-study. A standardized achievement test consisting of two forms was administered, one at the beginning and the other at the end of the semester, to measure the effectiveness of the experimental group on achievement gain.

The following summary findings resulted from the review of liter- . ature and the measurement of achievement differences: (1) there was no statistically significant difference in achievement gain between the two groups; (2) the findings indicate that females do slightly better by the individual method and males also by the individual laboratory method; (3) students of upper class standing do slightly better by the individual method; (4) students in the individual laboratory method do better on the application of laboratory experiences; (5) principles of learning can serve satisfactorily as guidelines for the use of appropriate multi-sensory aids in presenting the major principles of general biology; and (6) a combination of demonstrations and individual laboratory work will benefit the non-biology student in the laboratory.

Based upon the findings of this study, one conclusion can be drawn. If the limited sample were to be expanded and the same experiment be conducted under the same conditions and the same results be obtained, one could conclude that the demonstration method making extensive use of multi-sensory aids would be a satisfactory approach in meeting the laboratory needs of non-college biology students in general college biology.

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IMPLICATIONS OF LITERATURE FOR AND COMPARISON OF TWO LABORATORY TEACHING METHODS IN GENERAL COLLEGE BIOLOGY FOR NON-BIOLOGY STUDENTS: DEMONSTRATION METHOD AND THE INDIVIDUAL LABORATORY METHOD

by

CHARLES RICHARD KING

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

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Approved:

Robert J. Thibeault
Head, Major Department

M. Fred Franks
Chairman, Examining Committee

Henry L. Parsons
asst. Dean, Graduate Division

MONTANA STATE UNIVERSITY
Bozeman, Montana

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C.R.K.

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ABSTRACT

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CHAPTER I

INTRODUCTION

The laboratory has played an important part in the science programs of the secondary schools and colleges in America for nearly two centuries. It has been a place, both indoors and outdoors, for the training in science which would instill in the student an accuracy in observation, a precision in the formulation of a problem, and the accumulation of adequate evidence to arrive at a workable conclusion. The claims made in the past for the impact of the laboratory on the student have been widely accepted. Until 1900, no one doubted the absolute necessity of laboratory work in the college introductory science courses. Yet the discrepancy between the instructor's goal and the student's achievement has been more pronounced in the laboratory than in any other area of science teaching.

Today, the values of the individual laboratory teaching method in the science departments are being challenged more than ever before by people in science. Their challenges seem to stem from the following areas of concern:

1. The inadequacy of the individual laboratory teaching method as a teaching method in science.

2. The critical attitude of scientists and educators toward the individual laboratory teaching method.

3. The inherent role of science stressed in general education.

4. The problems complicated by the greatly increasing college

enrollment.

5. The influence on laboratory teaching of multi-sensory aids and principles of learning.

Each one of these areas of concern merits consideration as evidenced by a survey of literature and the interrelationships among these factors which are complicated and over-shadowed by the crisis of the rapidly expanding college enrollments.

Several inadequacies of the laboratory teaching method were revealed by Gloege[1] who investigated the current practices in the teaching of college general chemistry laboratory in forty-three colleges and universities in four states of Northwestern United States up to 1958. The study revealed the following major inadequacies of laboratory teaching: (1) the lack of a challenge to brighter students, (2) the prevalence of the laboratory manual which encouraged "cook-booking" and "dry-labbing" of laboratory experiments, and (3) the use of "classical experiments" which consisted of going through a set of motions to confirm already known results.

Other inadequacies were expressed by Kruglak[2] in Laboratory and Purposeful Activity on the nature of the laboratory stated that "the cook-book directions, the tedious verification of already known relationships, and the lack of integration with other course activities have been typi-

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[1] Gloege, George H., Current Practices in the Teaching of College General Chemistry Laboratory in the Northwestern States to 1958, Unpublished Doctoral Dissertation, 182 pp.

[2] French, Sidney, Accent on Teaching, p. 184-185.

cal of the short-comings in the science laboratory." In recent years, some instructors have become skeptical of any contribution that the laboratory teaching method might have for educational objectives, and they have turned to other laboratory teaching methods.

A critical attitude toward the individual laboratory teaching method has been expressed by several scientists and educators. For instance, Gibson stated that the individual laboratory experiments are repetitiously recorded in the laboratory manuals and the experiments do not teach scientific inquiry.[3]

The inherent role of science in general education has been recognized for over 60 years. During the past two decades a decided trend toward general education for science students has been apparent and has been accelerated by varying needs of students who come from a diversified social and cultural background. The many new scientific discoveries in the field have produced such a staggering amount of knowledge that it has become necessary to single out the most important scientific principles and findings.

The rapidly increasing enrollment in the American secondary schools and colleges has created severe problems of space, time, staff, and facilities in the laboratories. The need for a large staff to conduct and supervise the individual laboratory teaching has been a financial and manpower drain for many schools. The veteran enrollment after World War II and the "war-babies" enrollment in the early nineteen

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[3]Gibson, Raymond. The Challenge of Leadership in High Education, p. 192.

sixties each fostered critical demands on space, staff, and equipment in laboratory teaching of the colleges and universities.

The influence of experimental studies on laboratory teaching has been evident in science teaching. Cunningham[4] in 1946 summarized 37 experimental studies, mostly at the high school level with only 8 studies in biology, which compared the demonstration teaching method with the individual laboratory teaching method.

Cunningham's major criticism of the experimental studies was their lack of good experimental design and a failure to use proper statistical treatment of the data. His summary on the research appeared to indicate that the assumed values of laboratory work in science, such as (1) increasing the power of observation, (2) acquiring factual information, and (3) clarifying the understanding of structures through visualization are obtained equally well, and often more economically in time and money, by the demonstration teaching method than by the individual laboratory teaching method.

During the middle 1950's, new laboratory teaching methods were developed because of a reform movement in the science curricula in the secondary schools. The Physical Science Study Committee, the Chemical Bond Approach, and the Biological Science Curriculum Study introduced three new laboratory-oriented approaches which emphasized scientific inquiry in the laboratory for the science students in the secondary schools.

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[4]Cunningham, H.R., "Lecture-Demonstration Versus Individual Laboratory in Science." - A Summary, Science Education 30:70-82, March, 1946.

There are several research studies comparing these new approaches with the traditional laboratory methods.[5]

After World War II many colleges and universities initially turned to survey courses to facilitate the handling of this increasing enrollment which consisted mostly of freshmen who were non-science oriented and who took the science survey courses to fulfill the science requirements of their general studies programs. The survey courses were designed to teach the major principles in science courses. At first, many of the survey courses were taught without individual laboratory work, but after Sputnik in 1957 laboratory work was added to survey courses. The values of the laboratory work in survey courses for non-science students were questioned by such men as Ginsberg[6] who pointed out the dissatisfaction that fellow scientists and educators were expressing over the requirement of laboratory work for general science education.

The writer has been a staff member of a biology department in a State University in Wisconsin where a general college biology course of one semester is required for non-biology students. This course is taught as a terminal course in the biological sciences covering a survey of the major principles in integrated biology. The freshmen enrollment has in-

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[5]Lehman, David L., Abstracts of Recent Research and Development, BSCS Newsletter #30, Boulder, Colorado, January, 1967.

[6]Ginsberg, Benson, "To What Extent Should Laboratory Requirements be a Part of Science Education for Non-science Majors?", Current Issues in Higher Education, National Education Association, Washington, D.C., 1960, p. 70.

creased from five hundred to nearly three thousand students in the last five years with most of this enrollment comprised of non-biology students. During the 1962-63 school term, the five credit general biology course of two two-hour laboratory periods per week was reduced to four credits because one of the two-hour laboratory periods was dropped. The main reason for this reduction was lack of space and staff to maintain the normal amount of laboratory work for the non-biology students. This reduction in the amount of laboratory work with no apparent reduction in the number of biological principles covered in the laboratory produced some doubt in the department as to the assumed value of two two-hour laboratory periods as a necessary requirement for an adequate presentation of the general college biology course. The instructors were able to devote more time to the preparation and presentation of the one two-hour laboratory period per week, and there was an obvious opportunity to increase the use of the multi-sensory aids.

The universal nature of these concerns about the values of laboratory teaching methods in science in the universities coupled with the writer's personal experiences with problems of the individual laboratory teaching method led to the conviction that an investigation involving a different laboratory teaching method was necessary.

Statement of the Problem

The problem of this study was two-fold: (1) to review the literature to determine history and nature of laboratory teaching methods, to determine factors which would be used to equate the two groups, and to select statistical instruments to establish comparability of the two groups; and (2) to create an experimental method that utilized multi-sensory aids and to test the effectiveness of this method for achievement gain. The problem resolved itself into finding the answers to certain questions. The following major question was to be answered:

> Is the demonstration teaching method as effective as the individual laboratory method for non-college students in general college biology?

The following minor questions were also to be answered:

> Are there sex differences revealed in the effectiveness of the two laboratory teaching methods?
>
> Is class standing a factor in the effectiveness of the two methods?
>
> Does the nature of the application of laboratory experiences influence the effectiveness of the two methods?

Procedures

Specifically, the problem was investigated by the following procedures:

1. An examination of the literature relating to the problem of the study was made to determine the history, nature, and related experimental studies of laboratory teaching methods in general biology.

2. Prior to the study, the writer used one of his classes in general biology as a pilot group to determine the time required to present certain biological principles by the demonstration teaching method

utilizing multi-sensory aids. This procedure was used to reconcile time with course content.

3. Personal and science background factors were selected as revealed by review of experimental studies as a basis for equating the two groups. Techniques were developed for collecting information on each factor to establish comparability of the two groups.

4. Statistical instruments were selected for determining comparability of groups and effectiveness of the experimental method as measured by achievement gain.

5. Summary findings were reviewed and conclusions drawn.

Definitions

For this study, the following definitions are given to the terms listed:

Non-biology students are those students who are majoring in any field of study except biology.

General College Biology is a one-semester or one-term introductory course in college biology which covers the major biological principles of integrated biology.

Individual Laboratory Teaching Method is a method in which the student has a station, microscope, dissecting equipment, laboratory manual and other devices to explore biological principles with the student's own scientific creativity.

Demonstration Laboratory Teaching Method is a method in which the student has a station for viewing the instructor but neither microscope, dissecting equipment, nor laboratory manuals were used. Multi-sensory aids and other devices are used to present principles deemed important by the instructor.

Terminal Course is the name given to the course required in the field of biology of one semester duration and it can not be counted as biology credit for the biology major or minor.

Survey Course[7] is a course designed to give a general view of an area of study by covering the broad principles of the discipline.

General Education[8] is a broad type of education aimed at developing attitudes, interests, and behavior considered desirable by society but not for preparing the student for a specific type of vocation.

Multi-sensory aids are those auditory and visual learning materials which provide a concrete basis for conceptual thinking. A list of those used in the experiment appears on pages 44-46.

Limitations

Certain limitations were placed on this study and are noted:

1. The review of literature in laboratory teaching methods was limited to the libraries of Montana State University in Bozeman, Montana; Wisconsin State University in Whitewater, Wisconsin and the University of

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[7]Good, Carter V., Ed. Dictionary of Education, p. 108

[8]Ibid., p. 183.

Wisconsin in Madison, Wisconsin.

2. The experimental portion of this study was limited to one semester of 18 weeks since this was the length of the course opened to non-biology majors.

3. The study was limited to one university because the planned method required the availability of the multi-sensory aids at the university.

4. The selection of cooperating instructors was limited to full-time biology instructors who had previously taught general college biology at Wisconsin State University, Whitewater, Wisconsin.

5. The study was limited to non-biology majors who were enrolled in the course during one semester at Wisconsin State University, Whitewater.

6. The measure of achievement was limited to one well-standardized test of knowledge in general biology because this test had been one commonly used in other experimental studies of laboratory teaching methods. The test had comparable forms for measuring initial knowledge at the beginning of the study and for measuring achievement at the end.

A review of literature of laboratory teaching methods is reported in Chapter 2.

CHAPTER II

REVIEW OF LITERATURE ON LABORATORY TEACHING METHODS IN BIOLOGY

The purpose of the review of literature was to provide background information concerning the history and status of laboratory teaching methods, to search for relevant factors which might challenge the values of laboratory teaching methods, and to present a brief summary of previous investigations of this particular problem and closely related problems.

The review of literature was undertaken to consider the three following topics: (1) the history and status of laboratory teaching methods, (2) the nature of laboratory teaching methods, and (3) the experimental studies related to laboratory teaching methods. The three topics will be presented in the order listed.

The History and Status of Laboratory Teaching Methods

A review of literature relating to the history and status of laboratory teaching methods was made to establish a basis for the rest of the study and to determine if relevant factors have influenced the status of laboratory work during the last two centuries. Committee reports and the comments of professional people were sought because their statements usually described the rationale for proposed changes in laboratory teaching methods. Literature at the secondary school level was reviewed in conjunction with the college level information, since the laboratory teaching methods have been utilized at both levels of education. Recently, the application of laboratory experimentation in the secondary schools has helped to set patterns of laboratory work in colleges.

The history and status of those laboratory teaching methods were considered in periods which are related to changes in emphasis on laboratory teaching methods. They are discussed in a chronological sequence from the colonial period to the present and are described under the six following headings:

1. Approach to medical courses and regular science courses with laboratory teaching methods in pre-civil war period.

2. Influence of The Morrill Acts, Hatch Act, and German scientific training on laboratory teaching methods in the post-civil war period.

3. Effect of general education trends on the teaching of biology by the individual laboratory teaching method in the early twentieth century.

4. Influence of the economic depression on the teaching of biology by the individual laboratory teaching method.

5. Influence of increased scientific knowledge on laboratory teaching methods during and after World War II.

6. Emphasis on scientific inquiry in laboratory teaching methods after Sputnik I.

The preceding periods were chosen by the writer because the history and status of laboratory work has been closely related to the changing events in history. Laboratory teaching methods are usually associated with science courses, so it was necessary to make reference to science courses with and without laboratory work. Laboratory teaching methods in biology were meager in some of these time periods so reports on other science courses were included during this transition.

Approach to Medical Courses and Regular Science Courses Through Laboratory Teaching Methods in the Pre-Civil War Period

Medical training experience in a few colonial colleges formed the beginning of individual laboratory work in science training. Some individual dissections of cadavers were performed but more often the professors made the dissections while the students were observing, answering and asking questions about the parts concerned. This medical training was a carry-over from the laboratory movement in the European medieval schools with their dissection of human bodies for private research and for the teaching of anatomy.

The medieval universities in Europe had curricula which consisted mostly of law, divinity, and medicine which were copied by the colonial colleges. Aside from the individual laboratory training in medicine during this colonial period, the only other science course in the colleges was descriptive natural philosophy.

The first half of the nineteenth century witnessed a period of lecture-demonstration in college science courses where the instructors assembled "apparatus" for demonstration experiments. After 1800, the chalkboard was appearing in some schools as were some other new teaching aids. Simple equipment, such as model steam engines, air pumps, and machines to show simple mechanical powers, was being built to teach chemistry and physics. By 1830, such science courses as agriculture, geology, chemistry, botany, and economic entomology were being considered because the knowledge might help the farmer.

Harvard College founded the Hollis professorship for the express purpose of carrying on scientific training with demonstration experiments.[11]

Influence of Morrill Acts, Hatch Act, and German Scientific Training on Laboratory Teaching Methods in the Post-Civil War Period

The Morrill Acts of 1859 and 1862 gave public lands to create land-grant colleges of agriculture and engineering. New colleges were organized, specifically under this act; while other existing colleges agreed to serve as land-grant colleges. At first, there was little scientific agriculture to be taught because the science was in its infancy, but instructors encouraged students to bring in plant materials from their farms to be used in practical teaching experiences. This

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[11] Brubacher, John, and Willie Rudy, Higher Education in Transition, Harper and Brother Publishers, New York, 1958, p. 17.

allowed the student to perform individual laboratory work. The Hatch Act of 1887 created the experimental stations where extensive field laboratory work was instituted. This new scientific procedure was adopted by the colleges. This focused renewed emphasis on individual laboratory work. Several high schools began to teach manual training and agriculture thus allowing boys to work individually in the laboratory. During this period, many college science departments still taught science courses for the most part in a descriptive way with some teacher-demonstrations, since the equipment was either too expensive, scarce, or considered too dangerous for the students to handle. For instance, in the field of chemistry, the instructors gave lecture-demonstrations to be observed by the students.

However, during this same time period in American education Thomas Huxley and Louis Agassiz introduced the individual laboratory teaching method in biology because they believed that "seeing is believing."[12] These instructors used specimens and drew sketches on the chalkboard while the students examined, dissected and sketched their findings. The laboratory was considered a place to present the evidence from nature and illustrate the basic biological concepts to the students.

Many of the college professors in the American colleges during this post-civil war period had received their scientific training in

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[12]Hurd, Paul, Biological Education in American Secondary Schools, 1890-1960, B.S.C.S. University of Colorado, Boulder, Colorado, 1963, p. 145.

German universities, and they had brought back to the American colleges the wide-spread use of the laboratory as an indispensable part of scientific instruction.[13]

Even with this movement toward individual laboratory work in the colleges, the natural sciences in most institutions of higher learning were still treated with indifference or contempt until nearly the beginning of the twentieth century, because of the beliefs that there was a minimum of basic knowledge contributed by the sciences and that the laboratory was not designed for the teaching of the practical application of the natural sciences.

Between 1870 and 1890 the transition from the lecture-demonstrations to individual laboratory work was apparent in most schools. The land-grant colleges, agricultural experimental stations, and the German universities' influence on training in the scientific method all were factors which aided in the realization of the double laboratory periods for science courses in the high schools and colleges.

The Committee of Ten[14] in 1893 investigated the whole field of secondary education in both private academies and public secondary schools. Their study recognized that the secondary schools should not exist solely for the purpose of preparing students for colleges, but

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[13]Brubacher, John and Willis Rudy, op. cit., p. 184.

[14]National Education Association, Report of the Committee on Secondary School Studies, Committee of Ten, Washington, D.C., 1893.

rather that the schools' science curriculum should be tailored to fit those students whose entire formal education terminated with secondary school. The Committee of Ten concluded its meeting with the resolution that double periods of laboratory work in natural science courses should be required only for entrance to college and this increase in time favored the laboratory manual in biology. The implementation of the scientific method in laboratory work produced the laboratory manual because directions were needed to follow this new method of learning biology, and thus the laboratory manual became very popular to serve this aspect of learning in biology.

The period from 1890 to 1900 has been characterized by Hunter[15] as the great period of the laboratory manual in biology. Laboratory work in all of the experimental sciences was seen as an ideal procedure for the training and exercising of the faculties of the mind devoted to observation, will power, and memory. This growth of individual laboratory work with the manual received its strongest support from the "mental discipline theory" of psychological development rather than from any biological justification. As late as 1960, the excuse for laboratory work in a surprising number of curriculum studies and textbooks was still that of "mental discipline".

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[15] Hunter, G.W., Chairman, "Report on Committee on Secondary School Science of the National Association for Research in Science Teaching," Science Education 22: 223-233, May, 1938.

Effect of General Education Trends on the Teaching of Biology by the Individual Laboratory Teaching Method in the Early Twentieth Century

By the beginning of the twentieth century, the individual laboratory teaching method was deeply entrenched in the science curricula of most American secondary schools and colleges. In the biology laboratory, the student would gain a comprehensive and connected view of biological principles by the dissection and examination of specimens and reproduction of accurate drawings to secure precise observations.[16]

This emphasis on discipline and training in laboratory work, affected all aspects of secondary school science teaching. Under the influence of contemporary concepts of subject matter and methods appropriate for discipline, both subject matter and methods became highly formal and there developed a widespread dissatisfaction with individual laboratory work in the secondary schools. This dissatisfaction within the specialized sciences courses of botany and zoology opened the way for the development of general biology in secondary schools. Educators acknowledged that the formal individual laboratory work which had been required for the potential college student was not designed to benefit the non-specialist student who was seeking a general education and who did not expect to continue his formal education beyond the secondary schools. Educational theory that influenced the introduction of general biology in secondary schools also affected the authors of textbooks and

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[16] Hurd, Paul, op. cit., p. 15.

laboratory manuals who recommended less formal laboratory work for the student seeking a general education in biology.

The period after 1900 in America was one of great industrialization and urbanization, and along with this went an increasing awareness of the importance of science for general education and the place of science technology in the industrial expansion. The demand for a high school education increased but the percentage of students aspiring to a college education decreased. While the number of students in college rose during this period, the enrollment represented a decreasing fraction of the secondary school population.

In 1907, the Central Association of Science and Mathematics Teachers[17] appointed a committee to "prepare a statement of the biological creed that might serve as a guide in the development of biology courses in the secondary schools." The committee members thought that the biological subjects were particularly fitted for general educational purposes because of the "light they throw on the study of life." During this period, the "mental discipline theory" was rejected and more importance was attached to capitalizing on students' interests and experiences.

Several suggestions for the improvement of science teaching in secondary schools were made by the Committee on Natural Sciences of the

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[17]Otis W. Caldwell, Chairman, 1909, "A consideration of the Principles that should determine the courses in Biology at the Secondary School," School Science and Mathematics 9:241-247.

National Education Association in 1913.[18] The committee expressed the opinion that a variety of teaching methods should be used to present biology and other science courses. It was felt that the laboratory work should be better structured with less attention to useless drawings, detailed microscopic work and complicated experimentation.

A committee report published by the Commission on the Reorganization of Secondary Education in 1918 had considerable influence on laboratory teaching in secondary school science courses because observations concerning laboratory procedures revealed that the experiments were not original, but only checked generalizations which were already mentioned in the textbooks and the laboratory manuals. No new scientific data were being formulated by this method because the laboratory work consisted primarily of blank-filling and note-taking. This committee said that the aim of laboratory instruction should be to develop a consistence of significant "ideas" within the classroom and having the laboratory serve in providing concrete experiences.[19]

At the college level, general education returned to prominence in discussions of the college curricula after World War I. The interest in general education appeared to be a reaction against over-specialization brought on by World War I and a desire to return to the basic,

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[18]Peabody, James E., Chairman, "Preliminary Report of the Biology Subcommittee on the Reorganization of Secondary Education," School Science and Mathematics 15: 44-53, 1915.

[19]The Committee on the Reorganization of secondary schools, 1918, Cardinal Principles of Secondary Education, Bulletin, 1918, No. 35, Department of Interior, Bureau of Education, Washington, D.C., p. 32.

liberal, and unifying purposes of higher education.[20] General education was considered necessary for the preparation of a well-educated person in society.

Influence of the Economic Depression on the Teaching of Biology by the Individual Laboratory Teaching Method

The depression years of the 1930's in America produced a questioning attitude of educational practices that was characteristic of a time of economic and social crisis. Learning theory indicated that the selection of course content should be in the form of principles or generalizations, rather than detailed facts, in order to promote better learning and retention of knowledge. The strongest criticism was leveled at the individual laboratory work and its lack of educational returns for the time and money spent. Extensive research was performed during this time to determine the values to be gained from the individual laboratory method as compared with the teacher-demonstration method. The investigations revealed that the student could accumulate "facts" by either method but that the demonstrations were more economical in time and money. The net result was that the double or two-hour laboratory period in science teaching was dropped in the majority of secondary schools in America.[21]

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[20]Wahlquist, John and Thornton, James, State Colleges and Universities, The Center for Applied Research in Education, Inc. Washington, D.C., 1964, p. 35.

[21]Hurd, Paul, op. cit., p. 73.

By the early 1930's, some "big name" colleges were turning to new methods of laboratory teaching. One of those, the University of Chicago, began to use the demonstration method to teach those students who were enrolled in introductory science courses to serve their general educational needs. Since those students were not pursuing a field in science, the administration believed that the long hours spent in the laboratory were not necessary since the demonstration method could be used to cover adequately the same principles. However, the science majors were given laboratory work in the specialized science courses.[22]

An innovation at Iowa State College in General Botany in 1935 called the Group-Conference Method[23] eliminated the lecture, quiz section, and all routine laboratory exercises. Initially, the student was encouraged to feel that the laboratory was a workshop and that the instructor's function was not to pour out information, but rather to aid the student in arriving at tenable conclusions. After about thirty minutes of work on a problem, a student in the group would explain the demonstration and the instructor would guide the students' observations and deductions. The instructor utilized thought questions which encouraged the student to organize his previously acquired information.

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[22]Knight, Edgar W., Twenty Centuries of Education, Ginn and Company, New York, 1940, p. 316.

[23]Dietz, S.M., "The Development of the Group-Conference System of Teaching," Iowa State College Journal of Science, 11: 45-46, 1935.

Influence of Increased Scientific Knowledge on Laboratory Teaching Methods During and After World War II

World War II and the birth of the "atomic age" raised questions about the purposes of education as a whole and science teaching in particular. The movements in science toward general education which had begun in the 1930's were temporarily overshadowed by course adjustments made to meet "war-time emergencies." Severe shortages of laboratory equipment and staff made it necessary to use the demonstration method in teaching many science courses. Those science courses in high school which did offer individual laboratory work did so on a one-hour laboratory period basis. Most secondary school biology classes during the war were taught either by class discussions, student projects or instructor demonstrations.

Some evidence from World War II training programs[24] has been cited to support the claim that good demonstration experiments can accomplish most, if not all, of the ends of laboratory work in an introductory science course. It was recommended that in lieu of individual laboratory work an adequate number of good demonstration experiments be given in the science courses. The need for training large numbers of servicemen in a short time was met by utilizing multi-sensory aids in the demonstrations.

After World War II, the large veteran enrollment under the "G.I.

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[24] McGrath, Earl, Toward General Education, Wm. Brown Company, Dubuque, Iowa, 1948, p. 96.

Bill" in the colleges and universities put a premium on classroom space and staff so that many four-year institutions could not provide the necessary instructional quality and time to adequately supervise individual laboratory work. Under these adverse conditions of overcrowding, many administrators and scientists realized that the individual laboratory work in the college introductory science courses was neither practical nor realistic for all the incoming freshmen. Many four-year institutions turned to other methods and approaches of teaching laboratory science courses. Some science departments decided to reduce laboratory periods, others dropped them altogether, and still others turned to survey courses especially in the introductory science courses for the non-science students. The survey approach purported to teach the major principles of the science courses and often entirely omitted the individual laboratory work. The non-science students made up a majority of the college freshmen veteran enrollment.

The rapidly increasing enrollment after World War II was not the only factor which encouraged the survey courses, but their growth and development at the college level appeared to be a reaction against the growth of specialization and the philosophy that knowledge for its own sake was inherently valuable. By 1950, the number of survey courses in science for general education had increased so rapidly that over one-half of the four-year institutions of higher education were offering them.[25]

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[25] Anderson, Kenneth and Smith, Herbert, "Science," Encyclopedia of Educational Research, 3rd ed., The MacMillan Company, New York, 1960, p. 1219.

During the early 1950's, the enrollment in the colleges leveled off, but most science departments continued with the survey courses since they were considered an effective procedure for teaching introductory science courses for general education.

In this period after World War II, educators and scientists were confronted with the task of getting rid of the outmoded knowledge in courses to make room for the later and more adequate information. Both the physical sciences and the biological sciences since mid-century have taken on a new vigor. The many new research tools and techniques had advanced discoveries faster than anticipated. In many sections of the country the need for school construction, science facilities, and equipment could not keep pace with the demands of the enrollment, especially in the secondary schools.

Simon[26] in 1953, studied the teaching methods used by high school biology teachers and found that among seventy-seven teachers, demonstration-discussion techniques, lectures, and test recitation were the most often cited methods. Laboratory work was not considered essential for teaching biology as only three percent of the teachers were using individual laboratory work.

By the middle of the 1950's, many scientists had become increasingly disturbed regarding the textbook content in their fields at the secondary school level. The writers of the existing textbooks had attempted to squeeze new scientific information into traditional high

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[26]Hurd, Paul, op. cit., p. 210.

school and college level textbooks with the result that a patchwork of new scientific discoveries were included. In the secondary schools, the most important generalizations and principles in science could not be separated by the most capable instructor or the most brilliant student.[27] The secondary school science curriculum committees were meeting to determine new approaches to science teaching when Russia startled the scientific world with the launching of Sputnik I.

Emphasis on Scientific Inquiry in Laboratory Teaching Methods after Sputnik I

After the advent of Sputnik I, the science curriculum committees were given even more impetus to revise science courses. The committees sought to remove much of the descriptive materials of the existing courses. They also sought to reduce the number of concepts and to update the major ones in the courses. New laboratory experiments were devised that were appropriate to the development of science. The need to improve laboratory work received the most attention, and recommendations were made for a more experimental approach to the study of science courses. The first high school science course to be completely reorganized was physics, followed next by chemistry, and then finally by biology.

An attempted revision in biology was launched by the Biological

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[27] Bruner, Jerome, The Process of Education, Harvard University Press, Mass., 1961, p. 19.

Science Curriculum Study (B.S.C.S.) which was established in 1959 as the result of the efforts by the American Institute of Biological Sciences to improve biological education at the secondary school level. The program which was introduced into a few of the high school biology departments in the early 1960's placed considerably more emphasis on laboratory work than had the traditional biology. The experiments were of an investigative nature which introduced students to biology as a "process of inquiry" rather than a body of known facts.

Many of the secondary school science programs, because of these new laboratory-oriented approaches, were offering better science instruction to the students than were the survey courses in the introductory science courses in the colleges. After the advent of Sputnik, many college science departments reinstated individual laboratory work in the survey courses to improve science instruction and also to counteract criticism of the lagging science programs in the American educational system. The laboratory manuals in many of the survey courses still continued along traditional lines, but beginnings of revisions were showing themselves in certain of the new approaches in secondary school science courses. The authors of college textbooks were revising chapters on such concepts as the cell, cellular respiration, and DNA synthesis.

By the early 1960's the "war-babies" were entering college. The expansion in student enrollment forced science departments once again to question the values of individual laboratory work in the science curriculum for both the majors and the non-majors. Survey courses with laboratory work for the non-science students were continually increasing in number to meet the need of the incoming freshmen students, and new methods and approaches were also being devised to reduce or supplement the individual laboratory work for the science majors. The cost of maintaining the laboratory equipment, supplies, and staff for the survey courses along with the specialized courses was becoming such a burden to the science departments that the quality of the specialized courses for the majors was in danger of being down-graded.

Expansion has been a constant characteristic of American higher education. The total enrollment in all types of institutions of higher learning increased sixteen times between 1900 and 1960. The proportion of the age-group (18-21) who were enrolled in the colleges and universities rose during the same period from four percent to thirty-seven percent with the most rapid increase in the last decade.[28]

Current literature revealed several innovations in the methods and approaches to teaching specialized biology courses which appear to be the outgrowth of a shortage of space, staff, and equipment due to the increasing college enrollment with more students entering biology and other science courses. Some of the newer methods and approaches are: teaching machines, audio-tutorial system, programmed teaching, project teaching, taped lessons synchronized with 2 X 2 slides, close-circuit T.V., independent study, and a combination of lecture and demonstrations in one-hour periods.

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[28] Wahlquist, Thornton, State Colleges and Universities, The Center for Applied Research in Education, Washington, D.C., 1964, p. 2.

A study of the literature concerning the history and status of laboratory teaching methods disclosed that laboratory teaching has been performed since the colonial period. The creation of land-grant colleges and German scientific training had advanced the individual laboratory method while trends in general education and periods of economic depressions had encouraged the demonstration teaching method. The scientific knowledge explosion and the increasing enrollments coupled with the launching of Sputnik I has caused science departments to search for new approaches and methods to meet this challenge of laboratory teaching methods.

The nature of laboratory teaching methods is presented next.

The Nature of Two Laboratory Teaching Methods

The individual laboratory teaching method and the demonstration teaching method have been used in various forms for nearly two centuries in the secondary schools and colleges in America. The procedures will vary in their approaches to the solution of scientific problems as will the amount of time, space, and equipment required to apply the scientific method but the method chosen should be the one which the department or the instructors consider more beneficial for the students. The nature of two laboratory teaching methods are considered in this study: (1) individual laboratory teaching method and (2) demonstration teaching method.

The Nature of the Individual Laboratory Teaching Method. The conventional laboratory is the place for conducting individual or group research and for the teaching of students in connection with the materials and skills of a particular aspect of science. The laboratory can take on many forms, both indoors and outdoors, and consists of various facilities. The student can learn to apply the scientific method by actually dealing with problems which demand a solution. The laboratory is where one learns why science insists on precise measurements, accurate observations, and conciseness and clarity in communication. A laboratory activity is one in which the student gets first-hand sense experiences with materials, phenomena, and methods of science.

The essential steps involved in the scientific method are: (1) locating and defining a problem, (2) formulating one or more possible solutions to the problem, (3) accumulating data in relation to the problem, and (4) testing and verifying to obtain a conclusion.

The scientific method consists of a modified "trial and error" procedure. Some recent writers on scientific procedure have raised the question as to whether or not there is any one scientific method; suggesting rather that there are "related scientific methods" which have basic aspects in common.[29] There is also a tendency in current literature in science education to refer to "problem-solving" rather than to the scientific method.

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[29] Van Deventer, W.C., Laboratory Teaching in College Basic Science Courses, Science Education, Vol: 37, No. 3, April, 1953, p. 159.

Some common elements run through all scientific work to produce a scientific attitude. They include objectivity, open-mindedness, an insistence on accuracy of observation, precision of measurement, an accumulation of adequate data, a belief in the orderliness of natural processes, and a realization of the tentativeness of all conclusions. These are goals for the student and ones which are applicable to a wide range of life situations.

The advantages of the individual laboratory method are many as revealed by the review of literature. A few are listed:

1. The laboratory offers an opportunity for individualized instruction.

2. The laboratory is a place where the overt behavior of the student can be best appraised by direct observation.

3. Laboratory work can be used to illustrate certain characteristic stages in the development of science, such as to show the effect of instrument precision.

4. The laboratory can be used to dispel the notion that the scientific method is not a magic formula for making discoveries. The student is faced with situations which he must resolve through his own ingenuity.

The objectives for the individual laboratory teaching method were reviewed because they serve to give direction and purpose to laboratory teaching methods.

The Forty-Sixty Yearbook[30] presented a concise statement of these objectives under eight general headings:

1. Functional facts are the basis of scientific thinking and serve as one of the aspects of general education.

2. Functional concept is a "major idea" and may be confused with a principle. A principle is often composed of two or more concepts.

3. Functional principle is a statement of some fundamental process which is capable of being demonstrated or illustrated. Principles are important for laboratory teaching because of their application to solve daily problems in new situations, and to provide first-hand observations.

4. Instrumental skills are needed to handle laboratory apparatus and scientific instruments. Skills are necessary for experimentation.

5. The scientific method helps the student to develop problem-solving skills.

6. Attitude is the goal which helps one to develop science for a vocation or avocation.

7. Appreciation is the feeling of a student for scientific training.

8. Interest is a quality which makes a person curious about science.

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[30] Science Education in American Schools, Forty-sixty Yearbook of the National Society for the Study of Education, Part I, Chicago, Illinois: University of Chicago Press, 1947, p. 300.

These eight major objectives of individual laboratory methods have served as a guide for the teaching of laboratory work. However, "laboratory" as a term has been used in educational circles to refer to various types of teaching projects in which the students proceeds "on his own", either alone or as a member of a group in working on a chosen topic within the subject matter area. This use of the term "laboratory" usually implies some handling of materials on the part of the student and guidance rather than direction on the part of the instructor.[31]

Probably in no area has greater attention been given to the scientific method than in the area of undergraduate teaching of introductory science courses with laboratory work. Yet it is questionable in most cases whether this teaching embodies true laboratory procedure. Many "laboratory procedures" for teaching purposes have become essentially "cook-book" operations. The experiments are "exercises" which may give practice in the development of skills and techniques of laboratory work but this constitutes a distortion of the original meaning of laboratory work for undergraduate laboratory teaching.

One of the factors which may be blamed for encouraging "exercises" in laboratory work is the laboratory manual. The manual has been criticized as a teaching aid in laboratory work because it often does not fulfill the need for "real" experiments, "open-ended" experiments, proper evaluation of laboratory work, and the prevention of "cook-booking" and "dry-labbing". The laboratory manual should be written

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[31] Van Deventer, W. C., op. cit., p. 160.

considering the following points:

1. The problems of laboratory work must be "real" for the student or they must be given a semblance of reality for the purpose of motivation. The exploration must be at the student level of understanding or else he follows the directions without learning.

2. The experimental approach to a problem often requires a longer period of time than a single laboratory period. To pursue the objectives of a problem, the student needs a block of uninterrupted time of considerable magnitude so that he can press forward his investigation without interruptions by other class activities.

3. The proper evaluation of laboratory results by testing is needed to determine the amount of learning from the experiments which are conducted in the laboratory.

4. The use of formal or essay type of laboratory reports are needed to prevent "dry-labbing" and "blank-filling" of the laboratory manuals. These latter two practices rely heavily on copying from other students and obtaining the answers from the texts.

5. The so-called experiments in conventional manuals are practically worthless if used "as is".

In the laboratory, the instructor is the key to success, yet in most of the larger colleges graduate teaching assistants serve as laboratory instructors. One of the glaring faults of laboratory instructors has been their tendency to explain orally each step of the experiment with the result that they tell the students so much about the experiment that there is little time or curiosity left to carry out the work. Since laboratory work is based on performance with apparatus and materials, a partner is more likely to be a hindrance than a help.

Cole[32] in 1940 stated that "laboratory work will eventually be restricted for the most part to those intending to become specialists in a field of science and probably omitted altogether for those who want only a survey of main facts and general conclusions."

Despite strong recommendations in favor of laboratory work contained in the Harvard Report[33] in 1945, the physical science courses at Harvard were taught without individual laboratory work. Yet some science instructors have assumed that laboratory work is an essential part of biology or science instruction and that a non-laboratory course is not really a science course.

Mursell in 1949 stated that college freshmen are too immature for traditional laboratory work as shown by his comments:

> The instructor should realize that if a student is to learn much biology from a series of standard laboratory experiments in which he follows the instructions in the manual, the student must already have achieved considerable maturity in objective thinking. The laboratory work is highly specialized, with exacting manipulative problems. The purpose of the experiment is usually technical and narrow. The form of the write-up, dictated by the manual, is too stereotype, does not lend itself to a recording and focusing of the actual experiences and explorations that the student desires.
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> When scientific immature students, and this includes many college freshmen, are put up against experimental situations, they

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[32]Cole, Luella, The Background for College Teaching, Farrar & Rinehart, Inc., New York, 1940, p. 331.

[33]Harvard Committee, General Education in a Free Society, Harvard University Press, Cambridge, Mass., 1945, p. 168.

> are apt to go through the motions, without any real benefits in the way of improved objective thinking. They learn, as they always must, in accordance with their developmental level. The individual science laboratory is an example of the fallacy and the futility of premature challenge to be found in education.[34]

Furthermore, Ginsberg has questioned in particular the value of the individual laboratory method for the non-science student:

> The problem of laboratory requirements has a practical as well as a pedagogical side. The practical side has to do with the space, facilities, and manpower to carry out an adequate program of laboratory instructions for all students during an era of peak enrollment as is now facing the colleges. The important concepts in any scientific field can and have been taught without formal laboratory instructions. There are also many laboratory courses that keep the students occupied with highly dubious and dispensable busy work.[35]

In some institutions, a questionnaire has been used to obtain student's reaction to the laboratory. At Harvard[36] the students were overwhelmingly opposed to the individual laboratory work.

Huffmire[37] in an article entitled Teacher-demonstrations stressed four weaknesses of individual laboratory work. The conventional laboratory should:

1. Be a place where "real" problems are undertaken, but too often the students' only concern is to follow the directions in the

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[34] Mursell, James, Developmental Teaching, McGraw-Hill Book Company, New York, 1949, p. 239.

[35] Ginsberg, Benson, op. cit., p. 72.

[36] McGrath, Earl J., ed. Toward General Education, The MacMillan Company, New York, 1948, p. 108.

[37] Huffmire, Donald, Teacher-demonstrations, Science Education 33:263, April, 1965.

manual and confirm an already known principle. Thus, the scientific method is not followed or grasped.

2. Provide for individual differences in gaining laboratory experiences for the gifted student. Individualism of laboratory work is not the usual procedure as most instructors want uniformity in experimental results.

3. Not be required for all scientific investigations. Problem-doing experiments can benefit students who lack the ability for original research.

4. Be adequately equipped with facilities and time period for pursuing the objectives of truly scientific learning and training.

There is a great dichotomy between the biologist and the educator on the values of individual laboratory work. The biologist believes that laboratory work is an indispensable part of most biology courses. The training should develop in a student an understanding of the methods, attitudes, and approaches held by the biologist. The educator, on the other hand, wants the contents to be useful for the student as part of his general education. In departmental courses, the student is bent to the need of the subject matter while in the general education courses the subject matter is bent to the need of the student.[38]

The impetus toward general education is linked with the expansion of knowledge and its incorporation into an increasing number of disci-

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[38] French, Sidney, Accent on Teaching, Harper & Brothers, New York, 1964, p. 15.

plines and specialities.[39] The colleges and universities need to change the emphasis from facts about science and replace it with a more intelligent understanding of the principles of science and their broad implication to society. The methods of science are indispensable in the solution of world problems, but the results of science itself must be "humanized" by placing the emphasis on the development of better human beings in a better environment. So inadequate are the science requirements for the general education studies, that a student may graduate from college and yet remain scientifically illiterate. Then again, the science specialist may go through college without becoming aware of the social implications of science.[40]

The instructors of biology for general education must select from the vast storehouse of knowledge of life science those ideas and principles which have significance and which have functional meaning in the lives of students.[41]

Increased enrollment has brought with it a wide range of cultural and social backgrounds which the college must take into account in educating the students. Many scientific problems incorporated into the basic materials of general biology are tangible and objective while many of the social problems such as those discussed in esthetics, ethics, and

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[39] Dressel, Paul & Lorimer, Margaret, General Education, Encyclopedia of Educational Research, 3rd ed. The MacMillan Company, New York, 1960, p. 571.

[40] Hurd, Paul, op. cit., p. 34.

[41] French, Sidney, op. cit., p. 152.

religion are of a subjective and intangible nature. These problems find their way into general biology courses and the only objective data available are of a personal nature and possess only subjective validity.[42] Therefore, those social problems in biology can not be designed for a problem-solving situation as treated in the individual laboratory. Yet, many social problems can be taught by the demonstration teaching method with multi-sensory aids. For instance, by means of the motion pictures the reproductive process and live birth of the human can be observed in a matter of minutes. No amount of reading or experimentation can duplicate the effectiveness of this presentation.[43]

Statistical information concerning recent enrollment in the colleges and universities[44] revealed that only seven percent of the students who take biology are majors or minors in that discipline while most students are non-biology students who take general biology for general education requirements.

The laboratory has been a location in which one can obtain skills, techniques, and procedures of laboratory teaching, follow the steps of the scientific method, and develop a scientific attitude. The objectives of laboratory teaching give direction to science teaching. The individual laboratory teaching method has not been considered entirely satisfac-

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[42]Van Deventer, Donald, op. cit., p. 169.

[43]French, Sidney, op. cit., p. 155.

[44]Simon, Kenneth & Marie Fullam, Projections of Educational Statistics to 1974-75, United States Government Printing Office, Washington, D.C., 1965, p. 22.

tory for at least sixty years. The expansion of scientific knowledge has precipitated a trend toward the development of general education. General education and increasing college enrollments have thus become two major factors in creating a dissatisfaction with individual laboratory work.

A search of the literature was made to determine a different teaching method which might alleviate the problems of a shortage of space, staff, time, and equipment as well as an effective method of teaching students. The recurring reference to the demonstration method led to a survey of the nature of this laboratory teaching method. It is reported next.

<u>The Nature of the Demonstration Teaching Method</u>. The review of literature on the teaching of laboratory methods revealed that the demonstration method has been used as a teaching method throughout the history of laboratory work. The method has been considered important for laboratory teaching especially during periods of rapidly increasing enrollments in colleges and universities when it provided for an economy of space, staff, and facilities, as well as being an effective laboratory teaching method. The demonstration method, when utilizing the proper multi-sensory aids and sound principles of learning, can be used to help counter-act the problems created by the factors which are challenging the values of the individual laboratory teaching method.

One of the factors which has made inconclusive much of the research in the area of laboratory teaching methods has been a failure to adopt a standard definition of "demonstration." The term has been erroneously applied to teaching experiences which are basically very different in their approach and their effects on the students being instructed. A distinction should first be made between "lecture-demonstration" and "experimental-demonstration", and then the term "demonstration" itself. Good[45] in the Dictionary of Education defines the "lecture-demonstration" as a "method of teaching in which the instructor gives an oral presentation of subject matter while demonstrating with certain devices." A device is any activity having a justifiable educational aim which helps to stimulate the student to a greater effort in learning. The "experimental-demonstration" as defined by Anderson and Smith[46] in the Encyclopedia of Educational Research is "effective student participation in postulating, suggesting, testing and drawing conclusions about a problem."

A functional definition of demonstration is needed. Good[47] defines "demonstration" as the "procedure for doing something in the presence of others either as a means of showing them how to do it or in order to illustrate a principle." The definition of demonstration which the writer deemed best for this study is now given. The instructor demonstrates materials to focus attention on a natural phenomenon for the purpose of (1) stimulating inquiry, (2) adding realism and vividness in the process of concept formation by utilizing multi-sensory aids, and (3)

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[45] Good, Carter, op. cit., p. 124.

[46] Anderson, Kenneth & Smith, Robert, op. cit., p. 1223.

[47] Good, Carter, op. cit., p. 124.

exemplifying the application of a principle.

Mort and Vincent in an Introduction to American Education define the terms method and techniques as:

> "A method of teaching refers to a broader term which is used throughout the school year or term, while a technique in teaching refers to a specific procedure that may be used for a day, week or longer. Some techniques may fit any method. The demonstration method can be used throughout the semester but a laboratory technique may vary from concept to concept. An instructor may adopt some modern techniques and yet, for the most part, retain his old methods."[48]

Huffmire[49] listed the following contributions that the demonstration method can make to laboratory teaching: (1) creating a problem, (2) developing a point, (3) explaining a principle, (4) helping in review, (5) beginning or ending a lesson, (6) showing methods and techniques, (7) displaying objects and specimens, and (8) providing for a student's needs, such as teaching accurate observation, organizing data, and preparing a good report.

Huffmire[50] has also listed several limitations and disadvantages which have been attributed to the demonstration method. The writer critically considered them in designing this study. The possible limitations and disadvantages are (1) possible lack of visibility, (2) limitation of the students for opportunity to become familiar with materials, (3) the fact that scientific information cannot be grasped by sight and

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[48] Mort, Paul and Vincent, William, Introduction to American Education, McGraw-Hill Book Company, New York, 1954, p. 319.

[49] Huffmire, Donald W., op. cit., p. 262-265.

[50] Huffmire, Donald, op. cit., p. 262.

sound alone, (4) demonstrations may proceed so rapidly that the student may fail to grasp their full meaning, (5) certain students may dominate the discussion period, (6) no active student participation during the demonstration, (7) elaborate demonstrations tend to be too convincing, (8) the method is concerned with problem-doing, rather than problem-solving, and (9) the method does not use the inductive method in answering a problem since a conclusion is drawn from only one observation.

Demonstrations have been substituted for laboratory work either partly or wholly for several decades with varying degrees of success. In some colleges demonstrations are used effectively, and this method has been given good support by both faculty and student evaluation.[51] This fact has been recognized by instructors of courses for non-major students with the result that in some cases the use of the demonstration teaching method has come to replace individual laboratory work altogether. The increased use of multi-sensory aids has helped to meet the need for adequate demonstrations.

With the present rapidly increasing college enrollment, the number of students who take survey courses in general college biology to help fulfill their general education requirements in the biological sciences has placed a heavy burden on the existing laboratory space, facilities and staff. The biology department's major function becomes one of teaching survey courses to large numbers of students, largely freshmen, rather than the teaching of advanced biology courses to the

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[51] Van Deventer, W. C., op. cit., p. 186.

biology majors and minors in the department. This factor makes it imperative that a more economical and effective method of laboratory teaching be of vital concern in the best interests of future progress of biology departments. The demonstration method was considered as a laboratory teaching method that would help alleviate the population problem mentioned because the objectives of biological education can be presented by the demonstration method utilizing the proper multi-sensory aids. Multi-sensory aids appropriate to this method are presented next.

Use of Multi-sensory Aids for Laboratory Teaching Methods. Multi-sensory aids provide the concrete experiences which are essential for learning and are especially valuable in laboratory teaching methods. Multi-sensory aids are very important for presenting the biological principles in general biology. The following multi-sensory aids were available and they are listed with a short definition. The aids may assume a variety of forms, but in most cases their names are sufficient to indicate their nature and use in the demonstration method:

1. Chalkboard may serve to visualize work in practically every aspect of biology, such as for diagrams, sketches, and drawings.

2. Specimens, living or preserved, are usually displayed as a sample.

3. Model is a replica - a representation often in miniature of a plant or animal, or part of an organism. The model may be larger, smaller than life size, made to scale, or life-size but all provide depth to the organism.

4. Textbook illustrations are a variety of forms from photographic reproduction of pages in other books to diagrams and figures of every conceivable type.

5. Photographs and microphotographs have a life-like representation ranging all the way from natural size to the microscopic world seen under the compound and the electron microscopes.

6. Drawings are usually made for publication purposes by an artist.

7. Sketches are usually thought of as pictures in which the ideas are embodied in rather crude or simple fashion.

8. Diagrams may suggest a picture and often are not in the ordinary sense like the object represented, but corresponds to them in certain points and only in a vague way.

9. Charts are drawings or diagrams large enough to be used with the entire class.

10. Museum is a collection largely of visual material of the exhibit, object, and pictorial type for the purpose of displaying and making readily available the various materials housed there. The museum is essentially a grouping of materials to serve some general or specific purpose.

11. Slide-film or filmstrip are a series of related sequence pictures in a strip which are usually shown on a screen by means of a projector.

12. 2 X 2 slides are usually in color and can be obtained commercially or else an instructor can use an adapter on a microscope to pro-

duce pictures of microscopic life.

13. Motion picture consist of a series of photographs taken on a strip of film and when introduced into a motion picture projector gives the impression of life and motion, either black and white or colored.

14. Flannel board consists of a flat piece of stiff backing, such as plywood, covered with a felt-like material. Objects with a sensitive backing cohesively cling to the flannel board. The most effective feature is the flexibility and appeal that visual and manipulative materials, such as diagrams, symbols, sketches, letters, words and terms, have in the presentation of a concrete learning situation. The use of various colors for different headings and topics is very effective for discrimination.

15. Bioscope or microprojector projects microscope slides or minute objects greatly enlarged upon a screen so that the entire class can see the image at one time.

16. Duplicators can reproduce materials from a master copy, such as diagrams, sketches, and charts, for each student and with the aid of various colors can compare and contrast special topics and aspects of drawings.

The techniques and procedures employed with the multi-sensory aids will be brought out in Chapter 3 in presenting the design of the experimental method.

In summary, the review of literature revealed that the demonstration teaching method can stimulate inquiry, exemplify the application of a principle, and utilize multi-sensory aids for concept formation. The demonstration method requires less space, time, staff, and equipment than the individual laboratory teaching method. The disadvantages and limitations of the demonstration method might deter the student from learning laboratory skills but the proper use of multi-sensory aids can correct these limitations. The demonstration teaching method has been used by various secondary schools and colleges and has been favorably received by administrators, scientists, and educators. The constantly increasing enrollment has encouraged survey courses that place reliance on a large array of multi-sensory aids in teaching the students. These efforts have been successful.

Principles of Learning as Related to the Use of Multi-sensory Aids

The use of multi-sensory aids is especially valuable in demonstration teaching.[52] The student will make progress in the development of behavior patterns when he observes good demonstrations of the materials to be learned. The multi-sensory aids can provide concrete experiences which are essential for enriched learning.[53] In providing the concrete experiences essential in learning on the associative level of instruction, these aids not only give meaning to words and to symbols, but clarify

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[52] McClusky, F. Dean, Audio-Visual Teaching Techniques, Wm. C. Brown Company, Dubuque, Iowa, 1949, p. 12.

[53] Ibid. p. 11.

ideas involving higher abstractions. The multi-sensory aids help in the development of reflective thinking which in turn depends upon the learner's ability to recombine experiences and to relate them to problems at hand and to their solution.

In his book, Theories of Learning, Hilgard[54] reviewed 10 theories of learning and developed 14 points of sound psychology of learning as agreed upon by psychologists writing in the field of learning theory.

Five of these points have a particular bearing upon the use of multi-sensory aids in teaching: (1) A motivated learner acquires what he learns more readily than one who is not motivated; (2) Learning under the control of reward is usually preferable to learning under the control of punishment; (3) Meaningful materials and tasks are learned more readily than nonsense materials and tasks not understood by the learner; (4) Information about the nature of a good performance, knowledge of one's own mistakes, and knowledge of successful results aid learning; and (5) Transfer to new tasks will be better if the learner can discover relationships for himself and if he has experienced during learning the application of principles within a variety of tasks.

The first point by Hilgard deals with motivation as related to the use of multi-sensory aids in the teaching of general biology. Motivating the class toward an objective requires that attention be directed to the events at hand. When the student's attention is focused on events by self-direction, sufficient energy is assured to promote learning as long as

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[54] Hilgard, E. R., Theories of Learning, Appleton-Croft-Century, New York, 1948, p. 486.

necessary until mastery is obtained.[55] Motivation, as an element in the learning process, has long been regarded with respect. One of the most common and logical motivational devices is the instructional organization necessary for the usage of multi-sensory aids. This instructional motivation is centered in the sequence in which the student is introduced to the topic and to the content organization of the learning material. Learning seems to be more complete and more efficient when it is energized and directed by these two factors. The demonstration method, like learning, must be goal-directed. The implication of Hillgard's sound point is that carefully organized multi-sensory learning materials will aid in both goal setting and the motivating effect of seeking to achieve the goal.

The second point deals with learning under the control of reward. This reward may be in the form of reinforcement which strengthens appropriate responses and is most useful in facilitating learning when applied frequently and promptly.[56] Reinforcement has a significant effect upon the learning of concepts. The instructor can reinforce the students in the classroom by making them aware of what they are learning. By this approach a mental attitude or emotional tone is developed which is a key to more effective learning.

The third point of agreement among psychologists is that meaning-

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[55] Townsend, Edward A. and Burke, Paul J., Learning for Teachers, MacMillan Book Company, New York, 1962, p. 204.

[56] McDonald, Fredrick, Educational Psychology, Wadsworth Publishing Company, Inc., San Francisco, 1959, p. 120.

ful materials and tasks are learned more readily. The significance of the activities in which the student is engaged and the satisfaction which they bring to him when completed is promoted by meaningful learning. The rote learning, now so common in biology teaching, needs to be directed toward learning of a conceptual nature that leads the student to some understanding of the structures of the subject. When the problems are real and meaningful to the learner, problem-solving becomes the richest learning experience. Understanding tends to improve retention as meaningful material is more likely to be remembered than non-meaningful material.[57] An important factor that appears to influence the acquiring of generalizations is familiarity with material in which the generalization is formed.

A study by Tyler[58] demonstrates that knowledge of principles and generalization is more likely to be retained than is knowledge of less meaningful material such as terminology. Tyler measured how much course content was retained after one year, using the terms learned in biology, knowledge of principles, and ability to interpret new experiments. The results indicate that much of the terminology is forgotten but that the principles and experimental interpretations are retained.

The fourth point of agreement about learning concerns the value of student's information about the nature of a good performance, know-

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[57]Ibid., p. 120.

[58]Tyler, R., Some Findings from Studies in the Field of College Biology, Science Education 18 (1934), 133-142.

ledge of his own mistakes, and knowledge of successful result. The latter is an effective reinforcer for students as it serves to strengthen habits, evokes already established habits, and provides the motivation for learning or performing.[59] A good reason for summarizing at the end of each demonstration period is to establish full awareness of correct response and both reflection and contrast with a wrong answer or incorrect response. Thus the last response that stands out at the end of a learning period is the correct one.

The fifth point of agreement is that the transfer of learning to a new task will be better if the student can discover relationships for himself and through his own experiences apply the principles within a variety of tasks. Transfer of learning is more likely to take place when the "thing" or "idea" to be transferred is a generalization. Concepts cannot be learned without some experience in generalizing the phenomena which are to be conceptualized. This experience aids the student in making necessary discriminations. To acquire learning a person must abstract or infer from sensory data and his experiences. The permanence of student learning of principles and generalizations in biology is dependent to a great extent upon the degree to which the learner is able to conceptualize his knowledge of relationship between two or more concepts.

The principles "learning meaningful materials" and "the transfer of learning" are very appropriate guidelines for the use of multi-sensory

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[59] Mursell, James, op. cit., p. 246.

aids in the "demonstration method." Meaningful materials such as concepts or "ideas" can be transferred to a new task if the student can make generalizations from what he learns. Multi-sensory aids help in the development of "ideas" which the student can use to conceptualize his knowledge of relationships in his own experiences. He can discriminate because of the sensory data. This knowledge of ideas in a course will be retained while facts would soon be forgotten.

A recent experiment by Boguslavsky[60] illustrates the utility of accentuating essential characteristics. Two groups of biology students were to learn how to identify the parts of flowers. One group was given "real" flowers and was taught the parts with the real flowers as examples. The second group was presented with a large and simplified diagram of the parts of a flower from which the parts were to be learned. The results of the experiment indicated that the group using the diagram learned the parts of a flower more accurately and easily. They were also able to generalize their knowledge to real flowers better than the first group. Apparently for the group using the diagram there were no other stimuli to interfere with attention to the crucial features of the flowers which had to be learned.

Insight is the point in the learning process at which the student perceives meaning in the situation and understands what he is doing. When these understandings have been tested in many situations they become generalizations. The best learning is possible when these generalizations

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[60] Boguslavsky, G. W., "Psychological Research in Soviet Education," Science 125 (1957), p. 915-18.

are used to meet the demands of life in as many situations as possible.

Concept formation is a process in which a person interacts with his environment and organizes the mass of stimuli that he is experiencing. The following experiment reveals that the proper environment is necessary for concept acquisition.

Marks and Ramond[61] performed an experiment in which concepts were evoked in two different situations described as "real life" and "textbook". The concept formation task was the same for both groups except that the subjects in the "real life" situation actually performed the task themselves by manipulating the cards. The "textbook" group produced significantly more correct solutions at a significantly higher rate than did the "real life" group. The conclusion was that complex learning environment may be so threatening that it inhibits concept acquisition.

The fact that learning is a developmental process means that the sequence of learning experiences is important. Conceptual learning moves from the concrete to the abstract, from the visible to the invisible, and from the known to the unknown.

The learner normally proceeds from concrete observations to abstraction of ideas, to application of these ideas in real and concrete situations, to generalizations drawn from a number of such applications, and finally to assimilation of these generalizations as a part of the

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[61]Mark, M. R., and Ramond, C., "A New Technique for Observing Concept Evocation," Journal of Experimental Psychology, 42:424-29, 1951.

learner's permanent understanding.[62]

The use of multi-sensory aids provide concrete experiences essential for sound learning. Psychologists are in agreement on several principles of learning theory which can be applied to the use of multi-sensory aids. These are the concepts motivation, reinforcement, the learning of meaningful materials, a knowledge of results, and the transfer of learning.

Multi-sensory aids provide for known, concrete, and simple ideas which can be utilized to gain new generalizations of a more abstract and complex nature. Studies of a psychological nature provide information on why people learn and the factors which can inhibit learning. Research sudies in the teaching of laboratory methods are reported next.

Experimental Studies of Laboratory Teaching Methods

An examination of the literature was made to determine what experimental studies had been made concerning the methods and techniques used in laboratory teaching methods in general biology. These experimental studies have been divided into three groups on the basis of: (1) laboratory teaching <u>techniques</u> using multi-sensory aids, (2) Laboratory teaching <u>methods</u> using multi-sensory aids, and (3) Laboratory teaching methods appropriate to the achievement of the objectives of biology in general education.

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[62] Mursell, James, *op. cit.*, p. 384.

Laboratory teaching techniques using Multi-sensory Aids. Laboratory teaching techniques different from those generally covered in the individual laboratory method were found in studies at both the secondary and college level. Tobler[63], in 1945, made a study at the secondary school level which involved the value of the instruction prepared biology drawing versus the original student laboratory drawing. The conclusion was that high school biology students who used prepared biology drawings made better scores on examinations of factual learning than equated groups of students who prepared and labeled their own drawings.

Rulon[64], in 1933, found that the teaching effectiveness in science could be increased as much as twenty percent, when measured in terms of learning retention, with films used in combination with modern teaching methods.

Stathers[65] in 1933 and Breckhill[66] in 1941 reported studies comparing the effectiveness of the microprojector with the compound microscope. The study by Stathers compared experimental and control groups from the same high school to determine the effectiveness of the use of the microprojector on the achievement of students. The experimental

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[63]Tobler, I. Vance, "Teaching Values of the Prepared Biology Drawings Versus the Original Laboratory Drawings," Science Education 45:479-82, 1945.

[64]Hurd, Paul, op. cit., p. 225.

[65]Stathers, Allan, "The Microprojector Compared with the Individual Microscope in Teaching HIgh School Biology," Science Education 17:59--63, 1933.

[66]Breckhill, Edith, "A Study of the Microprojector as a Teaching Aid," Science Education 25:215-18, 1941.

classes used only microprojectors while the control classes used only the traditional microscopes. The data obtained supported the acceptance of the hypothesis that there was no significance in conceptual information between the experimental groups which used the microprojector and the control groups which used the microscope.

Two studies at the college level concerning techniques were reviewed. Alpern[67] in 1936 compared the effectiveness of the student-made and prepared drawings in college biology classes. He found that the labeling of prepared drawings and the procedures of making original drawings were equally effective with regard to students' acquisition and retention of the factual information derived from laboratory work. The time saved by the use of prepared drawings would rate it the more efficient procedure of the two techniques.

Two recent studies by Kiely[68] in 1958 and Novak[69] in 1961 utilizing photomicrographs produced objective data for current teaching techniques. Kiely compared the learning value of student-made drawings and photo-micrographs in pre-professional biology courses. He found that students of both low and high intelligence quotients learned and retained

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[67]Alpern, M., "A Comparative Study of the Effectiveness of Student-Made and Prepared Drawings in College Laboratory Work in Biology," Science Education 20:24-30, 1936.

[68]Kiely, Lawrence, "Student Drawing Versus Photomicrographs," Science Education 42:66-73, 1958.

[69]Novak, Joseph D., "The Use of Labeled Photomicrographs in Teaching General College Botany," Science Education 45:119-122, March, 1961.

more factual information when photomicrographs were used.

An experimental study by Novak in 1961 investigated the learning effect of labeled photomicrographs on a student's achievement in general botany. The time-honored procedure required each student to draw detailed replicas of the materials studied. The major hypothesis to be tested involved the measurement of the effectiveness of labeled photomicrographs supplied in addition to the regular outline drawings in the laboratory manual on student's achievement in a college general botany course.

The study involved forth-three students in a general botany class which met three times each week for two-hour periods. The first hour was a lecture and the second hour was devoted to laboratory work. The lecture was given by the author of the study and the laboratory was supervised by the author and teaching assistants. The students were divided into two groups at random and were given a pre-test. Four tests were given during the study.

The students were selected at random and then divided into two groups as follows: (1) Group I, the control group, with outline drawings provided by the laboratory manual; and (2) Group II, the experimental group, with outline drawings provided by the laboratory manual plus labeled photomicrographs.

The results of the study indicated that there was a tendency for higher scores on the tests given after a period of instruction when labeled photomicrographs were supplied. The data suggested that the use of labeled photomicrographs may be of value as a supplement to outline drawings in a laboratory guide.

A study by Donor[70] in 1965 dealt with the use of laboratory drawings. Drawings are usually considered as developers of the ability to observe specimens accurately, to think critically, to understand biological knowledge, and to apply this knowledge to the solution of a problem. The author's hypothesis was that the construction of laboratory drawings was not necessary for effective learning in biology. The students were randomly assigned at the time of registration to an experimental study group called the non-drawing group, and one called the drawing group or control group. Both groups followed the same syllabus, utilized the same materials, and met for the same periods of time. The experimental group did not draw or diagram any of the biological tissues or specimens which were studied but were requested to answer a series of questions pertaining to the materials studied. The Nelson Biology Test was used as the achievement test. The findings indicated that the conventional practice of having students construct their own drawings in the laboratory could be eliminated without any loss in achievement.

The reports on experimental studies of laboratory teaching techniques using multi-sensory aids revealed that the various techniques devised and used for the experimental groups revealed that in general the results compared favorably with those used by those in the individual laboratory work groups.

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[70] Donor, A. E., "An Investigation of the Value of Student-Made Drawings in Introductory Biology Laboratory Courses," Dissertation Abstracts, University Microfilms, Inc., Ann Arbor, Michigan, Vol. XXVI, No. 7, 1965, p. 82.

Laboratory Teaching Methods using Multi-sensory Aids. Cunningham[71] in summarizing 37 research studies in science teaching between the lecture-demonstration and the individual laboratory method obtained the following information on laboratory teaching methods using multi-sensory aids:

1. The research techniques used.
2. The appropriateness of the controls.
3. The measures of achievement.
4. The adequacy of the data.
5. The investigators' interpretations of the results.
6. The reaction of critics to the various research studies.

Some of the variables which were considered as factors in the comparative studies were: (1) Age and sex of students, (2) Time of day and length of periods, (3) Size of apparatus and closeness of students and who performed the demonstrations, and (4) Effect of reduction in laboratory time.

Cunningham drew several conclusions from the 37 studies in science teaching methods using multi-sensory aids. The more important conclusions were:

1. The demonstration method can be used effectively to teach science in the laboratory if the aim is to produce learning of the factual type and if economy of time, money, laboratory facilities, equipment and staff are desired.

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[71]Cunningham, Harry, *op. cit.*, p. 74.

2. The individual laboratory teaching method should be used if the acquisition of laboratory skills, resourcefulness, and solving laboratory problems are desired outcomes.

3. Both methods should be considered if the purpose is to allow for individual differences, to consider problem-solving situation, and to provide for a variety of techniques for many types of teaching conditions.

Since 1946, when Cunningham presented his summary on the demonstration versus the individual laboratory teaching method, there have been many changes in science teaching in the high schools and colleges.

There have been several post-World War II research studies in science at the college level but only a few in biology. One of those in biology was made by Mallison[72] in 1947. Two groups were equated on the basis of I.Q. and used to compare achievement of one group taught by the demonstration method with the other group which was taught by the traditional laboratory method. A list of experiments was compiled as suggested laboratory exercises for a general college biology course to be used by the instructors involved. One set of experiments was written up as a teacher's manual for the presentation of lecture-demonstration by the instructor. The other set was written up as individual laboratory exercises to be used by each student.

The students were given the same test and covered the same course

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[72] Mallison, George B., "The Individual Laboratory Method Compared with the Lecture-Demonstration Method in Teaching General Biology," <u>Science Education</u> 31:175-78, No. 3, April, 1947.

materials. The only test given was at the end of the study. An evaluation of the findings showed that no conclusion could be drawn as to the relative merits of either one of the two methods of laboratory presentation. However, the individual laboratory did show a slight trend toward the better preparation of the students for the examination.

The recommendations from this study were that a pre-test was needed to equate the students of the two groups instead of I.Q. scores and that the groups should have been larger than 75 students.

Schefler[73] in 1965 made a study which merits consideration because of the experimental design and the statistical treatment which was used to produce current research study in college biology.

The hypothesis tested was that there was no significant difference between students taught by the inductive method and those taught by the illustrative method in terms of gain from the pre-test to the post-test. The procedure involved 800 students in general college biology who were randomly assigned at registration and were considered a random sample of the sampling population.

A pre-test was given to all students at the beginning of the experimental study and a post-test at the end of the study using the same measuring instrument. The investigator taught three sections of the experimental group.

The data were assembled for analysis and the analysis of covari-

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[73]Schefler, William C., "A Comparison Between Inductive and Illustrative Laboratories in College Biology," Journal of Research in Science Teaching 3:218-223, 1965.

ance was applied. A five percent level of significance was selected. The New York State Biology Regent Scores and the Regents Scholarship Examination scores were included in the analysis as controls of academic aptitude.

The findings revealed that in no case did either method produce a statistically significant difference in achievement. In one case the effect of the instructor was significant with both methods.

Laboratory Teaching Methods Appropriate for the Achievement of the Objectives of Biology in General Education. Some recent studies were located in the literature which attempted to measure the objectives of general education in comparative studies of laboratory methods in science. No definite study in biology was located, but all were designed in the physical sciences.

Bullington[74] in 1949 carried out one of the first post-war studies at the college level for general education. Ward[75] in 1956, carried on a study in research comparing two methods in physical science instruction for general education of college students. Bradley[76] in 1962

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[74]Bullington, Robert A., "A Study of Science for General Education at the College Level," Science Education, 33:235-241, April, 1949.

[75]Ward, John N., "Group Study versus Lecture-Demonstration Method in Physical Science Instruction for General Education of College Student," Journal of Experimental Education, 24:197-210, 1956.

[76]Bradley, Robert L., "Lecture-Demonstration versus Individual Laboratory Work in a Natural Science Course at Michigan State University," Dissertation Abstracts, 23:4568, May 1962.

Moosnick[77] in 1963 produced studies in general education in physical science at the college level.

The purpose of Bradley's study was to determine the role of the individual laboratory and the lecture-demonstration methods of teaching natural science in achieving the objective of general education as measured by a paper and pencil test.

The aims and objectives of general education given for the natural science courses were to gain: (1) an understanding of science, (2) an understanding of subject matter, (3) the methods of science, and (4) an understanding of the relationship of science to other areas such as social studies and religion.

All students in the study were enrolled in one course at one time in one school. Four sections of students were randomly assigned at the time of registration. A factorial design involving five variables varying in two ways was involved. The experiment was carefully controlled with respect to the instructional time, laboratory apparatus and equipment, and the evaluational instruments.

Information on initial status of the students obtained by the College Qualification Tests, sex, and previous college laboratory science was tabulated. The criterion for achievement gain was the final examination.

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[77] Moosnick, Monroe, "An Exploration of General Education in the Natural Sciences," Dissertation Abstracts, 23:4263-4264, May, 1963.

In the experimental design, six null hypothesis were tested:

1. No difference between the subject matter achievement by methods.

2. Sexes.

3. Instructors.

4. The above median and the below median group as measured by the CQT-T Scores.

5. Groups who had previous college courses and those who did not.

6. No interaction between method, sex, above median and below median.

The experimental data were subjected to the analysis of covariance.

Five of the six null hypotheses were accepted and the sixth - no difference between the above median and the below median group was rejected.

The conclusion was that the experimental evidence showed that neither method was superior for teaching natural science when the achievement scores and the aims and objectives of general education are measured by a paper and pencil test.

There was evidence that one instructor was more effective with high ability students than with low ability students. The experimenter recommended that the teaching method or methods be considered in view of each college's own resources and that the method used be the one that is the most efficient for the situation.

In summary, the literature on experimental studies revealed several at both the secondary school and college level. Many of the pre-World War II studies lacked good experimental design and failed to use the proper statistical treatment. Current experimental studies are few in general biology and none for the non-biology student at the college level. These experimental studies were considered on the basis of laboratory teaching techniques which involved the value of the prepared drawings versus the original student drawings, the effectiveness of the micropro-jector with the compound microscope, and the value of the photomicrographs to supplement the regular outline drawings in the laboratory manual.

Experimental studies were also considered on the basis of labor-atory teaching methods using multi-sensory aids. The most important method considered was the demonstration method which was summarized to include all major experimental studies in secondary school science until 1946. At the college level, the available studies revealed that the dem-onstration method compared favorably with the individual laboratory teaching method.

Summary

Literature indicated that the demonstration method and the indi-vidual laboratory method have existed since the colonial period. Both laboratory teaching methods were used interchangeably until 1890. At that time, the individual laboratory method became dominant in both the secondary schools and colleges because of congressional acts which favored individual research and the influence of the German university training. By 1930, more and more schools were turning to the demonstration method as the individual laboratory was not considered entirely satisfactory for meeting the challenge of the trend toward general education and the increasing enrollment at a time when the country was in a social and economic crisis. However, the advantages of the scientific method allow for individualized instruction, for observation of overt behavior of students in the laboratory, and for illustration of certain characteristic stages in the development of science. The objectives of the scientific method which deal with skills, cognition, and interest and appreciation of science arè well recognized and have given direction to laboratory teaching methods in the secondary schools and college.

The demonstration teaching method was frequently mentioned in the literature and a definite relationship existed with the demonstration method and the reoccurence of the factors which affect the individual laboratory method. The nature of the demonstration method allows for less space, less staff, and equipment when proper multi-sensory aids are utilized. Psychologists and educators in the field of learning theory are in general agreement that learning is aided by the proper use of multi-sensory aids. The principles of motivation, learning meaningful materials, and transfer of learning have all been given great importance in laboratory teaching methods.

Laboratory teaching methods that have been compared in experimental studies for over forty years have in general lacked good experimental design, failed to consider many variables, and have not used the proper statistics for the data. Special techniques such as student drawings versus teacher drawings, use of micro-projector versus compound microscope, and use of the film versus its non-use compared favorably with effectiveness as techniques in the laboratory work. The demonstration teaching method has been compared with the individual laboratory teaching method mostly in the physical sciences, especially at the secondary school level. Few studies were available at the college level in biology with no studies reported concerning the non-biology student in general college biology.

To determine the effectiveness of the demonstration teaching method versus the individual laboratory teaching method in general college biology for non-biology students, an experiment was designed and conducted by the writer. This design is described in Chapter 3.

CHAPTER III

DESIGN OF THE EXPERIMENTAL STUDY

In setting up the experimental study, it was necessary to first secure permission from both the college administration and the biology department chairman since the experimental group in the study was taught in less required laboratory time than the control group. Once this was accomplished, there were five major problems to be considered in designing and conducting the experiment: (1) selection and assignment of students, (2) selection of factors to equate the two groups, (3) standardization of laboratory course content, (4) selection of instrument to measure achievement gain, and (5) determination of statistical techniques.

Instructors were selected who had previously taught the general biology course and who were scheduled to teach the course during the semester of the study. The number of class sections and the time of day for each class section of each cooperating instructor were studied to make certain the desired sample size of the experimental study could be set at approximately 150-175 students.

Selection and Assignment of Students

All non-biology major students were registered in laboratory class sections of general college biology at random. All were unaware of which instructor they would have for the course since all instructors in the biology department were listed by coded numbers in the registration schedule. Four cooperating instructors, who had previously been selected, each had one of the laboratory class sections selected for the study. These four sections with an enrollment of 77 students comprised the control group. Three of the laboratory class sections to be taught by the experimenter were selected so that there were 77 students to comprise the experimental group. The control of 77 students and the experimental group of 77 students combined to make a total of 154 students (7 sections) which fitted the desired sample size originally set at 150-175 students.

It was necessary to equate the two groups to determine if they were comparable for measuring achievement gain.

Selection of Factors for Equating the Two Groups

The review of literature and experimental studies revealed that certain underlying factors were common in equating the two groups. The eight selected factors appeared in the following four groupings in accordance with the means to be used for gathering information. The individual factors were underlined for easy identification.

1. Five factors were selected on which to secure information on personal data and science background. Age, sex, and class status were the personal data factors while the total number of science courses and achievement in high school biology were the science background factors.

Information on these factors was obtained by a questionnaire.[78]

Age was considered pertinent since students of the same age generally have similar high school backgrounds. Sex was selected as a factor since certain skills in the laboratory might be to the advantage of one sex over the other one. Class status was used since most freshmen take general college biology during the first year and would have equal years of previous schooling. The total number of science courses was used as an indicator of the science background of the students. Achievement in high school biology was considered since a difference might influence achievement in the college course.

2. Comprehensive background of high school achievement was measured by the American College Test (A.C.T.) composite scores in the areas of English, humanities, mathematics, and natural sciences. This test is given to entering college freshmen at Wisconsin State University, Whitewater, Wisconsin, and data were available.

3. The "Nelson Biology Test, Form Am" to determine initial knowledge of general biology was selected to be administered at the beginning of the study. A second form of the same test was selected to measure achievement gain at the completion of the study.

The "Nelson Biology Test, Form Am" was deemed appropriate for this study because it tested for the knowledge of biological facts, con-

[78]See Appendix C: Student questionnaire on Science and Personal Background.

cepts, principles, and the ability to evaluate experimental procedures and scientific problems in the laboratory. I also had two forms that were designed to be used as initial and final tests for measurement of achievement gain.

This was clearly brought out by Johnson, a reviewer for the Nelson Biology Test who stated:

> "Both forms, Am and Bm have broad coverage of subject matter which will meet the requirements of many subject-centered instructors. Nearly two-thirds of the 75 questions involve the application of information or interpretation of materials. The student must have a thorough understanding of a basic biology vocabulary to do well. The examination should be an asset through its influence upon the teaching of biology and as a measuring instrument."[80]

4. Laboratory course content was equated by standardizing the major topics and major principles inherent in the topics in general biology.

Standardization of Laboratory Course Content

To determine if the demonstration teaching method was as effective as the individual laboratory teaching method, it was mecessary to standardize the laboratory course content of the two methods. The instructors were to present the same course content. The following two sources were used in the determination of the laboratory course content

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[80] Buros, Oscar K. ed. Tests and Reviews: Science-Biology, The Fourth Mental Measurement Yearbook, Highland Park, New Jersey: New Jersey Gryphon Press, 1953, p. 604.

of the two groups:

1. The course syllabus of general biology designated by the biology department was the source for a checklist of major topics[81] and representative plant and animal specimens[82] to be emphasized by the cooperating instructors.

2. Martin's publication[83] was the source of the major principles selected under each major topic in general biology to be covered by the two groups.

Characteristics of the Two Laboratory Teaching Methods. In order that the differences between the two laboratory methods be clearly understood, understanding the characteristics of each is essential. Both methods are characterized:

The Experimental Group of 77 students was informed at the first laboratory period that they were part of an experimental study and would be given a test to determine initial knowledge in biology. They were told that they would be taught by a laboratory teaching method different from the conventional one at the university. Laboratory manuals or biology supply kits would not be used since microscope study or dissection of specimens would not be performed as in the control group. The

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[81] See Appendix A: List of Major Topics Covered in General Biology.

[82] See Appendix B: List of Representative Plant and Animal Specimens used in General Biology.

[83] Martin, Edgar, The Major Principles of the Biological Sciences of Importance for General Education, Bulletin 308, United States Government Printing Office, Washington, D.C., December 1962, p. 34.

required laboratory portion of the course would meet for two one-hour periods per week, and the biological principles would be demonstrated by the instructor through the use of multi-sensory aids. The second hour of each laboratory period was optional and could be used at the discretion of the student for observing displays and questioning the instructor who would be available during the hour.

The required one-hour laboratory period was characterized by the following utilization of time and the activities performed.

The class period structure for the experimental group during a demonstration period of 50 minutes incorporated the following procedures:

1. The first five to ten minutes were spent as an overview beginning with a brief introductory lecture to present the day's topics and followed by an elaboration upon the principles involved. At certain points in the lecture the instructor referred to the appropriate multi-sensory aids which would be demonstrated.

2. During the next 35 to 40 minutes, the instructor demonstrated the various multi-sensory aids to explain the topics previously mentioned and the principles involved. During the demonstration the students were allowed to participate with questions and discussions.

3. During the last five minutes of the period, the instructor summarized the principles inherent in the topics.

The nature of the demonstrations in the experimental method was designed for the instructor to use various multi-sensory aids to demonstrate the major ideas or principles of a biological topic while incorporating sound principles of learning. There were 20 major biology topics included in the general college biology course. However, only the four major topics of mitosis, parasitism, alternation of generation(moss) and embryology have been chosen here to illustrate how various multi-sensory aids were utilized to explain the principles inherent in a topic.

Mitosis was introduced to the demonstration group by making reference to a wall chart to give an overview of the sequences of stages for the process. Other multi-sensory aids to be used were: 2 X 2 slides, models of the various stages of mitosis, microprojector, and mimeographed materials.

The 2 X 2 slides were shown in order of sequence for a typical animal cell in the stages of mitosis, while the mimeographed material of the stages were labeled to show stages and the structures characteristic of each stage. Clear plastic models were used to show the depth of the cells and the position of the various structures including chromosomes while the cells were undergoing the process of mitosis. The microprojector was then used to project the image of the microscope slides from plant tissue on a screen so that the various stages were shown to be scattered throughout the actively growing tip of the plant tissue. This method also helped to show that mitosis was a continuous process but was divided into definite stages for better understanding of the process and the structures of each stage.

The review of the stages of mitosis was supplemented by the use of 2 X 2 slides not in a natural sequence so that the student recognition of the stages and structures was not dependent on memory in order of occurrence.

The major principles obtained from the study of mitosis were as follows: (1) the process is characteristic of both plant and animal cells, (2) the growth in number of cells is dependent on the process, and (3) the number of chromosomes remain constant for each generation. Although there are certain structural changes with mitosis in the animal cell as compared with the plant cell, the process is characteristic of all actively growing cells.

Parasitism was introduced by referring to a wall chart as an overview to show the highly specialized external structures and appearances of roundworms and flatworms which are endoparasites. The following mutli-sensory aids were used: 2 X 2 slides, plastic mounts, preserved specimens, filmstrip, and mimeographed materials of the life cycle of the liver fluke.

The filmstrip was then shown so that the shapes, sizes, numbers, and habitats of parasites could be compared and contrasted. Preserved specimens and clear plastic mounted specimens were passed among the students so that they could determine the actual size of the parasites.

Large wall models of the dissected parasitic worms were presented to show that certain systems have degenerated because of the nature of the habitat in a host. The same model illustrated that the reproductive system was very specialized because of the various stages necessary to complete the life cycle.

The 2 X 2 slides were displayed by the film projector to demonstrate the stages of the adult liver fluke as a host in man to the other two hosts and habitats which are included in the life cycle of the parasite. The students labeled the mimeographed sketches to follow the steps of the life cycle with the various hosts and to explain that the life cycle was an alternation of generations in these lower animals.

In summarizing parasitism the following major principles were expounded: (1) parasites are successful because of special external structures which resist being destroyed by the host, (2) the development of a specialized reproductive system helped the complexity of their life cycles, and (3) parasitism was due to poor sanitation conditions.

Alternation of generation in the moss plant was introduced by a wall chart to show the various stages in the life cycle.

The following multi-sensory aids were used: filmstrip, preserved and living specimens, models, microprojector, and mimeographed materials.

The filmstrip was used to show various representative mosses, their habitats, and the structures which are used in identification.

Living and preserved materials were demonstrated to show the actual size of the moss plant and the primitive nature of the structures in this group of plants.

The large model of the moss plant was displayed to contrast the difference between the sporophyte and the gametophyte stage.

The microprojector produced the image of the microscope slides on a screen to show details of the moss plant, especially the reproductive structures of both the males and females.

The wall chart and the mimeographed materials of the life cycle were used to explain the concept of alternation of generation which showed how the sexual stage alternated with the asexual stage.

In summarizing, the following principles were inherent in study of mosses: (1) the moss has a true alternation of generation in which the gametophyte stage (sexual) alternate with the sporophyte stage (sexual), (2) fertilization was necessary to produce the sporophyte stage and meiosis was necessary to produce the gametophyte stage, and (3) mosses have primitive plant structures.

Embryology was introduced by referring to a large wall model of the various stages in the development of the frog. This included stages from the egg to the adult. The various multi-sensory aids were used: 2 X 2 slides, whole set of embryo models, microprojector, models on wall, and mimeographed sketches of starfish embryos in various stages of development.

The microprojector showed the images of the microscope slides of starfish embryology for observation of various simultaneous stages of development for comparison, such as the two-celled, four-celled, and the morula stage. Mimeographed sketches of embryology were labeled for the different stages by the student with colored pencils to discriminate the germ layers.

Next, more complete stages of embryology were demonstrated with the 2 X 2 slides of frog development given in a sequence from the one-celled stage through a well developed embryo to the tadpole. Enlarged pictures of embryos of fish, frog, turtle and chicken and man were compared to show the similarity in early stages and how differentiation occurs as development proceeds.

In summarizing embryology, the principles inherent in the topic were as follows: (1) all organisms begin as one-celled and are similar in appearance, (2) as development occurs the characteristics of each organism becomes apparent, and (3) the type of cleavage is dependent on the amount of yolk available.

Control Group. The students were informed at the first laboratory period, at which time they were given a test to determine initial knowledge in biology, that they were the control group in an experimental study and they would be taught by the conventional laboratory method[84] of two two-hour periods per week. A laboratory manual was designated, and a required biological supply kit was indicated for the individual laboratory work.

The class period structure for the control group method. The two hour laboratory period was characterized by the following procedures:

1. The first 10 minutes were spent getting microscopes readied, reading laboratory manual for directions and receiving directions from

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[84] Bulletin of Wisconsin State University, Whitewater, Wisconsin, 1964-66, p. 57. "The general biology course, Biological Foundation 120, consists of three lectures and two two-hour laboratory periods per week for the semester."

the instructor of the topics and principles to be covered for the two-hour period.

2. The next 100 minutes were spent examining microscope slides, then sketching and labeling on plates or in the laboratory manual. After the dissection of specimens, they were examined, sketched, and labeled. Short periods might be spent directing the entire class to a special topic or principle.

3. The last ten minutes were spent clearing away materials and then handing in properly labeled sketches.

Contrasting Study Techniques with Specific Laboratory Materials for the Two Groups. Although the laboratory course content was standardized for both groups, the nature of this study purports to establish certain sharp contrasts between the two laboratory teaching methods. Specific laboratory materials for certain laboratory study techniques merit special consideration in the study. These are listed as follows: (1) microscope slides, (2) sketches, (3) laboratory manuals, and (4) dissected specimens.

1. Microscope slides. In the experimental group, all microscope slides were projected upon a screen by a microprojector to be viewed by the entire class while in the control group, all microscope slides were examined by the student individually. For example, the study of tissues was conducted as follows: The experimental group viewed the image on the screen and labeled mimeograph sketches and all viewing and studying of the same tissue at the same time. The control group examined and studied the various tissue slides and then sketched and labeled on plates or in the laboratory manual to show tissue types. These were handed in for

corrections.

2. Sketches. In the experimental group, all sketches were mimeographed, and the students labeled them during and after observing the demonstrations; while in the control group the materials studied were sketched and labeled by the student. For example, the study of morphology of the root, stem, and leaves of plants, was conducted as follows: The experimental group viewed the demonstrations presented by multi-sensory aids and then labeled the mimeographed sketches provided. The control group examined and studied microscope slides containing cross-sections of roots, stems and leaves, and then sketched and labeled on plates or in the laboratory manuals.

3. Laboratory Manual. The experimental group did not use a laboratory manual for directions but took notes on the demonstrations and labeled mimeographed sketches. In the control group, the laboratory manual was used to give directions for sketching, dissecting, and introducing new terms about each specimen covered. For example, the testing of classes of foods was conducted as follows: In the experimental group the instructor demonstrated various foodstuffs to the class and then tabulated the results on the blackboard.

In the control group each student took various foodstuffs and placed them in test tubes and added certain chemicals, and heat, to determine the classes of foods. The results were then entered in the laboratory manual.

4. Dissected specimens. In the experimental group, the dissected

specimens were displayed among the students at the tables and the instructor pointed out the structures on a large wall chart. The students labeled the structures on the mimeographed sheets. In the control group, the students dissected the preserved specimens and then sketched and labeled the appropriate parts in the laboratory manual. For example, the earthworm examination was conducted as follows: In the experimental group the students examined dissected earthworms displayed in plastic mounts while in the control group, each student followed the directions in the laboratory manual and dissected the earthworm to study and examine the structures. They then sketched and labeled in the laboratory manual before handing in completed work for corrections.

Selection of Instrument to Measure Achievement Gain in General Biology

To determine achievement gain in general biology by the two laboratory teaching methods, the "Nelson Biology Test, Form Am" was given at the beginning of the study and the "Nelson Biology Test, Form Bm" to measure achievement gain was given at the conclusion of the course to both groups.

Each form of the Nelson Biology Test consisted of eight pages with a total of 75 multiple choice items. Each item had one of five correct responses, with a total of 75 correct answers for the entire test which could be scored objectively. Each form was a timed-test of forty minutes.

Determination of Statistical Techniques

To determine the effectiveness of the individual laboratory teaching method versus the demonstration teaching method in college biology by non-biology students, it was necessary to choose statistical techniques to test the hypothesis of the study. The preliminary procedures involved: (1) determining the initial similarity of the two groups, (2) choosing statistical techniques for relating sample groups, and (3) selecting statistical techniques to measure achievement gain.

Initial Similarity of the Two Groups. The five factors of age, sex, total number of science courses, class status, and high school biology grade were treated by the statistical technique the measure of central tendency, the mean. The A.C.T. composite scores were treated by the t-test technique to determine if the means of the two groups were significant and could be matched on these scores.

Choosing Statistical Techniques for Relating Sample Groups. The specific statistical techniques for relating sample groups were chosen to determine (1) if the analysis of variance, F-test technique, was used to determine if the four samples from the control group could be pooled to form a composite control group and the three samples from the experimental group could be pooled to form a composite experimental group;

(2) if the pooled variance, the t-test technique, could be used to determine the pooling of the composite control group with the composite experimental group to determine a normally distributed population; and (3) if the Pearson-Product-Moment Correlation Co-efficient technique could be used to measure the relationship between the students of the experimental and the control groups on the two forms of the Nelson Biology Test.

Selecting a Statistical Technique to Measure Achievement Gain. The statistical technique selected to measure for achievement gain in general biology between the students of the experimental and control groups was the t-test, a measure of difference between the means for correlated samples.

The experimental investigation was conducted in accordance with the design, and all results were treated by these carefully selected statistical measures. A report of these results are presented in Chapter 4.

CHAPTER IV

THE EFFECTIVENESS OF THE DEMONSTRATION TEACHING METHOD VERSUS THE INDIVIDUAL LABORATORY TEACHING METHOD IN GENERAL COLLEGE BIOLOGY

To determine the effectiveness of the demonstration teaching method versus the individual laboratory teaching method in general college biology by non-biology students, five phases of statistical comparison of the research data collected during the experimental study were required. The five phases of statistical comparisons were conducted to determine: (1) personal and science background data for equating the experimental and control groups; (2) the pooling of the four samples from the control group to form a composite control group and the three samples from the experimental group to form a composite experimental group; (3) the pooling of the composite control group with the composite experimental group to determine a normally distributed population; (4) the extent of the correlation between the scores on the initial test of knowledge in general biology and the scores obtained on the final test for achievement gain in general biology by the two groups; and (5) the achievement gain in general biology between students of the composite experimental and control groups. These five comparisons are presented in the following sections.

Equating Personal and Science Background Factors of the Experimental and Control Groups

The review of experimental studies in the literature revealed that the nature of this experimental design encouraged the use of statistical comparison of the experimental and control groups on personal and science background data in order to establish greater confidence in the two as similar groups when considered in addition to the initial test scores. Data on the six factors used for equating the two groups are presented in Table 1. An inspection of these data reveals rather quickly the equality of the two groups on the basis of age, sex, class status, science background, and general high school achievement.

As a further check to determine the initial similarity of the two groups, it was decided to use the Chi Square[86] test of significance in regard to the criterion of sex. This check was made to test the hypothesis that the males and females in the two groups could be combined into one control group of males and females and one experimental group of males and females. The calculated value of significance of difference in sex was .654 at the 0.05 level. The hypothesis that there was no significant difference was not rejected since this value indicated there was no significant difference in the distribution of male and female students between the two groups.

Data in Table 1 reveal that the mean of the experimental group (47.50) differs from the mean of the control group (45.48) on A.C.T. composite scores. The t-test for difference[87] between the means of sample groups equal size was used to test the hypothesis that there was no sig-

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[86] Downe, N. M., and Heath, R. W., Basic Statistical Methods, New York: Harper and Brothers Publishers, 1959, p. 148.

[87] Wert, James, Neidt, Charles, and Ahmann, J. Stanley, Statistical Methods in Educational and Psychological Research, New York: Appleton-Century-Croft, 1954, p. 129.

nificant difference between the means of the two groups. The calculated value determined was 1.047 with 63 degrees of freedom at the 0.05 level of significance.

TABLE 1. DATA USED FOR EQUATING THE 77 STUDENTS OF THE EXPERIMENTAL GROUP AND THE 77 STUDENTS OF THE CONTROL GROUP; BY AGE, SEX, CLASS STATUS, TOTAL NUMBER OF SCIENCE COURSES, HIGH SCHOOL BIOLOGY GRADE, AND A.C.T. COMPOSITE SCORES

Factors Used for Equating		Experimental (77)	Control (77)
Mean Age		18 years 11 months	19 years 0 months
Sex	males	33	39
	females	44	38
Class Status: Number of Freshmen		71	72
Mean Science Courses Taken		3.2	3.3
Mean High School Biology Grade *		2.76	2.68
Mean A.C.T. Composite Score		47.50	45.48

*Biology grade based on scale A-1; B-2; C-3; D-4 for 71 students in Experimental Group and 74 in Control Group who had taken high school biology.

This value indicated there was no significant difference between the two groups. Thus the two groups were equated for the study on the basis of general high school achievement as measured by the A.C.T. composite scores.

Pooling the Four Samples of the Control Group to Form One Composite Control Group and Three Samples of the Experimental Group to Form one Composite Experimental Group

Since the samples used in this study were drawn by regular registration procedures from one University but taught by different instructors, it was necessary to determine if the students in the four class sections of the control group could be pooled to form one composite control group and to determine if the three class sections of students of the experimental group could be pooled to form one composite experimental group. The scores from the test of initial knowledge in general biology were obtained from the "Nelson Biology Test, Form Am", administered at the beginning of the experiment before laboratory teaching methods in general biology commenced. The analysis of variance - single classification, F-test for unequal size samples[88] was selected to analyze the test scores of the participating students to determine if the sample groups were derived from the same sample population or if they denoted significant population differences.

The hypothesis was established that no significant difference

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[88] *Ibid.*, p. 177.

existed among the initial test scores of the four sample groups of the control group taught by four different instructors. The values for the analysis of variance on initial test scores among four class sections and 77 students of the control group are presented in Table 2.

TABLE 2. ANALYSIS OF VARIANCE OF INITIAL TEST SCORES AMONG FOUR CLASS SECTIONS AND 77 STUDENTS OF THE CONTROL GROUP WITH UNEQUAL SIZE SAMPLES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Between Groups	3	483.51	161.17
Within Groups	73	5413.19	74.15
Total (N-1)	76	5896.70	

$$F_{3,\ 73} = \frac{161.17}{74.15} = 2.17 \text{ (F-value)}.$$

The F-value of 2.17 was not significant so the four sample groups of the control group could be treated as a composite control group.

Since the four samples of the control group could be treated as a composite control group, it was also necessary to determine if the three samples of the experimental group could be considered as a composite experimental group. The hypothesis was established that no significant difference existed among the initial test scores of the three sample groups of the experimental group taught by one instructor. The values for the analysis of variance on initial test scores among three class sections and 77 students of the experimental group are shown in Table 3.

TABLE 3. ANALYSIS OF VARIANCE OF INITIAL TEST SCORES AMONG THREE CLASS SECTIONS AND 77 STUDENTS OF THE EXPERIMENTAL GROUP WITH UNEQUAL SIZE SAMPLES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Between Groups	2	316.38	158.190
Within Groups	74	3211.91	43.404
Total (N-1)	76	3528.29	

$$F_{2, 74} = \frac{158.190}{43.404} = 3.644 \text{ (F-value).}$$

Since the F-value was 3.644 and the critical value was 3.313 at the 0.01 level, the hypothesis that there is no significant difference between the two groups was accepted.

Pooling the Samples of the Composite Control and Experimental Groups to Determine a Normal Population

The results obtained indicated that the four samples of the control group could be pooled to form one composite control group and the three samples of the experimental group could be pooled to form one composite experimental group.

To determine if both composite groups represented a single homogeneous and normally distributed population, the variances of the initial test scores for the composite control and composite experimental group were used. Before proceeding to pool the variances of the two composite groups, an F-test was made.[89] The F-value was 1.67 with 73, 74 degrees of freedom at the 0.01 level of significance. The null hypothesis was accepted.

Since the results indicated that there was no significant difference between the variances of the two groups, the two variances could be pooled. The variances of the initial test scores for the experimental group and the control groups were pooled[90] to determine if there was a significant difference in the sample population of the experimental and control groups. The t-value found was .480 with 152 degrees of freedom at the 0.05 level of significance. The hypothesis was accepted thus assuring that the two composite groups could be pooled and considered as a normally distributed population.

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[89] Ibid., p. 134.

[90] Ibid., p. 135.

Determining the Correlation Between Scores on Initial Knowledge and Final Achievement Gain in General Biology as Basis of Measuring Achievement

To determine the validity of using the initial test scores of the participating students in general biology as a basis for obtaining matched pairs in testing for difference in the results in final achievement gain in biology, it was necessary to determine the extent of the correlation between the scores of the students on the "Nelson Biology Test, Form Am," and on the "Nelson Biology Test, Form Bm."[91] The Pearson Product-Moment Correlation Coefficient[92] was computed to determine the relationship of the correlation between the initial test scores and the final achievement gain test scores. The experimental group correlation was .69 while the control group was .79. Both correlations at the 0.05 level of significance with 77 degrees of freedom were highly significant and clearly indicated that the t-test for correlated samples could be used to measure achievement gain.

Determining Achievement Gain Between the Composite Experimental and Control Groups

To determine the effectiveness of the demonstration teaching method versus the individual laboratory teaching method, it was neces-

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[91]Alternate forms of the same achievement test can usually be used for the initial matching and for the final test results in experimental studies concerning achievement gain that occurred under different methods of teaching.

[92]Wert, op. cit., p. 81.

sary to test that there was no significant difference in achievement gain between the composite experimental group and the composite control group.

The hypothesis stated that there was no significant difference in achievement gain in general biology between the students who were taught by the demonstration teaching method and the students taught by the individual laboratory teaching method. For all tests of significant difference in achievement gain between the composite experimental group and the control group, the level of significance was set at 0.05 on a two-tailed test.

The t-test technique for correlated samples[93] was employed in six different applications to test the hypothesis that there was no significant difference in achievement gain between students taught by the individual laboratory teaching method and the demonstration teaching method. The six applications for testing for no significant difference in achievement gain between the two groups as determined by the final achievement test scores involved matching the initial test scores of the control group with the initial test scores of the experimental group as follows: (1) sixty matched pairs of composite groups on initial test scores; (2) twenty-seven matched pairs of females: (3) twenty-seven matched pairs of males; (4) twenty-five matched pairs of upper-third class standing; (5) eighteen matched pairs of lower-third class standing; and (6) sixty-three matched pairs on basis of laboratory achievement.

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[93] Ibid., p. 141.

T-values in the six categories which were tested for achievement gain by the t-test for correlated samples are presented in Table 4.

TABLE 4. MEANS AND CALCULATED AND CRITICAL VALUES OF ACHIEVEMENT GAIN IN THE T-TEST FOR CORRELATED SAMPLES OF MATCHED PAIRS IN COMPOSITE GROUPS IN SIX CATEGORIES TESTED

Achievement Categories	No.*	Tests **	Achievement Test Means		Calculated Value of t	Critical Value of t***
			Experiment Group	Control Group		
General Group	60 60	I F	39.03 42.87	38.95 45.26	1.960	2.000
Females	27 27	I F	38.81 41.74	38.80 43.89	1.165	2.052
Males	27 27	I F	38.22 43.07	38.19 45.78	1.801	2.052
Upper-third Class Standing	25 25	I F	46.52 50.18	47.15 52.74	.147	2.060
Lower-third Class Standing	18 18	I F	32.65 37.39	27.50 35.19	.840	2.110
Laboratory Experiences Achievement	63 63	I F	18.01 18.21	17.91 19.52	1.811	1.995

*Number of matched pairs of experimental and control groups.
**Initial (I) and final (F) achievement.
***Critical value of t at the 0.05 level of significance.

The hypothesis of no significant difference in achievement gain in general biology between the experimental group and the control group at the 0.05 level of significance was not rejected in the six different categories.

The following findings are revealed by the data given in Table 4:

1. The closeness of the means (18.01-17.91) on the initial test and the mean gain of the control group (17.91-19.52) of the 63 matched pairs on laboratory experiences achievement, although not significant, favored the individual laboratory teaching method.

2. Since the means of the 27 matched pairs of females and males were almost identical on the initial test, the mean gain in score of 5.09, although not significant, indicated the females did slightly better by the individual teaching method. A comparison of mean gains also indicates that the males did slightly better with the individual laboratory teaching method also.

3. The mean gain in achievement of 25 matched pairs of upper-third class standing indicates that the control group was slightly superior (.63) on the initial test, but it gained 5.59 for the semester compared to a gain of 3.66 for the experimental group. The gain was not statistically significant but revealed some superiority by the individual method.

4. A comparison of results of 18 matched pairs in lower-third class standing reveals that those in the individual method gained 7.69 compared to 4.74 for the experimental group. Although not a significant difference, ability of the lower third to profit by the individual method was shown.

Differences in means of the 60 matched pairs reveal a mean gain of 6.31 for the control group and 3.84 for the experimental group. Although not statistically significant, it does point to some superiority for the individual method.

Summary

The data collected during the investigation were analyzed statistically to determine the effectiveness of the demonstration teaching method versus the individual laboratory teaching method in general college biology by non-biology students for achievement gain.

The data gathered of the six factors - sex, age, class status, previous science courses, high school biology achievement, and general high school achievement - clearly reveals (Table 1) equality of experimental and control groups for equating purposes. The one factor, high school general achievement on A.C.T., revealed a difference in means which was not found to be significant when the t-test was applied.

The analysis of variance was employed to show the validity of pooling the four sample groups to form a composite control group and the three samples to form a composite experimental group. Results showed this to be valid, and the use of mean-pooled variance validated the pooling of the two composite groups. The result did indicate that there was no significant difference in the sample population and that the sample groups did represent a normally distributed population for the study.

The relationship between the initial test scores and the final test scores was computed by the Pearson Product-Moment Method. The coefficients of correlation were significant for both groups and establish

the validity in the use of the t-test for correlated samples in measuring achievement gain. Results of its application (Table 4) to matched pairs of the composite groups revealed that there was no significant difference in achievement gain between students of the experimental and control groups in the six categories tested. Although not significant, there were differences revealed that would indicate (1) a slight favoring of the individual laboratory method, (2) slightly better work by females in individual teaching and also by males in the same method, (3) upper-third class standing students better in the individual method, and (4) that lower-third class standing students also did slightly better by the individual method.

A general summary, conclusions, and recommendations are presented in Chapter 5.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study resulted from the belief that the demonstration teaching method in biology laboratory teaching could be as effective as the individual laboratory method so commonly practiced. The conditions of greatly increased enrollments and the general education needs of non-biology majors accentuated the need to search for a laboratory teaching method to meet the problems of materials, space, and staffing. This study was a search for such a method. It was two-directional. Literature was reviewed to determine the validity of the belief and to substantiate the kinds of experiences and materials that would characterize an experimental demonstration laboratory teaching method which emphasized the use of multi-sensory aids in developing the effective learning of principles of biology for non-biology majors. The review of literature provided this and made possible the second part of the study - an experimental investigation of the effectiveness of the proposed demonstration method.

The experimental part of the study was made by selecting two equal-numbered samples of non-biology majors in a one-semester course and equating them as comparable groups on the basis of age, sex, class status, previous science courses, achievement in high school biology, general achievement in high school, initial knowledge of biology at the start of the college course, and laboratory course content. One hundred and fifty-four students were selected to comprise the equal numbered samples of 77 for four laboratory sections taught by four instructors to form the control group under the individual laboratory teaching method; and 77 for three laboratory sections taught by the author as the experimental group, using a demonstration teaching method based on extensive use of multisensory aids. Two two-hour periods per week were scheduled for both groups, but for the experimental group the second hour of each session was optional for self-study. A standardized achievement test (Nelson Biology Test) was administered at the beginning and end of the semester to measure the effectiveness of the experimental method for achievement gain.

Summary

The examination of literature revealed that both the individual laboratory teaching method and the demonstration method have existed in the United States since colonial time. By 1900 the individual laboratory method dominated, but since that time both methods have been used concurrently. Since the 1930's, scientists and educators have been increasingly critical of the individual laboratory teaching method because the values inherent in the method have not been fully realized by the students. At the present time various experimental methods are being explored in the continuing search for laboratory teaching methods which place emphasis on the general education values inherent in the sciences and which meet the demands of the rapidly increasing college enrollment.

Both general and specialized experimental study reports in literature revealed (1) that principles of learning can serve with confidence as guidelines for the use of appropriate multi-sensory aids in presenting the principles of biology, (2) that a combination of demonstrations and individual laboratory work will benefit the student in the laboratory, and (3) that there are rather well-established factors for equating groups, for experimental design, and for achievement measurement.

Results of the experimental investigation are given in a detailed summary at the end of Chapter 4, pages 95-96. There are, however, some general summary statements that can be made from the findings. They are as follows:

1. The measurement of achievement gain in the composite groups, although not significant, pointed in favor of the individual laboratory teaching method with 6.31 gain compared with 3.84 for demonstration teaching.

2. Females appear to do slightly better by the individual method, and males also appear to do slightly better by this method.

3. Students in the upper-third class standing were slightly superior in the individual teaching method but probably could do equally well if taught by either method. The lower-third class standing also did slightly better by the individual method.

By contrasting the mean achievement gain of all students in the experimental group, not just matched pairs, which was 3.94 (pre-test mean-39.62, post-test mean-43.56) with the mean achievement gain of all those in the control group which was 6.54 (37.67, 44.21) for one semester in biology, it appeared that there was very little achievement gain by the students of the two groups. However, when compared with the norms from Nelson Biology Test for a full year in biology, the experimental group revealed a 14 percentile rank increase (72, 86) and the control group revealed a 20 percentile rank increase (68, 88); both represent substantial achievement gain in general biology for one semester. The apparent large initial test scores as based on percentile norms (72, 68) could be accounted for since most of the students had taken high school biology.

The following observations were made by the experimenter during the study, and although not substantiated by statistical treatment nor by a summary of notes, are presented:

1. There was evidence of attentiveness by the students to all multi-sensory aids and their use of contrast and discrimination in the development of the principles during the demonstrations.

2. The highly structured nature of categorized displayed materials attracted the students' interest, even students from other classes who recorded structured materials.

3. The attitude exhibited by the students toward the demonstration method was favorable and was in contrast to the experimenter's previous experiences in teaching the individual laboratory method.

Conclusions

From the findings of the study, two conclusions were drawn:

1. From the strength revealed by achievement of persons in a biology laboratory situation with demonstration teaching stressing extensive use of multi-sensory aids and the apparently equal strength by one that stressed individual involvement, one could safely conclude that a search for a more effective laboratory teaching method should include the strengths of both - the value of contrasting and discriminating and that of individual involvement.

2. If the limited sample were to be expanded and the same experiment conducted under the same conditions with the same results obtained, one could conclude that the demonstration method making extensive use of multi-sensory aids would be a satisfactory approach in meeting the laboratory needs of non-college biology students in general college biology.

Recommendations

The following observations and recommendations became evident during the course of the experimental study and are presented here to indicate areas of possible future research related to laboratory teaching methods in general biology.

In view of the fact that increasing student enrollment is of paramount importance in maintaining proper laboratory facilities and staff, biology departments need to investigate the possibility of other laboratory methods than those used in this study.

A survey of learning principles and experiences with the experimental group clearly indicates that biology instructors need to become more involved in the use of multi-sensory aids in the development and presentation of principles in biology.

The attitudes of non-biology students toward laboratory teaching methods indicate clearly the need for investigation of ways of stimulating a greater spirit of inquiry.

Intensive experimentation is needed to determine the appropriateness and effectiveness of multi-sensory aids in the development of different major ideas in any discipline.

Considerable study and experimentation should be made of a "compact lecture-demonstration method" in each class period instead of certain days for lecture and other days for demonstrations.

LITERATURE CONSULTED

LITERATURE CONSULTED

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APPENDIX

Appendix A

List of Major Topics Covered in General College Biology

List of Major Topics Covered in General College Biology

The following major topics covered in previous semesters as presented in the course syllabus for Biology 120 (General College Biology) were used as standard course content for both the experimental and control groups.

1. Chemical and physical properties of matter
2. Diffusion and osmosis
3. Plant and animal cells
4. Plant and animal tissues
5. Mitosis and growth
6. Meiosis and reproduction
7. Plant processes
8. Cellular respiration
9. Digestion of foods
10. Photosynthesis
11. Protoplasm
12. Morphology
13. Alternation of generation
14. Taxonomy and classification
15. Genetics and heredity
16. Ecology
17. Parasitism
18. Embryology
19. Plant and Animal Distribution
20. Plant and animal diversity

Appendix B

List of Representative Specimens for General College Biology

List of Representative Plant and Animal Specimens for General College Biology

The following representative specimens will be used in General College Biology during the experimental study:

1. algae
2. fungi
3. bacteria
4. mosses and liverworts
5. ferns and fern allies
6. pines
7. flowers
8. fruits
9. seeds
10. leaves
11. stems
12. roots
13. protozoan
14. sponges
15. hydra and jellyfish
16. flatworms
17. roundworms
18. segmented worms
19. mollusk (clam)
20. grasshopper
21. crayfish
22. fish
23. frog
24. rat

Appendix C

Student Questionnaire on Science Background

Student Questionnaire on Science Background

Please answer all questions and make any added comment if you wish.

1. Name____________________ 2. Age____ 3. Sex__________

4. What is your present status? Freshman Sophomore Junior Senior

5. What high school were you attending when taking high school biology?

____

6. Which high school text did you use for biology?_______________

7. Which year did you take high school biology? First Second Third Fourth

8. Check the following courses taken in high school: ____biology, ____chemistry, ____physics, ____general science, ____advance science

9. Type of biology instruction? ____lecture-discussion, ____lecture-demonstration, ____lecture-laboratory, ____other

10. Greatest area of stress? ____botany, ____zoology, ____human biology, ____all three

11. Frequency of laboratory work? ____none, ____few, ____regular

12. Worked with a microscope? ____yes, ____no

13. High School biology grade? ____A, ____B, ____C, ____D

14. Did you enjoy high school biology? ____yes, ____no, ____indifferent

15. Did you have B.S.C.S. biology? ____yes, ____no

16. Did you have physical science in college? ____yes, ____no

17. Any comments concerning information not asked on this questionnaire?

APPENDIX D

Tables

TABLE 5. INDIVIDUAL DATA ON STUDENT NUMBER, AGE, CLASS STATUS, SEX, TOTAL SCIENCE COURSES, A.C.T. COMPOSITE SCORES AND HIGH SCHOOL BIOLOGY MARKS FOR 77 STUDENTS OF THE EXPERIMENTAL GROUP

Student Number	Age		Class Status	Sex	Total Science Courses	A.C.T. Composite Score	H.S. Biology Marks
	Yrs.	Mos.					
1	20	10	2	F	2	—	C/C
2	18	06	1	M	2	20	C/C
3	18	03	1	F	3	76	A/B
4	19	04	1	F	5	—	A/A
5	18	06	1	M	5	82	B/C
6	19	01	1	F	2	20	—
7	19	04	1	F	3	48	A/A
8	20	09	1	M	5	48	C/C
9	18	11	1	M	5	33	A/B
10	19	06	1	M	5	—	B/C
11	20	01	1	M	3	52	C/C
12	21	02	1	M	3	—	B/B
13	23	06	1	M	2	—	C/B
14	18	08	1	F	4	55	C/C
15	19	04	1	F	3	—	B/B
16	18	04	1	F	3	11	C/B
17	18	07	1	F	5	33	A/B
18	18	03	1	F	4	87	B/B
19	18	04	1	M	2	55	B/B
20	18	06	1	F	3	26	C/D
21	18	09	1	F	4	20	A/B
22	18	11	1	F	3	8	C/B
23	18	03	1	F	4	91	C/D
24	18	10	1	F	3	40	C/D
25	18	07	1	F	3	15	B/C
26	18	06	1	F	3	69	A/B
27	18	10	1	F	3	76	B/B
28	18	09	1	F	2	62	—
29	17	08	1	F	2	62	A/B
30	18	03	1	F	3	33	C/C
31	18	07	1	M	3	26	A/B
32	18	05	1	M	5	26	C/D
33	18	05	1	F	3	40	A/A
34	18	08	1	F	3	62	C/B
35	18	05	1	F	3	15	C/C
36	18	09	1	F	2	48	—
37	18	03	1	F	2	8	C/C
38	18	05	1	M	3	33	A/B

TABLE 5 (Continued)

Student Number	Age Yrs.	Age Mos.	Class Status	Sex	Total Science Courses	A.C.T. Composite Score	H.S. Biology Marks
39	19	01	1	F	3	48	B/B
40	19	02	1	F	3	33	C/C
41	18	05	1	F	3	76	A/B
42	18	07	1	M	3	26	C/D
43	18	02	1	M	2	69	—
44	18	03	1	F	4	91	A/B
45	18	10	1	M	4	33	B/B
46	18	03	1	F	4	62	A/A
47	21	05	3	M	2	—	C/C
48	23	07	2	M	4	—	C/C
49	19	04	1	M	2	40	C/C
50	18	10	1	M	4	33	C/B
51	18	11	1	M	3	55	B/B
52	20	05	1	F	3	20	B/C
53	18	07	1	M	2	40	—
54	18	11	1	F	4	55	B/B
55	18	09	1	F	4	55	C/C
56	19	03	1	M	2	40	A/B
57	18	09	1	F	4	76	A/B
58	18	07	1	M	4	82	C/C
59	19	04	1	F	3	33	C/B
60	18	10	1	M	4	26	C/C
61	18	11	1	M	4	62	A/B
62	18	09	1	F	1	40	A/B
63	18	06	1	F	3	48	A/A
64	19	00	1	M	4	40	C/D
65	18	10	1	M	4	20	A/B
66	18	09	1	F	3	76	A/B
67	18	10	1	M	2	40	—
68	18	08	1	F	4	87	B/B
69	19	07	1	F	3	40	C/B
70	18	10	1	M	3	87	B/B
71	18	11	1	F	3	55	B/B
72	18	11	1	M	4	55	C/D
73	18	00	1	M	4	15	C/B
74	18	03	1	M	2	48	C/C
75	19	03	2	F	3	—	C/B
76	19	01	1	F	4	82	C/B
77	20	08	2	M	2	40	C/C

TABLE 6. INDIVIDUAL DATA ON STUDENT NUMBER, AGE, CLASS STATUS, SEX, TOTAL SCIENCE COURSES, A.C.T. COMPOSITE SCORES AND HIGH SCHOOL BIOLOGY MARKS FOR 77 STUDENTS OF THE CONTROL GROUP

Student Number	Age Yrs.	Age Mos.	Class Status	Sex	Total Science Courses	A.C.T. Composite Score	H.S. Biology Marks
78	19	10	1	M	3	—	C/C
79	19	01	1	M	5	48	B/B
80	19	00	1	M	5	87	C/C
81	19	04	1	M	3	26	B/C
82	18	11	1	F	3	40	C/C
83	18	06	1	F	3	33	B/C
84	18	05	1	M	5	55	B/C
85	18	07	1	F	4	40	C/C
86	19	06	1	F	3	40	C/C
87	18	07	1	F	2	20	A/C
88	18	08	1	M	3	—	B/C
89	19	08	2	M	5	—	A/A
90	18	00	1	F	2	33	B/C
91	18	10	1	M	3	15	C/C
92	20	02	1	M	3	35	B/B
93	18	04	1	M	4	87	A/A
94	18	04	1	F	5	87	A/B
95	18	09	1	F	3	20	C/C
96	19	01	1	M	4	40	B/B
97	18	02	1	M	3	82	C/C
98	18	02	1	F	5	33	A/B
99	18	07	1	M	5	97	B/C
100	18	09	1	F	4	20	B/B
101	18	03	1	F	4	40	B/B
102	19	05	1	F	2	15	C/C
103	22	08	1	M	2	—	B/C
104	19	00	1	M	3	—	C/C
105	18	08	4	F	3	—	C/D
106	19	01	1	F	3	62	A/B
107	18	09	1	F	2	15	A/C
108	18	10	1	F	4	48	B/C
109	18	07	1	M	2	—	C/C
110	18	04	1	M	3	15	C/D
111	22	01	1	M	2	—	A/B
112	19	04	1	M	2	62	C/D
113	18	10	1	F	4	55	B/D
114	19	02	1	M	3	62	A/B
115	18	05	1	M	3	55	C/C

TABLE 6 (Continued)

Student Number	Age Yrs.	Age Mos.	Class Status	Sex	Total Science Courses	A.C.T. Composite Score	H.S. Biology Marks
116	18	06	1	M	4	62	–
117	19	00	1	M	4	55	C/D
118	19	02	1	M	4	11	A/B
119	18	10	1	M	4	40	C/D
120	18	05	1	F	2	62	A/A
121	19	09	1	M	5	76	A/B
122	18	06	1	F	3	33	A/B
123	19	02	1	M	3	82	A/B
124	18	02	1	F	3	4	B/B
125	18	01	1	F	2	33	C/D
126	20	00	1	M	4	20	C/D
127	18	07	1	F	4	40	C/C
128	19	00	1	F	5	33	C/C
129	22	01	4	F	2	—	A/B
130	18	07	1	F	3	82	B/B
131	18	06	1	M	2	48	A/A
132	19	00	1	M	3	26	C/C
133	18	07	1	M	5	76	B/D
134	18	04	1	F	5	26	B/B
135	18	08	1	F	2	69	A/B
136	18	07	1	F	3	55	C/C
137	19	00	1	M	3	5	C/C
138	18	04	1	F	3	33	A/A
139	18	09	1	M	3	40	C/C
140	19	02	1	M	3	20	A/B
141	18	11	1	F	4	26	C/D
142	19	02	1	M	2	—	C/C
143	18	04	2	M	1	55	B/B
144	22	01	1	M	2	—	–
145	18	11	1	F	3	69	–
146	19	11	2	M	2	—	–
147	18	08	1	F	5	8	C/C
148	18	04	1	F	3	15	B/C
149	19	00	1	F	4	82	B/B
150	18	09	1	F	4	33	A/B
151	18	09	1	F	4	40	C/C
152	18	07	1	F	4	62	A/B
153	18	10	1	F	2	33	C/C
154	23	10	3	M	2	—	C/C

TABLE 7. INITIAL KNOWLEDGE TEST SCORE, FINAL ACHIEVEMENT GAIN TEST SCORE IN BIOLOGY, AND INITIAL TEST SCORE, ACHIEVEMENT GAIN TEST SCORE ON THE APPLICATION AND IMPLICATION OF SCIENTIFIC KNOWLEDGE FOR EACH STUDENT OF THE COMPOSITE EXPERIMENTAL GROUP

Student Code Number	Facts, Concepts, Knowledge In Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
1	41	51	21	20
2	28	40	24	29
3	48	60	16	13
4	37	31	18	20
5	59	58	15	11
6	26	32	16	22
7	45	51	18	21
8	36	50	28	25
9	46	52	20	24
10	28	39	14	17
11	40	48	19	26
12	36	46	14	22
13	26	29	21	20
14	44	47	15	13
15	44	40	17	19
16	33	36	21	15
17	42	56	13	21
18	54	62	16	21
19	42	36	19	20
20	36	44	19	22
21	35	43	17	14
22	41	39	20	23
23	45	53	23	18
24	39	44	18	14
25	34	34	22	20
26	37	47	15	16
27	43	41	18	17
28	41	51	18	20
29	51	42	20	27
30	33	40	18	18
31	44	44	25	22
32	36	36	16	20
33	32	43	21	15
34	41	44	17	16
35	44	39	13	16

TABLE 7 (Continued)

Student Code Number	Facts, Concepts, Knowledge In Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
36	37	38	24	27
37	30	24	16	11
38	40	47	23	22
39	33	30	14	17
40	39	28	23	20
41	43	45	18	18
42	33	24	16	14
43	43	48	19	11
44	46	63	16	18
45	37	33	15	14
46	43	45	21	26
47	38	56	20	21
48	41	46	13	16
49	43	46	20	22
50	33	43	10	19
51	48	42	14	11
52	38	43	14	11
53	41	45	22	21
54	40	45	16	21
55	40	50	20	13
56	37	44	16	21
57	45	61	20	13
58	38	50	20	22
59	39	37	21	17
60	44	47	17	22
61	41	34	15	16
62	45	49	14	18
63	42	50	22	27
64	21	35	9	15
65	33	36	19	16
66	40	48	22	17
67	41	39	17	14
68	50	48	18	12
69	40	32	16	8
70	50	59	21	19

TABLE 7 (Continued)

Student Code Number	Facts, Concepts, Knowledge in Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
71	50	57	19	17
72	25	34	17	22
73	39	35	19	23
74	37	41	21	21
75	44	44	20	16
76	53	56	22	23
77	38	42	20	13

* 75 Test items
** 35 Test items

TABLE 8. INITIAL KNOWLEDGE TEST SCORE, FINAL ACHIEVEMENT GAIN TEST SCORE IN BIOLOGY, AND INITIAL TEST SCORE, ACHIEVEMENT GAIN TEST SCORE ON THE APPLICATION AND IMPLICATION OF SCIENTIFIC KNOWLEDGE FOR EACH STUDENT OF THE COMPOSITE CONTROL GROUP

Student Code Number	Facts, Concepts, Knowledge In Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
78	29	32	20	15
79	36	50	15	18
80	57	52	23	22
81	36	46	18	20
82	35	38	17	18
83	39	36	20	13
84	34	34	17	14
85	34	48	17	22
86	42	45	18	21
87	32	37	11	11
88	51	50	16	31
89	43	47	24	23
90	30	35	13	9
91	25	23	8	8
92	48	46	22	22
93	47	61	23	24
94	49	62	20	20
95	30	37	12	14
96	46	46	21	19
97	35	43	19	20
98	35	46	13	24
99	51	58	20	20
100	32	34	22	30
101	27	29	15	14
102	39	35	24	21
103	40	56	16	23
104	43	50	23	18
105	50	57	17	16
106	36	51	28	31
107	24	40	10	15
108	31	43	22	23
109	33	48	21	13
110	33	42	12	8
111	36	47	19	16

TABLE 8 (Continued)

Student Code Number	Facts, Concepts, Knowledge In Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
112	39	40	17	25
113	57	65	17	18
114	42	52	5	7
115	47	48	23	22
116	51	57	14	19
117	42	47	21	22
118	40	45	16	14
119	46	51	11	8
120	36	49	10	9
121	42	55	22	27
122	36	49	17	15
123	46	51	12	14
124	35	46	14	12
125	44	50	18	28
126	32	48	14	16
127	39	50	12	14
128	37	30	19	25
129	40	47	12	13
130	54	59	16	16
131	50	61	26	27
132	25	28	16	14
133	43	58	18	17
134	22	25	15	23
135	45	48	17	21
136	31	43	18	23
137	18	20	18	19
138	44	41	14	23
139	35	37	21	27
140	23	25	18	20
141	40	30	14	26
142	26	32	23	25
143	41	47	23	21
144	13	26	10	19
145	38	42	7	16
146	50	50	14	18

TABLE 8 (Continued)

Student Code Number	Facts, Concepts, Knowledge In Biology*		Application And Implication Of Scientific Knowledge In Biology**	
	Initial Knowledge Test Score	Achievement Gain Test Score	Initial Test Score	Achievement Gain Test Score
147	32	38	12	22
148	23	38	17	20
149	37	52	18	17
150	32	38	23	29
151	33	39	21	22
152	43	57	22	26
153	42	38	21	22
154	33	43	16	15

* 75 Test items
** 35 Test items