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
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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.

# 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

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

of

DOCTOR OF EDUCATION

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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 multisensory 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 re-

viewed 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.