An evaluation of four selected approaches to teaching high school biology
by William Altz Lewis

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 belief that there are significant differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology, led to this investigation. An examination of the literature concerning the teaching of biology revealed a need for improved courses of study and teaching techniques to help overcome the difficulties often encountered by pupils studying biology.

The study was conducted over a 36 week period. The investigation included five teachers and 510 students. In teaching their classes, the instructors followed the particular approach to teaching high school biology to which they had been assigned. The pupils were tested at the beginning of the course to measure final achievement in the improvement of the students' ability in biological concepts. The results indicate there was no statistically significant difference in the final achievement among students who studied biology according to the three B.S.C.S. approaches to teaching high school biology or the traditional approach to teaching high school biology.

The following conclusions concerning the teaching of biology were made on the basis of the review of literature and the findings of this study: (1) there is a need for improved teaching techniques in the field of biology; (2) the three B.S.C.S. versions of teaching high school biology represent an effort to improve high school biology teaching; (3) the belief that final achievement in biology, as measured by a standardized high school biology achievement test, is different among the four selected approaches to teaching high school biology, has no statistical justification; (4) the traditional approach to teaching high school biology still has its place in the high school biology program; and (5) final student achievement, as a result of following the three B.S.C.S. versions of teaching high school biology, does not represent a significant improvement over the traditional approach to teaching high school biology.

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W. A. L.

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ABSTRACT

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CHAPTER I

INTRODUCTION

The revolution through which we are now living, bringing even greater changes than the Industrial Revolution and the Agricultural Revolution did in the 17th, 18th, and 19th centuries, is the Scientific Revolution. The revolution which has already ushered in the era of atomic power has been widely heralded by scientists as likely to bring us, in the second half of this century, more momentous discoveries in the field of biology than any of the changes that have remade the life of mankind through the physical sciences in the first half of this century.

Look at the progress of biology during the present century. Suppose one were studying science in 1900. How much of the biology which is in the modern high school biology program would be in the textbook? Of course, there had been notable advances in biology in the 19th century: the theory of evolution; the development of the germ theory of disease; the demonstration that living organisms always arise, under present conditions, from other living organisms, and not spontaneously; and the story of the way cells divide and produce new cells as the basis of the organization of plants and animals. Yet by far the greater part of the important things we know about the nature of life were not dreamed of then.

The textbook of 1900 would have nothing about genetics, for Mendalian heredity was unrecognized, and the science of genetics did not really start until 1900. Biochemistry had begun in its modern sense only three years before. Eduard Farber's[1] classic studies on the nature of the enzymes had just begun. No one knew anything about hormones. Immunology did not exist. No one knew anything about specific vitamins in 1900. The science of experimental embryology was in its cradle. Pavlov[2] was still to do his classic studies in experimental psychology showing conditional reflex behavior.

By 1930, all of these previously mentioned sciences had reached a fairly high level of development. Three years before that, Herman J. Muller[3] and Lewis J. Stadler[4] had shown that mutations of genes can be induced--there had not even been a word for genes in 1900--by means of x-rays, thus placing in the hands of man the power to alter the agents of heredity.

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[1]Farber, Eduard, Nobel Prize Winners In Chemistry, 1901-1961, 341 pp.

[2]Pavlov, Ivan Petrovich, Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex, 430 pp.

[3]Muller, Herman J., Studies in Genetics, 618 pp.

[4]Stadler, L. J., "Studies in Genetics," Agronomy Journal, vol. 46, p. 109, 1930.

Another 30 years, and we are at 1960. During these years we have learned to induce gene mutations--chemically as well as with high energy radiations. Fredrick Sanger[5] has mapped the entire sequence of 51 amino acids in the insulin molecule. Quite a few other protein molecules have now been so mapped or "fingerprinted."

Many new blood groups have been discovered. Because of this, we can avoid the development of antibodies in the Rh-negative mother, or prepare to save the life of the child who is born affected.

During these same years, it was discovered that invertebrate animals as well as vertebrates have hormones. A new field of invertebrate physiology was begun. As a consequence, the hormonal control of molting and metamorphosis in insects was disclosed.

Antibiotics were discovered in this same period: penicillin, streptomycin, aureomycin, and a host of others.

Along with the practical kinds of discoveries mentioned has come a very great increase in our insight into the kinds of problems that face mankind biologically in the future, an understanding of race, and of evolutionary problems that we hope will enable us to act more wisely in the future, and

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[5]Sanger, Fredrick, "A Method to Study Structure of Proteins," Chemical and Engineering News, October, 1958, Vol. 36: p. 102.

still we experience the logarithmic effect in the increase of scientific knowledge. According to Dr. Bentley Glass,[6] if the doubling time for the amont of scientific knowledge is 10 years, than there is 64 times as much to know now as in 1900; by the year 2000, there will be over 1000 times as much to know.

What will biology be in the year 2000? The biologists of 1930 would not have dreamed of what we know today, and the writer does not profess to be able to dream of what biologists will know 30 years from now. However, a few possible directions in which our control over the forces of nature and the nature of life may be projected.

We will probably learn not only how to increase the human life span, but how to maintain the vigor of mature life into advanced years. So far, we have not measuredly, if at all, increased the human life span. It is also possible that by 1990 biologists will have learned how to create some simple forms of living organisms and that geneticists will have learned to replace defective genes with sound ones.

It is also possible to expect that before the next 30 years are finished, man will have learned how to conduct artificial photosynthesis and so will have finally assured himself

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[6]Glass, Bentley, Taken from an address to participants at the B.S.C.S. 1960 briefing session for teachers in the B.S.C.C. 1960-1961 testing program.

of an inexhaustible--and we hope palatable--food supply.

These conjectures may be wrong, but this would seem to be the general direction in which history is moving: a logarithmic increase of human power in the biological as well as physical realm.

At no time in our history has there been so much interest in improving course content and methods of teaching science at all levels of the school system. Never before has so much financial support been provided for curriculum experimentation, new equipment and teaching materials, and joint research projects of scientists and educators.

As a result of these coordinated efforts, in 1959 the Education Committee of the American Institute of Biological Sciences established the Biological Sciences Curriculum Study (B.S.C.S.) to seek improvement of biology education.

The first major focus of the Biological Sciences Curriculum Study has been on high school biology and on the preparation of general biology courses for the typical tenth-grade student.

Grobman[7] pointed out that about half of the students taking high school biology never again take another science course--they take no more high school science, and they do not

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[7]Grobman, Arnold B., Lecture, Biological Sciences Curriculum Study, University of Colorado, Boulder, Colorado, 1960.

go to college. This gives high school biology the added responsibility of interpreting our scientific society to these students, and of preparing them for living in a civilization which will be laced with revolutionary scientific changes.

In view of this and the staggering amount of biological knowledge that has been thrust upon us, we are suddenly confronted with the question of how, where, and in what ways this knowledge should become a part of the high school curriculum in biology. The Biological Sciences Curriculum Study group has attempted to answer these questions by its development and preparation of three different versions of tenth-grade biology. It was the development of these three versions and how they may best be used in the high school biology program that led to this investigation.

Statement of the Problem

It was the problem of this study to evaluate the achievement of the students being taught under each of the three versions of biology as developed by the Biological Sciences Curriculum Study group, plus those students using the traditional texts and materials.

The hypothesis (H_1) to be tested was that there are differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology.

Procedures

An examination of the literature relating to the problem of the study was made to determine:-

1. The development of biological education in American secondary schools from 1890 to present.
2. The background, emphases, and aims of B.S.C.S. biology.
3. The findings of other investigators as related to the problem of this study.

In order to obtain data for testing the hypothesis, it was necessary to enlist the aid of teachers of two-semester courses in high school biology. The assignment of teachers to either the Biological Sciences Curriculum Study or traditional approaches to teaching biology was according to the way the assignments were made by the school official in charge of such scheduling.

Since it was assumed that those teachers involved in the study were competent and capable of handling their own subject and related materials, no restrictions were put upon individual teachers as to teaching procedures, except that they were expected to follow the curriculum for any of the versions that they may have been assigned to teach.

In order to obtain information to be used in evaluating student achievement, a standardized biology achievement test was selected. The test selected for this purpose was the "Biology Achievement Examination for Secondary Schools, Form 4."[8] This test was administered to all pupils participating in the study on the first day of the class, and again on the last day of the class. The results were then examined statistically to determine the validity of the hypothesis.

Limitations

Several limitations in this investigation should be noted.

The experimental portion of this study was limited to a period of 36 weeks or two semesters.

The students utilized in this study were those who were duly enrolled as high school students in high school biology courses at Austin High School, Austin, Minnesota, and Rochester High School, Rochester, Minnesota, and for whom records were available.

Definitions

Since constant reference is made to the Biological Sciences Curriculum Study group, henceforth in this study, this group will be referred to as B.S.C.S.

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[8] Whittinger, B. R., Biology Achievement Examination for Secondary Schools: Form 4, 4 pp.

It has already been indicated that the Biological Sciences Curriculum Study Steering Committee elected to prepare three different versions of tenth-grade biology. In order not to convey any idea of preferred sequence, colors were picked as titles. Henceforth in this study, when reference is made to the Blue Version, it will be assumed that its emphasis is on the molecular level of life, its origin, and evolution. When reference is made to the Yellow Version, it will be assumed that the emphasis is on the cellular level as the basis of organization. Likewide, when reference is made to the Green Version, it will be understood that the emphasis is on an ecological approach.

The term "traditional biology" is used in comparison of B.S.C.S. biology in this study. As it is used here, and in succeeding pages, it would refer to a biology program which places greatest emphasis on the organ-tissue level, and relatively less emphasis on the levels as emphasized by the B.S.C.S. Blue, Green, and Yellow Versions.

In this experiment, frequent use is made of the terms curriculum and course of study. Henceforth in this study, they will be used synonymously.

In order to establish an explicit, if arbitrary, foundation for the rest of the study, the review of literature was devoted to examining the development of biological education in American secondary schools from 1890 to present, followed by the background, emphasis, and aims of the B.S.C.S. group and its eventual writing of the three major versions of high school biology programs: the Blue, Green, and Yellow. Chapter 4 is devoted to an explanation of the experimental design and investigational procedure, while the succeeding chapters, 5 and 6, present reviews of the investigation to evaluate the achievement scores of the students being taught under each of the three versions of biology as developed by the B.S.C.S. group plus those students using the traditional texts and materials.

A review of biological education in American secondary schools from 1890 to present will be presented next.

CHAPTER II

BIOLOGICAL EDUCATION IN AMERICAN SECONDARY SCHOOLS 1890 TO PRESENT

A concern about the nature of biological education in American secondary schools has been the cause of much debate in the twentieth century. As science and technology have been distinguishing characteristics of our culture and increasingly important in the solution of the problems basic to our social, economic, and political welfare, the nature of an education appropriate for a science-oriented society has become less clear. T. Keith Glennan's comments about the course of scientific development illustrate one aspect of the problem of science teaching:

> In science, particularly, the tendency more and more has been to penetrate farther and farther into chosen subjects until specialists dig themselves out of sight, out of hearing, and out of understanding of what other scientists are doing in their own and neighboring fields. And, if this state of affairs is alarming, even more alarming is the growing cleavage between science and scientists as a whole and the great mass of humanity in other callings.[1]

In view of this communication problem, the curriculum maker has the responsibility for sifting through the accumulated research in biology to retrieve, by means of certain philosophical criteria, ideas and achievements in a quantity to occupy about 175 hours of instruction--the duration of an average high school course.

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[1]Glennan, T. Keith, "New Order of Technological Challenge," Vital Speeches, Vol. 36, p. 237.

Committees of scientists and educators have been at work for over a half century to develop better instruction in science. They have recognized the desirability of courses suitable for the non-specialist, the non-college oriented, the everyday citizen, who finds himself in a world where he cannot escape the need to understand something of the nature of science. They have also seen the problem of providing an added intellectual stimulus in the sciences for those who plan to continue their education beyond high school and who may or may not be considering science as a career. The structure of high school courses--purposes, content, and methods--needed to accomplish these ends has been the cause of much educational ferment. Curriculum problems are persistent and demand a continuous cycle of appraisal, research, and development. This search of literature reviews the development of biology teaching in the schools of America for the period 1890 to present.

Committee reports were used to trace the history of modern biology teaching because these statements usually describe the rationale for proposed changes.

The investigator decided to discuss the committee reports in a chronological sequence and to group them by ten-year periods with a summary for each decade. There is some logic to this arrangement. The conditions influencing American life and in turn educational practice since 1890 have brought about a series of "crises" in secondary school education. The growth of science and technology has been a major factor in creating these tensions. These peaks of concern about the curriculum in schools and the contributing factors become more relevant when the committee reports are presented in the order of their development.

At the risk of over-simplification, the events which have in some way influenced education in the sciences for the period covered by this review, 1890 to present, may be described as follows: (1) the closing of the frontier and the beginning of an urban industrial society; (2) the growth of the scientific professions and major contributions to scientific theory, at the turn of the century; (3) the acceleration of scientific and technological developments catalyzed by the first World War; (4) the development of the industrial research laboratory, unknown in 1900; (5) the rise of automation and the economic depression of the thirties; (6) World War II and the birth of the "atomic age;" (7) the engineering and scientific achievements which are symbolized by the "space age;" (8) the systematizing of research and development and the "explosion" in scientific knowledge which are characteristic of the decade 1950-1960; and (9), upon entering the sixties, we find that the measure of competitive power in the modern world has become a country's inventory of scientific and technical manpower. In turn and cumulatively, these events and others have led to curriculum obsolescence, but at the same time suggest direction for redevelopment.

This search of literature, then, attempts to summarize and relate work which has been done in biological teaching in America. The first decade, 1890-1900, is presented next.

Biological Education, 1890-1900

In the period between 1890-1900, American secondary education underwent serious questioning relative to its proper functioning and purpose. Increasing enrollments and a diversity of interests of pupils entering high school caused high school administrators to consider a broader curriculum than one centered exclusively on college preparation. Previous to 1890 nearly everyone who was graduated from high school continued his education in a college or university.[2] With the onset of industrialization and urbanization, the demands for a high school education increased but the percent of students aspiring to a college education decreased.

A new era in secondary education and high school biology teaching opened in 1893 with the report of the National Education Association's Committee on Secondary School Studies, also known as the Committee of Ten.[3] Charles W. Eliot, President of Harvard University, and a former professor of chemistry at the

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[2]Bessy, Charles E., "Science and Culture," Addresses and Proceedings, National Education Association, Washington, D. C., 1896, Vol. 35: pp. 939-942.

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

Massachusetts Institute of Technology, had been the general chairman for this committee. Its function was to investigate the whole field of secondary education as conducted in private academies and public high schools. Subcommittees on natural history, botany, zoology, and physiology were established to study the teaching of these subjects in grades one through twelve. The Committee of Ten recognized that the secondary schools in the United States, taken as a whole, do not exist only for the purpose of preparing boys and girls for college, but rather that the school science curriculum intended for national use must, therefore, be made for those pupils whose formal education terminates with the high school. The committee concluded its meeting with the following resolution on the science program for high schools that "at least one fourth of the time of the high schools should be devoted to nature studies, and that this amount of preparation should be a requirement for entrance to college."[4]

A science committee, under the chairmanship of E. H. Hall of Harvard, and sponsored by the National Education Association, issued a statement in 1898 reacting to the reports of the science committees established by the Committee of Ten. The committee's reaction to the teaching of high school science was that courses "should be designed in the interest of the high

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[4]*Ibid.*, p. 14.

[5]Hall, E. H., and Committee, "Memorandum Concerning Report of Committee of Sixty," *Addresses and Proceedings*, National Education Association, 1898, Vol. 37: pp. 964-965.

school pupil, without reference to whether the pupil will enter college or not."

The decade from 1890-1900 has been characterized by G. W. Hunter[6] as the great period of the laboratory manual in biology. Laboratory work in all the 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 "mental discipline" theory of learning was rejected by most psychologists soon after the turn of the century. However, as late as 1960 the excuse for biology laboratory work in a surprising number of secondary school curriculum studies and textbooks was still that of "mental discipline."

A final distinguishing characteristic of the 1890-1900 period in biological education was a shift away from a natural history approach to courses of botany and zoology, with the major emphasis upon morphology. The 1900-1910 decade is presented next.

The Beginning of General Biology, 1900-1910

Although a few high school courses were taught under the title of biology before 1900, they were not organized around a biological theme, nor did they present an integrated picture of the biological sciences. In the period from 1900 to

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

1910 various local and national committees gave thought to a unified biology course. It was assumed that biology for the citizen and biology for the potential specialist should be different in character and content.

In 1905 the Biology Committee of the Central Association of Science and Mathematics Teachers presented the following recommendations for the teaching of high school biology.

1. There should be a full year of botany or zoology rather than a half year of each subject.
2. The work in biology should be preceded by an "elementary science" to familiarize the student with laboratory methods and to provide a basic knowledge of chemistry and physics.
3. The course should meet six periods per week with double periods for laboratory or field work.
4. Botany and zoology should be acceptable to colleges as entrance requirements.[7]

The New York Board of Regents developed a course in general biology as early as 1899. George W. Hunter,[8] then a New York City high school biology teacher, in 1907 published a textbook called Elements of Biology, which attempted to "place the topics as suggested by the regents' syllabus into a

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[7]"Report of the Committee on Biology," School Science and Mathematics, 1905, Vol. 5: pp. 50-52.

[8]Hunter, George W., Science Teaching at Junior and Senior High School Levels, 552 pp.

connected form."

The American Society of Zoologists[9] in 1906 made recommendations for improving the teaching of zoology in the high schools. The society was of the opinion that "zoology should have a place in general education" and should be studied in high school since so many students do not continue into college.

In 1906, E. G. Dexter[10] studied the impact of the report of the Committee of Ten (1893) on the teaching of biology in high school. He felt that little was achieved by the report even though it had been well advertised and had had the widest reading. He also found that biology teachers reacted against the morphological approach suggested as desirable by the committee.

H. R. Linville, reflecting on the teaching of biology in the high schools from 1890-1900 made this observation:[11]

> The teachers of morphological biology in the schools brought with them from the colleges certain ideas of method. Possibly the lecture system never took strong hold in the schools, but the laboratory method of the college with much of its paraphernalia, did. The consequence of this was that thousands of untrained pupils were required to cut, section, examine, and draw the parts of dead bodies of unknown and unheard of animals and plants and later to reproduce in examination what they remembered of the facts they had seen.

This mechanical and impractical approach to teaching high school biology reflected the 1890-1900 decade.

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[9]Bigelow, M. A., "College Entrance Option in Zoology," <u>School Science and Mathematics</u>, 1906, Vol. 6: pp. 63-66.

[10]Dexter, E. G., "Ten Years' Influence of the Reports of the Committee of Ten," <u>The School Review</u>, 1906, Vol. 14: p.254.

[11]Linville, H. R., "Old and New Ideals in Biology Teaching," <u>School Science and Mathematics</u>, 1910, Vol. 10: pp. 210-216.

The decline in enrollments in human physiology, the general dislike of the course by students, and the difficulties experienced in teaching it were popular topics of discussion at association meetings of science teachers between 1900 and 1910.

In 1907, the Central Association of Science and Mathematics Teachers appointed a committee "to prepare a statement of a biological creed that might serve as a guide in the development of biology courses."[12] The committee published its deliberations in 1909.

The committee thought that biological subjects were peculiarly fitted for general education purposes because of the "light they throw on the study of life."[13] Accordingly, biology courses in high school were seen as having general and cultural values for all students.

The Central Association of Science and Mathematics Teachers in 1910 issued a committee report described as taking "stock of our philosophy of using the sciences and mathematics as a means of education."[14] The committee agreed that the general purpose of high school education must always be allowed to

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[12]Caldwell, O. W., "A Consideration of the Principles That Should Determine the Course in Biology in the Secondary Schools," School Science and Mathematics, 1909, Vol. 9: pp. 241-247.

[13]*Ibid.*, p. 19.

[14]Galloway, T. W., Chairman, "Report of the Committee on Fundamentals of the Central Association of Science and Mathematics Teachers," School Science and Mathematics, 1910, Vol. 10: pp. 801-803.

condition the special purposes of the sciences.

The decline of the special biological sciences was both heralded and condemned. Some writers felt a combination course would force biology teachers to focus on the important ideas about living things, and others thought that a course of this nature could only be superficial.

This decade from 1900-1910 might well be summed up in the following significant developments in biology teaching:

1. A growing commitment to a single course of general biology in the high school, integrating material from botany, zoology, and human physiology.
2. An awareness of the "average" student who will not continue into college and the desirability of developing for him a more practical (applied or economic) type of biology course.
3. The appearance of the first high school textbooks on biology intended to replace the separate texts of botany, zoology, and human physiology.
4. The attempt to orient biology teaching toward biological principles, ideas, and interrelationships.
5. More emphasis on the "scientific method" and the "practical" objectives for biology teaching.
6. The breakdown of the "mental discipline" theory in learning with more importance attached to capitalizing on student interests and experience.

7. The failure of human physiology to become established as a separate course in the curriculum.

The period from 1910-1920 is presented next.

The Changing Science Curriculum, 1910-1920

A major development in the science curriculum between 1910 and 1920 was the introduction of general science into the ninth grade. The first courses in general science were a compendia of several sciences: physiology-hygiene, physiography, astronomy, geology, meteorology, chemistry, physics, botany, and zoology. It was expected that the course would provide a more adequate preparation for tenth grade biology and an orientation to all the science offerings in the high school. It was also hoped that students taking general science would be stimulated to elect further courses in science.

The course content of general science was concentrated in the physical sciences. Whatever was given in the biological fields was usually repeated in the biology course itself, a duplication which still persists.

Several significant committee reports were developed during the 1910-1920 period. The first was the report of the Committee of Nine[15] on the Articulation of High School and

[15]Kingsley, Clarence D., Chairman, "Report of the Committee of Nine on the Articulation of High School and College," Addresses and Proceedings, National Education Association, 1911, Vol. 49: pp. 559-567.

College of the National Education Association in 1911. A recommendation was made that high schools require every student to complete two subject majors of three credits each and one minor of two credits. Science was designated as one of the possible majors. This recommendation further established science as a part of the secondary school curriculum and strengthened the position of biology.

The Committee on a Unified High School Science Course[16] in 1915 submitted a report. With the many changes in the high school program taking place, the committee felt that much more experimentation should occur before a final statement about the "unification of sciences" was developed.

In 1913, the Committee on Natural Sciences of the National Education Association appointed ten high school teachers, three university professors, three normal school instructors, and one physician to study the high school biology curriculum. After seven meetings the objectives for the teaching of biology were given as follow:

1. To train the pupil in observation and reasoning.
2. To acquaint each pupil with his environment and the common forms of plant and animal life, together with structure function, and care of his own body; biological principles would be derived from this study.

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[16]Caldwell, O. W., Chairman, "Report of the Central Association of Science and Mathematics Teachers Committee on a Unified High School Science Course." <u>School Science and Mathematics</u>, 1915, Vol. 15: pp. 344-346.

3. To show the pupil his place in nature, his share of responsibility in the present and future of human society.[17]

It was strongly recommended by the Committee on Natural Sciences of the National Education Association, that a concept of human welfare underlie all elementary instruction in science. It was further suggested that the principles of human reproduction should form a part of the course, but that instruction in sex hygiene should not be compulsory. The recommended theme for the course was human biology. Thus the work in botany and zoology should be correlated with man and show how he may use his biological knowledge.

A final report of this decade which was to have considerable influence on the teaching of science was published by the commission on the Reorganization of Secondary Education in 1918. The commission defined the aims of secondary education to be: health, command of fundamental processes, worthy home membership, vocation, citizenship, worthy use of leisure, and ethical character.[18] It was expected that all courses in secondary school would contribute to the realization of these seven Cardinal Principles of Secondary Education.

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

[18]The Commission on the Reorganization of Secondary Education, Cardinal Principles of Secondary Education, Bul., 1918, 32pp. Dept. of Interior, Bureau of Education, Washington, D. C.

The commission members recommended the following central ideas for a course in biology:

1. Maintenance of organisms and life of species.
2. Interrelationships between different organisms and groups of organisms.
3. Dependence and interrelation of living things with the physical world.[19]

The developments in biology teaching from 1910-1920 reflect suggestions made by earlier committees and a rethinking of the basic issues. A general biology course, in point of view at least, was felt to be the best way to present the biological sciences in the high school. The period from 1920-1930 is presented next.

A Period of Curriculum Refinement, 1920-1930

The decade following the close of World War I was a time in which biology curriculum makers attempted to implement the education theory developed earlier. The influence of the Commission on the Reorganization of Secondary Education[20] and the work of the related Committee on the Reorganization of Science[21]

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[19] Ibid., p. 23.

[20] Ibid., p. 23.

[21] Caldwell, O. W., Chairman, "Reorganization of Science in Secondary Schools," Commission on Reorganization of Secondary Education, 1920, Bul. 26: 62 pp., Dpt. of Interior, Washington, D. C.

is seen throughout the 1920-1930 period. These reports immediately stimulated local communities to re-examine their biology curriculums in light of the Cardinal Principles of Secondary Education, as defined by the Commission on the Reorganization of Secondary Education.[22]

In 1923, a committee under the chairmanship of George W. Hunter[23] of Knox College, reported on a new biology course for the State of Illinois. The Illinois group was concerned with the objectives of the Committee on the Reorganization of Science.[24] Much concern was expressed, however, about the kind of curriculum materials prepared by the research biologists and their failure to consider the interests and needs of the adolescent.

In 1924, the Committee for Reorganization of the Biological Sciences of the Cleveland Biology Teachers Club[25] reported on a new curriculum for biology teaching. The Cleveland committee accepted the philosophy of the Commission on

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[22]The Commission on the Reorganization of Secondary Education, op. cit., p. 23.

[23]Hunter, G. W., "Report of the Committee on a One-Year Fundamental Course of Biological Science," School Science and Mathematics, 1923, Vol. 23: pp. 656-664.

[24]Caldwell, op. cit., p. 24.

[25]Pershing, E. C., "Report of the Committee on Reorganization of the Biological Sciences Appointed by the Cleveland Biology Teachers Club," School Science and Mathematics, 1924, Vol. 24: pp. 241-246.

Reorganization of Secondary Education[26] in developing both the tenth and twelfth grade courses.

In 1928, the American Association for the Advancement of Science, through its special Committee on Science Education, published a report, "On the Place of Science in Education."[27] After reviewing developments in science and the impact of science on man's life, the conclusion was reached that: "Science instruction in school and out needs better organization, more effective cooperation to make even the health knowledge available function more completely in the lives of people generally."[28]

The movement to "humanize" the study of biology, which had been gaining momentum for several decades, was by now a generally accepted point of view for curriculum makers. The report of the American Association for the Advancement of Science[29] in 1928 lent further support in this direction.

The efforts to develop a "standard" course in biology were not apparent from the committee reports of this decade.

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[26]Caldwell, op. cit., p. 24.

[27]"On the Place of Science in Education," A report presented to the Council of the American Association for the Advancement of Science at the Second Nashville Meeting, December, 1927, by the Special Committee of Science in Education, School Science and Mathematics, 1928, Vol. 28: pp. 640-664.

[28]Ibid., p. 26.

[29]Ibid., p. 26.

There were surveys and studies to find the common elements of biology courses and to identify the basic principles of biology. This was also the period of the standardized test which in turn demanded fairly uniform courses of study if the tests were to be valid.

The 1920-1930 period in biological education was not an exciting one from the standpoint of new developments. But the enrollment in high school biology continued to mushroom and the course became increasingly prominent in the secondary school curriculum. The decade from 1930-1940 is presented next.

A Period of Questioning, 1930-1940

The depression years in America produced the usual questioning of educational practices that characterizes a time of economic and social crisis. The teaching of science was extensively examined by a number of influential organizations as well as by the federal government.

The 1930's represented a time in education when attention was focused upon the individual student and his personal, social, and economic welfare. Health information and consumership loomed large in the biology curriculum.

The biology committee of the North Central Association of Colleges and Secondary Schools submitted two reports in

1931, one a general report on the teaching of biology[30] and an investigation on the time needed to teach particular units.[31] Members of the committee expressed the opinion that one's knowledge of science was serviceable in life only if it was acquired or retained in the form of principles or generalizations.

In 1932, a Program for Teaching was developed by a committee under the chairmanship of S. Ralph Powers and sponsored by the National Society for the Study of Education.[32] More attention was given to the establishment of a point of view on science teaching, the psychology of learning, and curriculum theory, than can be found in committee reports to this time.

In 1932, the Progressive Education Association, through its commission on Secondary School Curriculum, established the Committee on the Function of Science in General Education. The primary concern of the committee was the contributions science could make to the education of young people and therefore the special subject fields were not considered.

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[30] Downing, Elliot R., "The Teaching of Biology," North Central Association Quarterly, 1931, Vol. 5: pp. 395-398.

[31] Downing, E. R., "Teaching Units in Biology--An Investigation," North Central Association Quarterly, 1931, Vol. 5: pp. 453-470.

[32] Power, S. R., "A Program for Teaching Science," The Thirty-first Yearbook of the National Society for the Study of Education, Part I, 1932, 364 pp.

The committees reporting in this decade took serious note of the past developments in science teaching, examined current practices, and then sought to develop a consistent theory of education in science. For the first time, a science curriculum committee was cognizant of learning theory as a factor in curriculum planning.

These curriculum groups were more influenced by the contemporary American scene and the growing importance of science and technology than were the committees in previous decades. How these factors should be represented in the science curriculum of the high school was widely debated. Essentially each committee felt that science was imperative in the education of young people for their intelligent understanding of the present society. This approach differed from that used by earlier committees in which emphasis was more upon what is significant in terms of subject or discipline. The 1940-1950 decade is presented next.

Biology in General Education, 1940-1950

In the decade 1940-1950, World War II and the birth of the "atomic age" raised questions about the purposes of secondary school education as a whole and science teaching in particular. The movements in science education which began in the thirties were temporarily overshadowed by course adjustments made to meet "war-time emergencies." Biology teaching was not particularly affected by these developments, although there was a tendency to place more emphasis on hygiene, food, and disease.

In 1940, a special committee on the American Council on Education[33] issued a report on What the High Schools Ought to Teach. The central recommendation called for a program of general education suitable for all students with some provision for specialized training.

In 1942, a committee[34] with representatives from seventeen scientific and science teaching societies met to develop "a philosophy or point of view" for instruction in secondary school science. The committee throughout its report gave strong support to the social function of science and the importance of providing the kind of education that will help individuals live effectively in a scientifically oriented world.

In 1942, the Committee on the Teaching of Biology of the Union of American Biological Societies[35] published the results of a questionnaire survey on high school biology teaching in the United States. The major purpose of the study was to ascertain the status of biology instruction in high schools. A

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[33]American Council on Education, 1940, What the High Schools Ought to Teach, 36 pp.

[34]Neal, Nathan A., Chairman, Science Teaching for Better Living--A Philosophy or Point of View, The American Council of Science Teachers, 1942, National Education Association.

[35]Riddle, O., Editor, The Teaching of Biology in Secondary Schools of the United States, Union of American Biological Societies, 1942, 76 pp.

conclusion of the committee was that there is a tendency "to teach biology not as a science, but (a) as a way to pleasing hobbies, or (b) as a series of practical technologies."[36]

The Educational Policies Commission of the National Education Association[37] in 1944 issued a report. The report represented three years of study. It was suggested that a considerable part of the tenth grade course should be devoted to the role of science in human progress.

In general, all of the committees of this decade agreed that science had become imperative in the education of the American youth. There was a consensus that all young people should have some knowledge of science as a social force and that this would demand knowing something of the nature of the scientific enterprise.

The general biology course continued to gain enrollment throughout the 1940-1950 decade. Nearly all the high schools in America were offering the course, and in 1950, 21.7% of all high school students were enrolled in a biology class. Several of the curriculum committees during this period noted the growing enrollment in biology and pointed out that it was the high school biology teachers who must now assume the responsibility of conveying to the majority of youth most of what they will learn

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[36] Ibid., p. 30.

[37] Educational Policies Commission, 1944, Education For All American Youth, 421 pp.

about the nature of science, since for many high school students biology would be a terminal science course. The period from 1950 to the present is presented next.

The Crisis In Science Education And a Reappraisal, 1950 to Present

The decade from 1950-1960 has been described as one of "confusion and crisis" in science education. Dozens of state and national committees have published statements about needed improvements in secondary school science teaching. The Second Session of the Eighty-Fifth Congress of the United States recorded 1600 pages of testimony in twenty-two days on the question of "science and education for national defense." An understanding of science was becoming imperative in the education of all people. The nature of this education had not yet evolved. The biological fields since mid-century had taken on new vigor. New research tools and techniques had advanced discoveries faster than anticipated.

The first major effort to review the teaching of biology in American secondary schools during the 1950-1960 decade was carried out at the Southeastern Conference on Biology Teaching held during the summer of 1954.[38] Six biological scientists

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[38]Breukelman, J., and Armacost, R., Cochairmen, "Report of the Southeastern Conference on Biology Teaching," <u>The American Biology Teacher</u>, 1955, Vol. 17 (1): pp. 4-55.

prepared written summary statements on how their special fields could and should contribute to the training of biology teachers. From these papers, most of the resource material for the development of the high school curriculum and the teacher training programs were formulated. Furthermore, conference representatives were of the opinion that biology courses should be designed to meet the needs and interests of individual students. Course objectives should be both general and local in character, embracing the principles of biology with local applications.

The North Central Conference on Biology Teaching[39] was held in 1955 at Cheyboygan, Michigan. The work of this committee was similar to that of the Southeastern Conference on Biology Teaching,[40] held in 1954. The conferees recognized that local conditions must influence what can be done in the study of biology.

In 1954, the Division of Biology and Agriculture, National Academy of Sciences--National Research Council,[41] established a Committee on Educational Policies, to consider

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[39]Armacost, R., and Klinge, P., "Report of the North Central Conference on Biology Teaching," The American Biology Teacher, 1956, Vol. 18 (1): pp. 4-72.

[40]Breukelman and Armacost, op. cit., p. 32

[41]Conference on Biological Education, March 10, 1953, National Academy of Sciences--National Research Council, (mimeo) Division of Biology and Agriculture, Washington, D. C.

problems of biological education. It was felt that major changes were needed in biological education at all levels and for both general and professional education.

Pressures were being brought to bear, by various committees, for a rethinking of the goals of education in the sciences. The plea was for "quality," "excellence," or "rigor" in high school science courses. Precise definitions of what those attributes meant for the curriculum in science were lacking.

The first high school science course to be reorganized during the 1950-1960 period was physics, followed next by chemistry. The curriculum committees sought to remove much of the descriptive aspect of the courses, add more "science," reduce the number and update concepts in the courses. New laboratory experiments were devised that were more in terms of the nature of science.

The biology curriculum committees developed their courses for the typical tenth grader. Their efforts were to develop a more integrated course built around an interpretative theme, such as ecology, evolution, and energy exchange. Teaching units on "radiation biology" and "space biology" were added to textbooks and courses of study. Conservation education had a renewed emphasis. Advanced biology became popular in many schools. Frequently this meant using a college biology textbook in high school.

The need to improve laboratory work received much attention. Most of the recommendations were for a more experimental approach to the study of biology.

The 1960-1970 decade began with a series of new biology courses, laboratory experiments and teaching resources.

The problems and issues of biology teaching at this time are extensive, possibly more so than a decade or two ago. This does not mean that there has been a lack of progress in biological education, but simply that the conditions in our culture, biology, and education have changed radically in recent years. This is not the world of the 1940's or even the 1950's; we should not expect that the answers to the problems of the past decade are entirely pertinent today. The objectives and curriculum for biology teaching in the sixties may be quite out-dated by 1970; progress in biological thinking and discovery will make sections of present courses of small educative value; they may even be misleading in another decade.

During the school year 1960-1961, over 14,000 students in 110 high schools were experimenting with a new biology course developed by the Biological Sciences Curriculum Study. Some preliminary work was under way to study the place of biology in the curriculum from the first grade through high school.

Summary

There is no real way to judge the extent to which biology curriculum committees were effective in bringing about changes in either the content or conduct of biology courses. One would find it difficult to date or to place in sequence the committee efforts of the past if they were not identified by year of publication or membership. Yet, there have been changes in biology teaching. Sometimes the suggestions of a specific committee did not bear fruit until a half century later.

As examination is made of the various committee reports, it may be noted that several basic changes have resulted in biology curriculums due to the influence of these reports. In the early years the committees stressed attention to basic biological principles; this was followed by a shift emphasizing the personal hygiene era of biology. Again the committee influence was felt and the course of study swung back again to emphasizing basic biological techniques. During this entire period there seemed to be more and more attention given to ecology and its importance in the teaching of high school biology.

Constant attempt must be made to seek better definitions for the meaning of a basic education in the biological sciences. All that is known for certain is that the answers are not found in the past, although there are signals which may prove useful.

The program of the Biological Sciences Curriculum Study of the American Institute of Biological Sciences was designed to overcome the majority of the inadequacies of previous committees.

The Biological Sciences Curriculum Study will be presented next.

CHAPTER III

THE BIOLOGICAL SCIENCES CURRICULUM STUDY

It was not until 1950-1960[1] that educators and scientists alike became fully aware that the existing curriculum in science was inadequate for a rapidly changing society and inadequate for conveying an understanding of current science. It was because of this and similar considerations[2] that the Biological Sciences Curriculum Study Biology Program came into being.

B.S.C.S. biology is the result of an effort by the American Institute of Biological Sciences (A.I.B.S.) to improve biological science education by establishing the Biological Sciences Curriculum Study in 1959.

These considerations, along with previous efforts toward curriculum reform,[3] led the B.S.C.S. Steering Committee to decide to prepare materials for a general biology course for the average high school student. Three phases pertinent to an explanation of the B.S.C.S. biology program are: (1) origin and purposes of the Biological Sciences Curriculum Study, (2) the three versions, and (3) differences among B.S.C.S. and traditional biology textbooks. These three phases are presented in the following sections.

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[1]See Chapter II, pp. 32-33.

[2]See Chapter II, pp. 11-36.

[3]See Chapter II, pp. 11-36.

Origin and Purposes of the Biological Sciences Curriculum Study

In 1955, the American Institute of Biological Sciences (A.I.B.S.), a professional society representing 85,000 biologists, began discussions of plans to improve biological education at all levels. The B.S.C.S. was organized in the fall of 1958 by the Education Committee of the American Institute of Biological Sciences. Major financial support has come from the National Science Foundation. Additional grants to support the international aspects of the program have been given by the Rockefeller Foundation.

The function of the B.S.C.S. as stated in the original proposal to the National Science Foundation was as follows:

> To evaluate the content of present biology course offerings, to determine what biological knowledge can and should be learned at each level, and to recommend how this latter goal can be achieved.

The policy-making body for the B.S.C.S. is a Steering Committee composed of 27 members, including research biologists, high school biology teachers, science supervisors, education specialists, medical specialists, agricultural educator, and university administrators. H. Bentley Glass of Johns Hopkins University was chosen chairman of the Steering Committee, and Arnold B. Grobman of the University of Colorado was appointed director.

<u>The High School Biology Program</u>. The B.S.C.S. committee decided to focus its attention at the secondary school level. In about 80% of the American high schools, the first course in biology is offered in the tenth grade. A smaller proportion offer it in ninth grade, and a few high schools offer the first course in biology in the eleventh or twelfth grades.

The B.S.C.S. Steering Committee decided early that it would design a course appropriate for general education in biology, rather than to attempt to design a more sophisticated course for a select minority. Grobman[4] summarized reasons for choosing the tenth grade as the level of focus of the B.S.C.S. materials as follows:

> In tenth grade biology, for the student who does not go on to college, the biology is the last chance in the classroom to prepare these students, who comprise over half of our adult population, for the rapid changes in scientific knowledge and the concepts they will face in their lifetimes. It must be a course that most tenth grade students can handle, and at the same time prove challenging to the above average student. For these reasons, the committee thought it undesirable to limit the course to a single design.

<u>Different Approaches To High School Biology</u>. The committee recognized that a valid course in biology could be developed from several points of view. For example, courses could be organized which represent all of the levels of biological complexity: the molecular level, the cellular level,

[4]Grobman, <u>op. cit.</u>, p. 6.

tissue and organ level, the individual organism, the population, the community, and the world of living things. A biology course at any one of these levels could be equally effective. The committee has carefully avoided any statement or action which, even by implication, might cause anyone to infer that there is a "best" approach to teaching biology, or that a particular emphasis is necessarily most appropriate for all situations.

Recognizing that a valid course in biology could be developed from several points of view, the B.S.C.S. committee decided to develop three different versions of teaching high school biology. A discussion of these three versions is presented next.

The Three Versions

Similarities. The task of preparing preliminary experimental materials for a high school biology course was assigned to three writing teams who met for the First Summer Writing Conference at the University of Colorado in 1960. The materials prepared by each of the three teams utilized a different approach to the high school biology course. The three approaches were designated the "Blue," "Green," and "Yellow" versions.[5]

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[5]Blue Version is Biological Science, Molecules to Man; Green Version is High School Biology, BSCS Green Version; Yellow Version is Biological Science: An Inquiry Into Life.

These experimental materials were tested in 1960-1961 by 118 teachers with 14,000 students in experimental centers located in various sections of the country in both urban and rural schools. The comments of teachers and students were obtained on a systematic basis throughout the year and were used in preparing a third and final re-writing of the textbooks.

Although the three versions of B.S.C.S. High School Biology differ in the emphasis placed on the various levels of biological organization, they possess in common nine themes which serve as unifying threads:

1. Change of living things through time-evolution.
2. Diversity of type and unity of pattern of living things.
3. Genetic continuity of life.
4. Biological roots of behavior.
5. Complimentarity of structure and function.
6. Complimentarity of organisms and environment.
7. Regulation and homeostasis: the maintenance of life in the face of change.
8. Science as inquiry.
9. History of biological concepts.

The first seven themes define the content of the B.S.C.S. courses; the last two convey the logical structures of each course. The specific content of each version differs, but whichever course the pupil studies, he will be developing an understanding of the same unifying themes.

The three versions are similar as to purpose. The B.S.C.S. committee was of the opinion that a secondary school course in biology should: (1) present the most significant concepts of biology, (2) focus on the nature of scientific inquiry, and (3) provide the student with a coherent picture of contemporary biology.

The approaches are also alike in that the writers of all three versions have attempted to present materials and related concepts in such a way as to develop those attitudes and skills which are regarded as basic objectives of American public education.[6] The three versions are alike in that the laboratory materials have been designed to represent and reveal the structure of modern biology, the state of its knowledge, its objectives and its methods. In all three versions, considerable emphasis has been placed on the laboratory activities. Although the laboratory exercises have been selected to reflect both the investigatory and illustrative function of laboratory work, greater emphasis has been placed on real experiments and open-ended problems. Finally, they are alike in that they represent attempts to prepare materials that are interesting, useful, and challenging to students as well as to teachers.

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[6]The Commission on the Reorganization of Secondary Education, _op. cit._, p. 23.

Differences. After a consideration of ways in which the three versions of B.S.C.S. high school biology are alike, the question frequently arises: how are the three versions different?

The major differences among the B.S.C.S. versions are the levels on which each places its emphases. The Green Version[7] places greatest emphasis on the community and world biome levels; the Yellow Version[8] on the cellular level, with high emphasis on the molecular level also; and the Blue Version[9] on the molecular level, with high emphasis on the cellular. This does not mean that the Green Version omits physiology and biochemistry; nor does it mean that ecology has been left out of the Blue and Yellow Versions. Each version is a balanced representation of biology. The Green Version approaches the study of biology from the world community level, then moves through ever-decreasing units to the molecular level. The Blue Version approaches the study from the molecular level and moves through ever-increasing units to the world community. The Yellow Version approaches biology on the cellular level, then moves downward to the molecular level and upward to the world community level. All three

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[7]The Green Version, op. cit., p. 41.

[8]The Yellow Version, op. cit., p. 41.

[9]The Blue Version, op. cit., p. 41.

B.S.C.S. versions differ from the traditional texts, which place greatest emphasis on the organ-tissue level, and relatively less emphasis on other levels.

Differences Between B.S.C.S. and Traditional Biology Textbooks

One of the questions most frequently asked concerning B.S.C.S. is: how does B.S.C.S. High School Biology differ from traditional biology courses? Briefly, B.S.C.S. differs in several ways.

1. It is the product of the cooperative efforts of teams composed of research biologists, high school biology teachers, and other educational experts.

2. It is constructed on a basis of up-to-date ideas and concepts in the field of biology. It is not simply a revision of old concepts and ways of thinking.

3. It places considerably more emphasis on laboratory work than do traditional courses. Moreover, greater stress is placed on exercises of an investigative nature which introduce the student to science as a process of inquiry rather than as the traditional illustrative type of laboratory exercises. Some of the ways the approach to inquiry may be characterized are as follows: (1) "We do not know," (2) "We have been unable to discover how this happens," and (3) "The evidence

about this is contradictory."

4. Although the B.S.C.S. versions differ in the emphasis placed on the various levels of biological organization, they possess in common nine themes which serve as unifying threads.[10]

5. The treatment in the B.S.C.S. materials of certain traditionally taboo areas such as reproduction and evolution is straightforward and to the point. The writers have recognized these for what they are, essential pieces in the pattern that represents the present state of our biological knowledge. As such, they form two unifying themes (genetic continuity and evolution) and are woven throughout all three versions.

6. The new teaching material, invitations to inquiry,[11] is designed to show how knowledge arises in biology and how it may be interpreted and used to provide specific experience in the many phases of inquiry. Each invitation to inquiry reveals something about the nature of science as well as adding to one's understanding of biology.

Such factors as these fit together to form a contrasting picture between the B.S.C.S. materials and traditional biology materials.

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[10] See p. 42.

[11] Schwab, Joseph J., The Teaching of Science As Enquiry, pp. 108-109.

Summary

The B.S.C.S. texts represent a re-established communication among the major groups involved in education. Teachers have come from the schools; educators have come from colleges and universities; scientists have come from their laboratories; the three groups together have begun to learn how to communicate and collaborate in producing better materials for our schools.

These three groups have attempted to select the best and most significant materials in biology for the purpose of public education. They have tried to develop these materials in forms that would best contribute to the attitudes and skills which are the objectives of American public education. They have tried to reflect the structure of biology as that science now exists, and they have tried to produce these materials in a way that will make them useful to the biology teachers of the American schools.

The experimental design and investigational procedures in this study will be presented next.

CHAPTER IV

EXPERIMENTAL DESIGN AND INVESTIGATIONAL PROCEDURES

The purpose of this investigation was to determine whether there are differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. The following items were considered in designing the experiment and in conducting the investigation: (1) selection and content of materials included in the study, (2) determination of the time required for completion of the study, (3) selection and assignment of the teachers to the various versions, (4) selection and assignment of students to the various versions, (5) teaching procedures, (6) criteria used in initial comparison of groups, and (7) measurement and comparison of final achievement in biology.

These seven items are presented in the following sections.

Selection and Content of Materials Included in the Study

The principal criterion to be met in the selection and content of the study materials was that these materials should follow generally accepted principles of learning;[1] that is, they should: proceed from the known to the unknown, provide opportunities for successful learning, require the active participation of the pupils, and provide opportunities for the self-discovery of principles.

The writer feels that the B.S.C.S. Blue, Green, and Yellow versions and the traditional approach to the teaching of high school biology as used in this study meet these basic principles of learning.[2] However, the basic biological emphasis of the B.S.C.S. Blue, Green, and Yellow versions[3] as contrasted to the traditional[4] approach to the teaching of high school biology do, in themselves, result in the use of different materials in the respective approaches. As a result, the determining factor as to the selection and content of the materials to be used in the study was that of the particular approach to the teaching of high school biology which was followed.

A discussion of the determination of the time required to complete the study follows.

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[1]Hilgard, E. R., Theories of Learning, pp. 485-487.

[2]Ibid., p. 49.

[3]See Chapter III, pp. 41-43.

[4]See Chapter III, p. 45.

Determination of the Time Required For Completion of the Study

A necessary part of the planning of the study required a determination of the duration of the time required for its completion. Since the B.S.C.S. versions and the traditional approach to teaching of high school biology are designed and structured so they may be completed in one school year, it was decided that the study should be of one school year duration, a period of two semesters or 36 weeks. In order to determine if there are differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology, it was necessary to secure the aid of several teachers who would teach the B.S.C.S. versions and the traditional approach according to the prescribed curriculum of each. This section is presented next.

Selection and Assignment of Teachers to the Various Approaches

To obtain data to evaluate the achievement scores of the students being taught under the B.S.C.S. Blue, Green, and Yellow version, plus those using the traditional texts and materials, it was necessary to enlist the aid of teachers of 36-week or two-semester biology courses.

The assignment of teachers to either the B.S.C.S. Blue, Green, Yellow, or traditional approaches to teaching biology was according to the way the assignments were made by school officials in charge of such scheduling. These teachers were experienced teachers with a mean of 13.7 years of teaching high school biology classes. The range of their total teaching experiance was 9-20 years. Each teacher held a Master's degree. The five participating teachers taught a total of 510 students in 25 classes of high school biology. The class period for each group was 60 minutes, and the classes met five days a week for 36 weeks.

Each of the five teachers, along with school officials responsible for scheduling of pupils and assignment of teachers to courses, was contacted ahead of time and all readily agreed to participate in the study.

The assignment of students to the various versions will be presented next.

Selection and Assignment of Students To the Various Approaches

The assignment of students to the various sections and approaches to teaching high school biology, as used in this study, was according to the way pupils were assigned to the different teachers. The pupils of the teacher who was assigned to teach the B.S.C.S. Blue Version were taught according to the B.S.C.S. Blue Version approach. The pupils of the teacher who was assigned to teach the B.S.C.S. Green Version were taught according to the B.S.C.S. Green Version approach, and similarly with the B.S.C.S. Yellow Version and traditional approaches. In this way, it was felt that random assignment of students to different teachers and approaches to teaching high school biology was achieved. The question of teaching procedures used by the participating teachers of the four selected approaches to teaching high school biology is reported next.

Teaching Procedures

Since it was assumed that those teachers involved in this study were competent and capable of handling their own subject and related materials, no restrictions were put upon individual teachers as to teaching procedures except that they were expected to follow the curriculum for any of the approaches which they may have been assigned to teach.

A discussion of the way in which the groups were initially compared will be presented next.

Criteria Used in Initial Comparison of Groups

To determine the effect on final achievement in biology of each of the four selected approaches to teaching high school biology, it was necessary to initially compare each of the five groups to ascertain the extent to which they were similar. The herein designated term total groups refers to the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. To facilitate the statistical comparison of the total groups, several procedures were followed. All pertinent data on each student participating in the study was key punched into individual IBM cards. It was then possible by means of IBM machines to group and sort the cards on the basis of any of the information contained on the cards. In addition, the use of key-punched IBM cards made it possible to further process them in the IBM 1620 computer.

The computer calculated the following data for each of the total groups:

1. Mean I.Q.
2. Mean pre-test score.
3. Mean post-test score.
4. Mean difference score (post-test minus pre-test).
5. Mean final grade--9 science.

Furthermore, the services and programs of the IBM 1620 computer were utilized in calculating the F-score ratios resulting from the single classification analysis of variance program as applied to the experimental data based on total groups. The choice of statistical techniques used to test the experimental data was determined after several conferences with three faculty members of Montana State University.[5]

Since two of the five groups were taught by the traditional approach, one group from the Austin High School, Austin, Minnesota, and the other group from the Rochester High School, Rochester, Minnesota, it was decided that if it could be demonstrated statistically that no significant difference existed between these two groups, then they could be combined and treated as one group. The criteria used in the initial comparison of the groups was as follows: (1) I.Q., (2) pre-test score, (3) final grade--9 science, (4) sex, (5) age, and (6) grade placement in school. The statistical comparison of the two traditional groups will be presented first, followed by a discussion of each of the six previously mentioned criteria as related to all the approaches.

<u>Comparison of the traditional groups</u>. Since the traditional groups used in this study were from two different schools and the pupils taught by two different teachers, it was necessary to determine if the pupils from the two traditional groups could be pooled to form one composite group. It was

[5]Picton, John O., Assistant Professor, Education; Suvak, Albert, Assistant Professor, Testing and Counseling; Quesenberry, Charles P., Associate Professor, Mathematics; Montana State University, Personal Interviews, August, 1964.

decided to use the t-test statistic[6] to test the null hypothesis of no difference between the means. This statistic would be used to test the following criteria: (1) I.Q., (2) pre-test score, and (3) final grade--9 science.

1. To be able to test the null hypothesis of no significant difference between the mean I.Q.'s of the two traditional groups[7] using the t-test, it was first necessary to determine if the two sample variances could be pooled. The F-test[8] was used to determine if this was possible. An F ratio of 1.28 was calculated for the sample variances. The number of degrees of freedom, based on the larger variance (greater mean square), and the smaller variances (lesser mean square), yielded a critical

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6 Downie, N. M., and Heath, R. W., Basic Statistical Methods, p. 135.

$$t = \frac{\overline{x_1} - \overline{x_2}}{S_{D\bar{x}}}$$

where

$t = t$ score

$\overline{x_1}$ = mean of the larger of the two groups.

$\overline{x_2}$ = mean of the smaller of the two groups.

$S_{D\bar{x}}$ = standard error of the difference between two means.

7 See Appendix B, Tables 9 and 10.

8 Downie and Heath, op. cit., pp. 123-139

$$F = \frac{S_1^2}{S_2^2}$$

Where S_1^2 = the larger of the two sample variances, S_2^2 = the smaller of the two sample variances.

value[9] of df = 1.65 at the 0.01 level of significance. Since the derived value of F (1.28) was less than the critical value (1.65), it was assumed that there was no significant difference between the variances and that the samples could be pooled.

A t-test score of 2.02 was calculated. The number of degrees of freedom[10] to test the significance of this score was computed. In this case, a df value of 193 was determined. The critical value[11] of 193 df at the 0.01 level of significance was 2.576, for the two-tailed test. Hence, the null hypothesis of no significant difference between the means was accepted.

Since it was determined that there were no significant differences between the variances or the means of the I.Q.'s of the two traditional groups, the two groups were treated as a single group.

2. A pre-test score was determined by the use of a standardized high school biology achievement examination. The author of this examination was Dr. B.R. Whittinger,[12] University of Minnesota, and edited by Dr. Walter Cook, Dean, College of

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[9]Downie and Heath, op. cit., pp. 272-273.

[10]Downie and Heath, op. cit., p. 135.

$$df = (N_1 + N_2) - 2$$

where

df = degrees of freedom.

N_1 = number of cases in the larger sample.

N_2 = number of cases in the smaller sample.

[11]Downie and Heath, op. cit., p. 265.

[12]Whittinger, op. cit., p. 8.

Education, University of Minnesota. The examination was administered on the first day of classes to all students participating in the study.

An F-ratio[13] was determined to see if it was possible to pool the variances of the two traditional groups on the basis of pre-test scores. The calculated F-ratio of 1.19 was determined. Based on 193 degrees of freedom, the null hypothesis of no significant difference between the two variances was accepted and the variances were pooled.

A t-test score[14] of 2.12 was determined. Based on 193 degrees of freedom, a critical value[15] of 2.576 at the 0.01 level of significance for the two-tailed test was determined. Hence, the null hypothesis of no significant difference between the means was accepted. Since it was determined that there were no significant differences between the variances or the means of the pre-test scores of the two traditional groups, the two groups were treated as a single group.

3. The final grades from 9-science for those students of the traditional groups participating in the study were obtained from the counselors' student files.

An F-ratio[16] was computed to see if it was possible to pool the variances of the two traditional groups on the basis

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[13] Downie and Heath, op. cit., p. 272-276.

[14] Downie and Heath, op. cit., p. 135.

[15] Downie and Heath, op. cit., p. 272-276.

[16] Downie and Heath, op. cit., p. 272-276.

of final grades from 9-science. The calculated F-ratio of 1.33 was determined. Based on 193 degrees of freedom, the null hypothesis of no significant difference between the two variances was accepted and the variances were pooled. A t-score[17] of 1.48 was determined. Based on 193 degrees of freedom, a critical value[18] of 2.576 at the 0.01 level of significance, for the two-tailed test, was determined. At this level of significance the null hypothesis of no significant difference between the means was accepted.

Since it was determined that there were no significant differences between the variances or the means of the final grades from 9-science for the two traditional groups, the two groups were treated as a single group.

On the basis of the t-test results which indicated no significant differences in the means of the I.Q. scores, the pre-test scores, and the final grades from 9-science, the two traditional groups were combined and henceforth treated as one traditional group in the remaining statistical analysis of the study.

<u>I.Q.</u> To demonstrate that no significant difference existed, initially, among the mean I.Q.'s of the students participating in the B.S.C.S. Blue, Green, and Yellow versions of biology and those students in the traditional biology program, the single[19]

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[17]Downie and Heath, <u>op. cit.</u>, p. 265.

[18]Downie and Heath, <u>op. cit.</u>, p. 265.

[19]Downie and Heath, <u>op. cit.</u>, p. 158-167.

classification analysis of variance statistical technique was selected. By this method, it is possible to make one set of calculations on the mean I.Q.'s of the four groups and thus determine if any significant differences exist among them.

In order to be able to reject the null hypothesis (H_0) on the basis of a single classification analysis of variance, an F-test score of a particular magnitude is required. The size of the F-test score is a function of the number of total groups involved in the study, and also the number of students comprising the total group. For the purposes of this investigation an F-test score of 8.54[20] or greater, based on four groups and 510 students, would indicate that the differences found were not attributable to chance at the 0.05 level of significance. See Table 1, page 59.

TABLE 1. ANALYSIS OF VARIANCE FOR THE MEAN I.Q'S OF THE B.S.C.S. BLUE, GREEN, AND YELLOW GROUPS AND THE TRADITIONAL GROUP

Source of Variation	df	Sum of Squares	Mean Square	F-test Score
"Between" groups	3	164.7	54.9	
"Within" groups	506	64848.2	128.2	
Total	509			.42

[20]Downie and Heath, *op. cit.*, p. 272.

The F-test score for the data presented in Table 1 was .42, not large enough to permit rejection of the null hypothesis of no significant difference among the mean I.Q.'s of the B.S.C.S. Blue, Green, and Yellow groups and the traditional group. Therefore, it was assumed that no significant difference existed among the four groups, based on I.Q.

Pre-test score. In order to determine if any significant difference existed, initially, among the mean pre-test scores of the students participating in the B.S.C.S. Blue, Green, and Yellow versions of biology and those students in the Traditional biology program, the single classification analysis of variance statistical technique was used. See Table 2, page 60.

TABLE 2. ANALYSIS OF VARIANCE FOR THE MEAN PRE-TEST SCORES OF B.S.C.S. BLUE, GREEN, AND YELLOW GROUPS AND THE TRADITIONAL GROUP.

Source of Variation	df	Sum of Squares	Mean Square	F-test Score
"Between" groups	3	291.9	97.3	
"Within" groups	506	36824.1	72.8	
Total	509			1.33

Based on the four groups and 510 students, an F-test score of 1.33 was determined for the data presented in Table 2. Since the derived value of F (1.33) was less than the critical value (2.62), at the 0.05 level of significance, it was not large enough to reject the null hypothesis of no significant difference among the means and it was assumed that no significant difference existed among the four groups based on pre-test scores.

Final grade-9 science. In order to determine if any significant difference existed, initially, among the mean final grades for 9-science of the students participating in the B.S.C.S. Blue, Green, and Yellow versions of biology and those students in the Traditional biology program, the single classification analysis of variance statistical technique was used. See Table 3, page 61.

TABLE 3. ANALYSIS OF VARIANCE FOR MEAN FINAL GRADE-9 SCIENCE OF THE B.S.C.S. BLUE, GREEN, AND YELLOW GROUPS AND THE TRADITIONAL GROUPS.

Source of Variation	df	Sum of Squares	Mean Square	F-test Score
"Between" groups	3	.4	.1	
"Within" groups	506	358.3	.7	
Total	509			.18

Based on four groups and 510 students, an F-score of .18 was calculated for the data presented in Table 3. Since the derived value of F (.18) was less than the critical value (8.54), at the 0.05 level of significance, it was not large enough to reject the null hypothesis of no significant difference among the means and it was assumed that no significant difference existed among the four groups based on final grades for 9 science.

<u>Sex</u>. As a further statistical check to determine the initial similarity of the four groups, it was decided to use the chi square test of significance in regard to the criteria of sex.[21] This statistic is a useful one in research because

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[21]Downie and Heath, <u>op. cit.</u>, pp. 147-155

$$\chi^2 = \frac{N\left[(ad) - (bc)\right]^2}{(k)\ (l)\ (m)\ (n)}$$

This formula avoids the computation of the expected frequencies when used with a 2x2 contingency table.

	Rochester	Austin	
male	a	b	k
female	c	d	l
	m	n	

where

χ^2 = chi-square
N = total number of frequencies
a = number of observed frequencies
b = number of observed frequencies
c = number of observed frequencies
d = number of observed frequencies
k = total of rows a and b
l = total of rows c and d
m = total of columns a and c
n = total of columns b and d

no particular assumptions have to be made about the shape of the distribution of the frequencies being tested. The null hypothesis as used with the chi-square statistic and related to the experimental data was that the distribution of male and female students involved in the experiment did not differ from what would be expected by chance.

A 2x2 contingency table was first drawn, based on only the two traditional biology groups as taught at Rochester High School, Rochester, Minnesota, and Austin High School, Austin, Minnesota. A chi-square value of 2.57 was calculated. Since this was a 2x2 table, one degree of freedom resulted in a critical value of 3.84 at the 0.05 level of significance. Therefore, it was assumed that no significant difference existed in the distribution of male and female students between the two traditional groups. On the basis of the first test of chi-square, the male and female students in the two traditional groups were combined into one traditional group of male and female students.

The chi-square statistic was again used to test the sex distribution based on the total number of male and female students in each of the B.S.C.S. Blue, Green, and Yellow groups and the traditional group. A 2x4 or eight-celled contingency table was established. A chi-square value of 3.143 was calculated. Based on a 2x4 contingency table, three degrees of freedom resulted in a critical value of 7.815 at the 0.05 level of significance. Therefore, it was not possible to reject the null hypothesis of no significant difference in the distribution of male and female students among the four groups.

Age. An examination of the records of the 510 students participating in the study from Austin High School and Rochester High School revealed that of this number, 455 were 15 years of age. Out of the remaining 55 students, 51 were 16 years of age and 4 were 17 years of age. However, since the biology programs of Austin High School and Rochester High School were designed for the tenth grade student, it is not surprising that the age range was concentrated in the 15-16 year age group. As a result, it was obvious by inspection of the data that there were no significant differences in student ages among the four groups.

Grade in school. The approaches to teaching high school biology, as used in this study,[22] were designed for the typical tenth grade student. Of the 510 students participating in the study, 485 were classified and duly enrolled as tenth grade students, and the remaining 25 were classified and enrolled as eleventh grade students. As a result, it was obvious by inspection of the data that there were no significant differences in grade placement of the students among the four groups.

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[22]See Chapter III, pp. 35-44.

The measurement of final achievement in biology is presented next.

Measurement of Final Achievement in Biology

To determine the effect on final achievement in biology of each of the four selected approaches to teaching high school biology, it was necessary to select a test which would be appropriate to analyze achievement in biology. The test selected should be valid and reliable.[23] A published test was preferred over a teacher-made test because of the good design and high reliability of most published tests.

The test selected for this purpose was the "Biology Achievement Examination for Secondary Schools, Form 4."[24] This examination was originated by Dr. B. R. Whittinger, University High School, University of Minnesota, and edited by Dr. Walter Cook, Dean, College of Education, University of Minnesota. It was originally prepared for use in the Minnesota State Board Achievement Examinations Programs and is published by the University of Minnesota.[25] Well standardized over the years it

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[23] The "validity of a test may be defined as the extent to which the test measures what it is presumed to measure. The "reliability" of a test may be defined as the extent to which similar results are attained when the test is given a number of times.

[24] Whittinger, B. R., Biology Achievement Examination for Secondary Schools: Form 4, 4pp.

[25] Educational Test Bureau, University of Minnesota, Minneapolis, Minnesota.

has been in use as a biology achievement test, it offers an extensive list of validity and reliability figures in support of the test.[26]

Initial test. The "Biology Achievement Examination for Secondary School, Form 4,"[27] was administered to the pupils of each of the four selected approaches to teaching high school biology,[28] as used in this study, on the first day of the biology course. These scores could then be used for initial comparison of groups and also as a means to determine final achievement.

Final test. In order to have a basis for comparing the difference in final achievement in biology between the pupils of the four selected approaches to teaching biology, it was necessary to administer a test[29] at the conclusion of the 36 week course. This would make possible the determination of a difference score.

Difference score. The difference between the initial test score and the final test score would represent the achievement or improvement score in biology for each pupil. Because four selected approaches to teaching high school biology were included in this study, this difference score for each pupil would represent a means of comparing and evaluating the

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[26] Ibid., p. 62.

[27] Whittinger, op. cit., p. 65.

[28] See Chapter III, pp. 38-44.

[29] Whittinger, op. cit., p. 65.

effectiveness of a particular teaching approach to biology. In planning for the final evaluation of the data which were obtained from the study, certain procedures were necessary. These procedures are presented next.

Comparison of Final Achievement in Biology

In order to reach an objective decision on the basis of the data collected in this study as to whether or not there are differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology, certain procedures were necessary prior to the actual computation of the values of the statistical tests. The preliminary procedures involved: (1) statement of the hypotheses, and (2) statistical technique used in testing hypotheses.

<u>Statement of the hypotheses</u>. The usual procedure in establishing the hypotheses to be tested in any statistical study is to formulate a null hypothesis (H_o) and an alternate hypothesis (H_1). The null hypothesis (H_o) was that there is no significant difference, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. The alternate hypothesis (H_1) was that there are significant differences, in terms of final student achievement,

as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology.

Statistical technique used in testing hypotheses. The choice of statistical technique for testing the hypotheses in this investigation was determined after several conferences with three faculty members at Montana State University.[30] A single classification analysis of variance[31] was used to test the hypothesis that there are differences, in terms of final student achievement, as measured by a standardized high school biology test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. This hypothesis was tested at the 0.05 level of significance.

Summary

To determine the effect on final achievement in biology of each of the four selected approaches to teaching high school biology, an experiment requiring the cooperation of biology teachers and pupils was designed and conducted.

Five teachers participated in the study. The assignment of teachers to either the B.S.C.S. Blue, Green, Yellow, or traditional approaches to teaching biology was made by the school

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[30] See footnote 5, p. 54.

[31] Downie and Heath, op. cit., p. 57.

officials in charge of such scheduling, and the biology pupils of each teacher were placed in the classes to which their teacher had been assigned. Furthermore, no restrictions were put upon individual teachers as to teaching procedures, except that they were expected to follow the curriculum of any approach which they were assigned to teach.

In order to make comparisons of the four groups, information concerning each group and each individual was collected. The t-test statistical technique was used to initially compare the two traditional groups in three areas:- I.Q., pre-test score, and final grade-9 science. In each area there was no significant difference between the means of the two groups at the 0.05 level. On the basis of this information, the two traditional groups were combined and treated as a single group. At this point a single classification analysis of variance statistic was used to initially compare the pupils of the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. The areas of comparison were:- I.Q., pre-test scores, and final grade-9 science. In each area there was no significant difference among the means of the four groups at the 0.05 level. As a further statistical check on the initial similarity of the groups, a chi-square test was used to compare the distribution of the male and female students participating in the study. A 2x2 test was first used with the two traditional groups and the resulting chi-square ratio indicated no significant difference at the 0.05 level. The possible influence of age and grade placement of each of the students participating in the study was examined. Since most of the students were enrolled as tenth grade students and were of the 15-year old age group, it was obvious by inspection of the data that no significant difference existed among the four groups, on these two criteria.

The statistical technique that was used to test the hypothesis that there were significant differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S versions of teaching high school biology and the traditional approach to teaching high school biology, was the single classification analysis of variance. This statistic was tested at the 0.05 level.

The effect of the various versions on final student achievement in biology is presented next.

CHAPTER V

EFFECT OF FOUR SELECTED APPROACHES TO TEACHING HIGH SCHOOL BIOLOGY ON FINAL STUDENT ACHIEVEMENT IN BIOLOGY

Determining the effect on final student achievement in biology of four selected approaches[1] to teaching high school biology was the purpose of this investigation. Through the use of a standardized high school biology achievement examination[2] administered on the first day of the course and again at the end of 36 weeks, it was possible to determine pre-test and post-test scores of the participating students in each of the four selected approaches. It has previously been established that no significant difference existed, initially, among the four groups. Hence, it is possible to statistically analyze the achievement scores of the students in each of the four groups to test the hypothesis that there were significant differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology. This information is presented in the following section.

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[1] Whittinger, B. R., Biology Achievement Examination for Secondary Schools: Form 4, 4pp.

[2] Ibid., p. 71.

Significant Differences in Final Achievement Among the Four Selected Approaches

To determine the effect on final student achievement in biology, it was necessary to test for a significant difference in final achievement among the four selected approaches to teaching high school biology. The two criteria to be tested for significance were the mean post-test scores and the mean difference scores of the total groups among the four selected approaches to teaching high school biology.

For all tests of significant difference in final achievement among the four groups, the null hypothesis, (H_0), was that there are no significant differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. The alternate hypothesis, (H_1), was that there are significant differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology. For all tests of significant difference in final achievement among the four groups, the significance level was set at 0.05.

Post-test scores. A single classification analysis of variance[3] test, based on the mean post-test scores of the four groups was utilized. See Table 4, page 73.

TABLE 4. ANALYSIS OF VARIANCE FOR THE MEAN POST-TEST SCORES OF THE B.S.C.S. BLUE, GREEN, AND YELLOW GROUPS AND THE TRADITIONAL GROUPS.

Source of Variation	df	Sum of Squares	Mean Square	F-test Score
"Between" groups	3	529.4	176.5	
"Within" groups	506	73356.9	144.9	
Total	509			1.21

An F-test score of 1.21, based on 510 students in four groups, was determined. The number of degrees of freedom[4] yielded a critical value of 2.62. Since the derived value of F (1.21) was less than the critical value (2.62), at the 0.05 level of significance, it was not large enough to reject the null hypothesis of no significant difference among the means and it was assumed that no significant difference existed among the four groups based on post-test scores.

[3]Downie and Heath, *op. cit.*, p. 158-167.

[4]Downie and Heath, op. cit., p. 158-167.

Difference scores. A single classification analysis of variance[5] test, based on the mean difference scores between the pre-test score and the post-test score of the four groups, was utilized. See Table 5, page 74.

TABLE 5. ANALYSIS OF VARIANCE FOR THE MEAN DIFFERENCE SCORES OF THE B.S.C.S. BLUE, GREEN, AND YELLOW GROUPS AND THE TRADITIONAL GROUPS.

Source of Variation	df	Sum of Squares	Mean Square	F-test Score
"Between" groups	3	125.9	41.9	
"Within" groups	506	28601.0	56.5	
Total	509			.74

On the basis of 510 students and four groups, an F-test score of .74 was determined. The number of degrees of freedom[6] yielded a critical value[7] of 8.54. Since the derived value of F (.74) was less than the critical value (8.54), at the 0.05 level of significance, it was not large enough to reject the null hypothesis of no significant difference among the means and it was assumed that no significant difference existed among the four groups based on difference scores.

[5]Downie and Heath, op. cit., p. 158-167.

[6]Downie and Heath, op. cit., p. 158-167.

[7]Downie and Heath, op. cit., p. 158-167.

Summary

The data collected during the investigation were analyzed statistically to determine the effect of the four selected approaches to teaching high school biology on final student achievement in biology.

To test for a significant difference in final achievement among the groups of the four selected approaches, a single classification analysis of variance statistical technique revealed that no significant difference existed among the mean post-test scores and the mean difference scores of the groups of the four selected approaches to teaching high school biology.

It was determined that there were no significant differences in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology.

A summary, conclusions drawn, and recommendations follow.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this investigation was to determine the effect, on final student achievement, of four selected approaches to teaching high school biology. A concern about the nature of science teaching has been the cause of much debate in the twentieth century and professional opinion was that the teaching of high school biology had not been satisfactory for many years, and the need for improved teaching techniques was apparent. Consequently, the B.S.C.S. versions of teaching high school biology were developed and made available for all high schools. The belief that there are differences, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology, led to this investigation.

Summary

An examination of the literature concerning the teaching of high school biology revealed a need for improved techniques of teaching to overcome the difficulties often encountered by pupils studying biology.

Following a study of the course content of the three

B.S.C.S. versions and the traditional approach to teaching high school biology, an investigation was conducted in which a number of teachers and their pupils cooperated. In teaching their classes, no restrictions were put upon individual teachers as to teaching procedures, except that they were expected to follow the curriculum of the approach to which they had been assigned. Pupils of the four selected approaches were tested at the beginning of the 36 week course and again at the conclusion of the course.

The data obtained during the investigation were examined statistically to determine the effect on final student achievement in biology, of the four selected approaches to teaching high school biology. It was determined that there was no significant difference, in terms of final student achievement, as measured by a standardized high school biology achievement test, among the three B.S.C.S. versions of teaching high school biology and the traditional approach to teaching high school biology.

Conclusions

The following conclusions concerning the teaching of high school biology were made on the basis of the review of literature:-

1. There is a need for improved teaching techniques in the field of biology.

2. The three B.S.C.S. versions of teaching high school biology represent an effort to improve high school biology teaching.

On the basis of the experimental findings of this study, subject to the assumption that the samples were indicative of the characteristics of student population, and subject to the limitations of the sensitivity of the tests employed, the following conclusions were made:

1. The belief that final achievement in biology, as measured by a standardized high school biology achievement test, is different among the four selected approaches to teaching high school biology, has no statistical justification.

2. The traditional approach to teaching high school biology still has its place in the high school biology program.

3. Final student achievement in biology, as a result of following the three B.S.C.S. versions of teaching high school biology, does not represent a significant improvement over the traditional approach to teaching high school biology.

Recommendations

The following observations and recommendations became evident during the course of this investigation and are presented here to indicate areas of possible future research relative to the teaching of biology.

In view of the fact that the concepts studied in biology are becoming increasingly important and because the methods of teaching biology have not kept pace with other advances, more research is needed into methods of improving instruction in the fundamental ideas studied in biology.

Biology teachers need to re-evaluate their own skills in applying biological principles to the teaching of biology.

Research is needed to determine the optimum grade placement, sequence, and necessary prerequisites, if any, which will lead most efficiently to an understanding of the fundamental concepts of biology.

Studies are needed which will identify the specific abilities needed for success in working with the fundamental concepts of biology and also what abilities or skills can be improved by the study of biology.

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APPENDIX

Appendix A

Biology Achievement Examination
for Secondary Schools, Form 4

Achievement Examinations for Secondary Schools

FORM 4

Biology

Time: 1½ hrs.

Student's Score ....

Perfect Score 108

DR. B. R. WHITTINGER, *Author*
University of Minnesota High School

NAME...
Last Name First Middle Initial Age Grade

CITY (or P. O. Address).. COUNTY .... DIST NO. .... TIME USED ....

Name of Parents .... Address ....

To the student: Be sure to fill out the blanks above. Read directions carefully and answer the questions on this sheet; no other sheet is needed except scratch paper. If you cannot answer a question, leave it and go on to the next one. Answer as many as you can.

I. *DIRECTIONS: Write in each answer space the letter of the best response.*

1. The fruit of a plant
(a) is sweet (b) has much stored food (c) contains the seeds (d) consists of the ovary .... 1. (........)

2. Animals have the same functions as plants except for
(a) respiration (b) irritability (c) reproduction (d) excretion (e) photosynthesis .... 2. (........)

3. Identical twins originate from
(a) two eggs fertilized by one sperm (b) one egg fertilized by two sperms (c) two eggs fertilized by two sperms (d) one egg fertilized by one sperm .... 3. (........)

4. The essential organs of the flower are
(a) petals and pistils (b) sepals and corolla (c) pistils and stamens (d) stamens and calyx .... 4. (........)

5. Growth and repair of body tissues involves
(a) protein (b) fats (c) starch (d) sugar .... 5. (........)

6. The human embryo gets its food through
(a) the placenta (b) the uterine tube (c) cell division (d) the mother's blood stream directly .... 6. (........)

7. When the habitat of an organism changes, that organism
(a) usually increases in number (b) becomes extinct there (c) usually must change in structure or life habitat or become extinct (d) usually is not affected (e) usually dies in great numbers from disease .... 7. (........)

8. The post-natal period of greatest growth is
(a) the fetus (b) infancy (c) the embryo (d) childhood (e) adolescence .... 8. (........)

9. A bald-headed father and a straight haired mother have children who have curly hair. Straight hair is a recessive trait. The explanation for the children having curly hair is
(a) the mother carried genes for curly hair which she passed on to her offspring (b) the father carried genes for curly hair which he passed on to his offspring (c) both the mother and the father carried genes for curly hair (d) neither parent had an influence in determining the type of hair in the offspring .... 9. (........)

10. Bacteria
(a) need air to grow (b) are produced by toxins (c) are smaller than viruses (d) are macroscopic (e) more than one of the above (f) none of the above .... 10. (........)

11. Girdling is likely to be destructive to a tree because
(a) the growing tissue is likely to be squeezed (b) the conducting tissue may be destroyed (c) the stem can not get air (d) the roots will be extruded by osmotic pressure .... 11. (........)

12. Secretions of endocrine glands are referred to as
(a) enzymes (b) lypmh (c) toxins (d) hormones (e) anti-toxins .... 12. (........)

13. Reference to an organism indicates
(a) anything made up of organs (b) anything consisting of organic matter (c) any living thing (d) a systemic organization.... 13. (........)

14. A person with blood type "O" may give blood to another person with blood type
(a) A (b) B (c) AB (d) more than one of the above .... 14. (........)

15. When two brown eyed parents have a blue eyed child it probably indicates
(a) hybrid eye genes in one parent (b) a mutation (c) hybrid eye genes in both parents (d) this result is impossible .... 15. (........)

16. Proteins are different from the other energy foods in that they contain
(a) nitrogen (b) oxygen (c) hydrogen (d) carbon .... 16. (........)

17. The history of the payment of bounties for the destruction of predators indicates
(a) the results justified the outlay of necessary funds (b) the destruction of the predators corrected the balance of nature (c) the predator program disrupted the balance of nature (d) the program provided a much stronger game animal population .... 17. (........)

18. Plants that grow each year from seeds are
(a) biennials (b) annuals (c) spermatophytes (d) perennials .... 18. (........)

19. The unique contribution legumes make to the soil in which they are planted, is
(a) the fortifying of the calcium content (b) the rich supply of humus (c) the fortification of nitrates by harboring nitrogen fixers (d) the production of a superior mulch .... 19. (........)

44. A biology class tried to determine the effectiveness of two hand-lotions. Lotion "A" and lotion "B" were applied to a randomly selected group of 50 right-handed people, alternating the two lotions between the two hands on each subject without the subject's knowledge of which lotion was placed on which hand. One recommendation we could make for this plan would be
(a) place the same lotion on both hands (b) include a third classification of no lotion or false lotion on a third of the subjects (c) place the lotions A or B on the same hand, right or left (d) mix the two lotions together before applying .... **44. (......)**

45. The downward curling of a leaf at various times
(a) reduces transpiration (b) increases photosynthesis (c) indicates increase in osmosis (d) is due to rapid respiration .... **45. (......)**

46. The cambium of a stem
(a) provides for oxygen exchange (b) increases the diameter of a stem (c) is the principal conductor of fluids (d) increases the length of a stem .... **46. (......)**

47. The mathematical sex ratio tends to be
(a) 3:1 (b) 2:1 (c) 2:2 (d) 8:10 .... **47. (......)**

48. Evergreens are plants which
(a) do not drop their leaves (d) drop their leaves in the fall (c) drop their leaves in the spring (d) do not drop all leaves at the same time .... **48. (......)**

49. The start of a young plant in a seed is
(a) a cotyledon (b) an hilum (c) an endosperm (d) an embryo .... **49. (......)**

50. Monocot stems are different from Dicot stems in that
(a) the vascular bundles are scattered in the monocot (b) the monocot stem has no support (c) monocots have no vascular bundles (d) dicot stems have no pith .... **50. (......)**

51. Pollination has occurred when
(a) pollen has been transferred from flower to flower (b) the sperm cell unites with the egg cell (c) pollen has been transferred from stamen to pistil (d) pollen has been transferred from pistil to stamen .... **51. (......)**

52. The main devices of water absorption in the plant are the
(a) stomata (b) lenticles (c) cuticle (d) root hairs .... **52. (......)**

53. In mitosis the chromosomes
(a) double in number (b) remain the same in number (c) triple in number (d) are reduced in half .... **53. (......)**

54. A disease associated with lack of iodine in the diet is
(a) cancer (b) diabetes (c) simple goiter (d) yellow fever (e) arterial sclerosis .... **54. (......)**

55. In diabetes the excess sugar goes into the urine. A doctor testing a urine specimen for sugar would use
(a) iodine (b) phenolphthalein (c) Fehling's solution (d) lime water .... **55. (......)**

56. Which of the following contains all the rest?
(a) codeine (b) opium (c) morphine (d) heroin .... **56. (......)**

57. Geotropism is the
(a) tendency of a plant to grow toward the sun (b) study of geographical influence (c) tendency of man to migrate (d) tendency of plant roots to respond to gravity .... **57. (......)**

58. We would expect to find no nervous system in the
(a) earthworm (b) amoeba (c) fish (d) hydra .... **58. (......)**

59. If a moth causes damage by chewing, we would blame it on the
(a) adult (b) nymph (c) larvae (d) pupae .... **59. (......)**

60. A disease very often associated with hookworm, in countries with high percentage of infection, is
(a) trichinosis (b) tuberculosis (c) ascaris (d) taenia .... **60. (......)**

II *DIRECTIONS: In each of the following statements, one term is not related to the others in the group. Select the letter of the misfit and place it in the answer space.*

61. (a) mushroom (b) wheat rust (c) diatoms (d) bread mold .... **61. (......)**

62. (a) mistletoe (b) lichen (c) tubercular bacillus (d) lilac mildew .... **62. (......)**

63. (a) spores (b) fission (c) budding (d) conjugation .... **63. (......)**

64. (a) spider (b) locust (c) katydid (d) cockroach .... **64. (......)**

65. (a) garter snake (b) painted turtle (c) skink (d) tiger salamander .... **65. (......)**

66. (a) respiration (b) osmosis (c) irritability (d) reproduction .... **66. (......)**

67. (a) pituitary (b) thyroid (c) salivary (d) adrenal .... **67. (......)**

68. (a) egg (b) pupa (c) larva (d) nymph 68. (......)

69. (a) Banting (b) deVries (c) Mendel (d) Thomas Morgan .... **69. (......)**

70. (a) plumule (b) hypocotyl (c) cotyledon (d) cambium .... **70. (......)**

III *DIRECTIONS: Write in each answer space the letter of the term that includes all the rest.*

71. (a) sensory (b) motory (c) associative (d) neuron .... **71. (......)**

72. (a) insulin (b) hormone (c) thyroxin (d) estrogen .... **72. (......)**

73. (a) enzyme (b) pytalin (c) pepsin (d) trypsin .... **73. (......)**

74. (a) protozoa (b) bacillus (c) microorganisms (d) bacteria .... **74. (......)**

75. (a) veins (b) leaf (c) midrib (d) petiole 75. (......)

IV *DIRECTIONS: Select the letter of the phylum which best fits each description and place it in the answer space after the description. Some phyla may be used more than once, and some may not be used at all.*

PHYLA	DESCRIPTIONS
A. Arthropods	76. Flower-Like animals .... (......)
B. Chordates	77. Soft bodied animals .... (......)
C. Coelenterates	78. First jointed appendages.. (......)
D. Echinoderms	79. Single celled animals .... (......)
E. Flat worms	80. Worms with one body opening .... (......)
F. Mollusca	81. Have a dorsal nerve cord (......)
G. Protozoa	82. Have a water vascular system .... (......)
H. Porifera	83. First segmented bodies...... (......)
I. Round worms	84. First many celled animals (......)
J. Segmented worms	85. Have a chitinous exoskeleton .... (......)

Appendix B

Tables

TABLE 6. STUDENT NUMBER, I.Q., PRE-TEST SCORE, POST-TEST SCORE, DIFFERENCE SCORE, FINAL GRADE-9 SCIENCE, AND SEX FOR 91 STUDENTS OF THE B.S.C.S. BLUE VERSION BIOLOGY GROUP.

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
1	57	33	36	3	2	M
2	57	39	42	3	2	M
3	57	43	50	7	1	F
4	57	41	50	9	2	M
5	57	47	60	13	3	M
6	57	48	61	13	1	F
7	57	27	44	17	1	F
8	57	31	50	19	1	F
9	57	34	62	28	3	M
10	59	46	63	17	2	F
11	60	36	43	7	2	M
12	64	40	53	13	3	F
13	64	34	52	18	2	F
14	64	40	65	25	3	M
15	64	40	65	25	2	F
16	64	43	71	28	3	F
17	65	39	67	28	2	F
18	65	29	64	35	2	M
19	66	43	53	10	2	F
20	66	45	58	13	2	F
21	66	46	67	21	3	M
22	66	33	60	27	3	F
23	69	37	63	26	2	F
24	71	49	65	16	3	F
25	75	44	65	21	3	F
26	76	48	70	22	4	M
27	65	50	62	12	3	F
28	66	51	64	13	4	F
29	70	51	66	15	2	M
30	69	51	70	19	3	F
31	72	50	67	17	2	F
32	72	50	68	18	4	F
33	77	51	72	21	3	F
34	77	52	66	14	3	F
35	64	53	72	19	3	M
36	66	54	67	13	3	F
37	64	54	66	12	3	F
38	66	53	74	21	3	F
39	67	53	74	21	3	M
40	69	53	68	15	3	F

TABLE 6. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
41	36	33	39	6	1	F
42	36	52	64	12	0	M
43	37	32	39	7	1	F
44	39	35	49	14	2	M
45	42	23	38	15	2	M
46	42	30	33	3	1	M
47	42	34	41	7	0	M
48	43	35	36	1	1	F
49	44	32	34	2	1	M
50	44	35	41	6	1	M
51	44	24	43	19	2	M
52	46	32	39	7	2	M
53	46	23	41	18	1	F
54	48	31	47	16	2	F
55	48	28	30	2	1	M
56	48	32	34	2	1	F
57	48	40	42	2	1	M
58	48	45	54	9	1	M
59	48	42	52	10	1	F
60	48	42	61	19	3	M
61	49	47	48	1	2	F
62	49	47	56	9	2	F
63	51	39	51	12	2	M
64	51	34	54	20	1	M
65	53	51	57	6	3	F
66	53	40	48	8	2	F
67	53	33	46	13	2	F
68	53	46	66	20	2	F
69	53	21	43	22	1	M
70	54	42	47	5	1	M
71	54	36	58	22	1	F
72	55	47	50	3	1	M
73	55	38	45	7	2	F
74	55	53	61	8	2	F
75	55	50	63	13	2	F
76	55	52	80	28	3	F
77	56	29	36	7	2	M
78	56	48	61	13	3	M
79	56	34	51	17	3	F
80	56	47	65	18	3	F

TABLE 6. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
81	56	33	51	18	2	F
82	56	39	58	19	2	F
83	25	39	44	5	1	F
84	25	36	43	7	0	F
85	26	21	22	1	1	M
86	26	26	29	3	1	M
87	26	33	38	5	1	F
88	28	28	34	6	1	M
89	29	28	34	6	1	M
90	30	31	37	6	1	F
91	32	32	37	5	1	F

TABLE 7. STUDENT NUMBER, I.Q., PRE-TEST SCORE, POST-TEST SCORE DIFFERENCE SCORE, FINAL GRADE-9 SCIENCE, AND SEX FOR 111 STUDENTS OF THE B.S.C.S. GREEN VERSION BIOLOGY GROUP.

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
1	57	42	62	20	3	F
2	57	43	59	16	2	F
3	57	32	50	18	1	F
4	57	35	59	24	3	M
5	57	41	67	26	2	M
6	57	47	73	26	4	F
7	58	32	49	17	2	M
8	58	43	66	23	3	M
9	59	34	56	22	1	M
10	59	39	42	3	1	F
11	59	36	45	9	1	F
12	59	46	53	7	2	F
13	62	48	49	1	2	M
14	62	45	51	6	2	M
15	62	61	70	9	2	F
16	62	40	50	10	3	F
17	62	38	51	13	2	F
18	62	43	59	16	2	M
19	62	36	56	20	3	M
20	64	49	60	11	2	F
21	64	52	59	7	3	F
22	64	54	61	7	1	F
23	64	42	50	8	2	F
24	64	46	56	10	3	M
25	64	53	64	11	3	M
26	64	44	56	12	2	M
27	64	44	57	13	2	F
28	64	45	62	17	2	M
29	64	44	63	19	2	F
30	64	48	67	19	2	F
31	64	42	62	20	3	F
32	64	41	66	25	2	F
33	64	43	70	27	3	F
34	64	34	67	33	3	F
35	65	38	61	23	2	F
36	65	52	59	7	3	M
37	67	44	54	10	3	F
38	67	39	54	15	3	F
39	67	42	58	16	3	F
40	67	31	57	26	1	F

TABLE 7. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
41	67	34	60	26	3	M
42	67	50	77	27	3	F
43	69	50	57	7	2	M
44	72	42	61	19	2	M
45	76	51	72	21	4	F
46	78	44	58	14	2	F
47	44	38	47	9	2	M
48	44	30	47	17	1	M
49	44	24	37	13	1	M
50	46	35	39	4	1	M
51	46	40	43	3	1	F
52	47	36	54	18	2	M
53	48	30	51	21	2	M
54	48	36	57	21	2	F
55	48	43	47	4	1	F
56	48	37	42	5	2	F
57	48	38	45	7	1	M
58	48	23	31	8	1	F
59	48	36	45	9	2	F
60	48	32	46	14	2	M
61	48	34	50	16	2	M
62	48	42	45	3	2	M
63	48	38	55	17	2	F
64	48	41	59	18	2	F
65	48	32	52	20	2	M
66	49	27	38	11	1	F
67	51	42	62	20	3	M
68	51	52	56	4	2	M
69	53	26	56	4	2	M
70	53	35	50	15	2	F
71	53	37	53	16	1	M
72	53	20	56	36	2	M
73	54	40	52	8	1	F
74	54	40	50	10	2	F
75	55	40	46	6	2	F
76	55	40	50	10	2	M
77	55	31	41	10	1	M
78	55	46	59	13	4	M
79	55	39	53	14	2	F
80	56	45	56	11	2	F

TABLE 7. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
81	56	41	45	4	2	F
82	56	35	43	8	2	M
83	56	39	47	8	2	F
84	56	39	49	10	1	F
85	56	64	74	10	4	F
86	56	29	44	15	2	F
87	56	38	53	15	1	M
88	56	42	57	15	3	F
89	56	38	54	16	3	M
90	56	47	63	16	2	M
91	56	27	44	17	2	M
92	56	35	52	17	2	M
93	17	26	38	12	1	M
94	26	27	30	3	1	F
95	31	33	38	5	1	F
96	35	32	36	4	1	F
97	35	29	31	2	1	F
98	35	40	43	3	2	M
99	36	30	35	5	2	F
100	36	32	37	5	2	M
101	36	25	31	6	2	M
102	36	24	36	2	1	M
103	36	38	42	4	1	F
104	36	35	49	4	2	M
105	37	36	47	11	2	F
106	37	39	44	5	2	M
107	37	23	29	6	1	M
108	39	37	41	4	3	M
109	41	32	40	8	2	M
110	42	23	34	11	1	M
111	43	26	35	9	1	M

TABLE 8. STUDENT NUMBER, I. Q., PRE-TEST SCORE, POST-TEST SCORE, DIFFERENCE SCORE, FINAL GRADE-9 SCIENCE, AND SEX FOR 113 STUDENTS OF THE B.S.C.S. YELLOW VERSION GROUP.

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
1	64	52	62	10	2	M
2	64	54	67	13	4	F
3	64	38	54	16	3	F
4	64	45	61	16	2	F
5	64	40	56	16	2	F
6	64	48	66	18	3	F
7	64	39	58	19	2	M
8	64	34	54	20	3	F
9	64	39	61	22	2	F
10	64	35	58	23	2	M
11	65	52	71	19	3	F
12	66	46	63	17	2	F
13	66	42	65	23	2	M
14	67	45	56	11	3	M
15	67	49	58	9	4	F
16	67	60	69	9	3	M
17	67	48	64	16	4	F
18	67	35	53	18	2	F
19	67	43	70	27	3	F
20	69	48	59	11	2	M
21	69	43	57	14	3	M
22	69	50	58	22	3	F
23	74	36	58	22	3	F
24	78	56	71	15	4	F
25	48	39	26	15	2	M
26	48	26	52	26	1	M
27	49	39	41	2	1	M
28	49	40	46	6	1	M
29	49	42	50	8	2	F
30	49	43	51	8	1	F
31	51	34	38	4	1	F
32	51	45	66	21	2	F
33	53	38	50	12	3	F
34	53	36	38	2	1	F
35	53	33	43	10	1	F
36	53	40	63	23	2	M
37	54	29	30	1	1	F
38	54	42	45	3	2	M
39	54	36	43	7	1	M
40	55	47	56	9	2	F

TABLE 8. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
41	55	32	42	10	2	F
42	55	33	47	14	2	M
43	55	38	54	16	2	F
44	55	42	58	16	2	F
45	55	62	78	16	2	M
46	55	36	54	18	2	M
47	55	49	68	19	2	M
48	56	35	71	36	3	M
49	56	25	33	8	1	M
50	56	48	61	13	2	F
51	56	45	60	15	2	F
52	56	38	54	16	1	M
53	57	44	71	27	2	M
54	57	37	48	11	2	M
55	57	45	51	6	1	M
56	57	36	45	9	1	F
57	57	44	54	10	2	F
58	57	48	60	12	3	M
59	57	49	61	12	3	M
60	57	42	55	13	3	M
61	58	46	60	14	3	F
62	59	38	44	6	3	F
63	59	51	59	8	2	M
64	59	38	55	17	2	M
65	61	46	54	8	1	F
66	61	52	60	8	2	M
67	62	45	51	6	3	M
68	62	45	55	10	3	M
69	62	50	60	10	4	M
70	62	41	54	13	2	M
71	62	41	74	33	3	M
72	64	49	60	11	3	F
73	64	37	42	5	1	F
74	64	47	52	5	2	M
75	64	30	38	8	2	F
76	64	49	59	10	2	F
77	25	26	27	1	1	M
78	26	25	34	9	1	M
79	27	29	31	2	1	M
80	28	34	39	5	1	M

TABLE 8. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
82	32	35	37	2	1	M
83	33	30	34	4	1	F
84	36	30	34	4	1	F
85	36	33	37	4	2	M
86	36	31	41	10	2	M
87	36	35	49	14	0	M
88	37	34	36	2	1	F
89	37	25	29	4	1	F
90	37	30	39	9	1	M
91	39	24	35	11	1	M
92	39	36	39	3	1	F
93	39	38	42	4	2	F
94	40	29	32	3	1	F
95	43	20	36	16	1	M
96	43	33	53	20	2	M
97	43	21	45	24	2	M
98	44	41	45	4	1	F
99	44	32	40	8	2	M
100	44	40	49	9	1	F
101	44	30	45	15	2	F
102	44	34	51	17	3	M
103	44	33	52	19	2	F
104	45	29	53	24	2	F
105	47	35	40	5	1	F
106	47	22	44	22	1	F
107	48	54	55	1	2	M
108	48	38	40	2	1	F
109	48	33	37	4	2	M
110	48	45	51	6	1	M
111	48	28	36	8	1	M
112	48	40	48	8	2	M
113	48	35	44	9	1	M

TABLE 9. STUDENT NUMBER, I.Q. PRE-TEST SCORE, POST-TEST SCORE, DIFFERENCE SCORE, FINAL GRADE-9 SCIENCE, AND SEX FOR 82 STUDENTS OF THE AUSTIN TRADITIONAL GROUP.

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
1	64	42	56	14	3	F
2	64	53	64	11	3	M
3	64	52	55	3	2	F
4	64	42	61	19	2	M
5	64	33	58	25	1	M
6	64	39	62	23	3	F
7	64	47	61	14	2	F
8	64	43	54	11	2	M
9	64	48	68	20	3	F
10	64	35	60	25	2	F
11	64	42	49	7	2	F
12	66	40	51	11	2	M
13	66	43	55	12	1	F
14	66	33	41	8	1	M
15	69	50	62	12	3	F
16	69	52	70	18	2	F
17	69	49	56	7	2	F
18	72	46	85	39	3	F
19	74	47	62	15	3	F
20	74	41	58	17	2	M
21	75	47	71	24	4	F
22	76	58	70	12	4	F
23	78	56	77	21	4	M
24	51	45	55	10	2	M
25	53	52	62	10	3	M
26	53	35	50	15	1	M
27	54	31	49	18	2	M
28	54	33	48	15	2	M
29	54	39	55	16	1	F
30	54	35	36	1	2	F
31	55	33	51	18	1	F
32	55	39	49	10	2	M
33	55	54	66	12	2	M
34	55	42	51	9	1	M
35	56	38	74	36	2	F
36	56	36	46	10	2	F
37	56	42	55	13	2	M
38	56	37	60	23	2	F
39	56	34	44	10	2	F
40	57	35	64	11	2	M

TABLE 9. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
41	57	51	63	12	3	M
42	57	46	55	9	1	M
43	57	42	58	16	1	M
44	57	41	52	11	2	F
45	57	42	62	20	1	M
46	57	47	54	7	2	M
47	57	43	54	11	2	M
48	57	52	67	15	2	F
49	57	47	62	15	2	F
50	58	40	49	9	2	M
51	58	56	66	10	3	F
52	59	38	69	31	3	M
53	59	45	58	13	3	M
54	59	56	65	9	2	F
55	59	27	44	17	2	M
56	59	40	58	18	2	M
57	61	42	63	21	3	M
58	62	49	63	14	3	F
59	62	37	58	21	3	F
60	62	43	55	12	2	M
61	62	52	63	11	2	M
62	62	64	83	19	4	M
63	62	39	48	9	1	M
64	64	41	56	15	2	M
65	64	43	56	13	2	M
66	64	44	57	13	3	M
67	64	41	61	20	3	F
68	31	32	42	10	1	M
69	44	33	40	7	1	M
70	44	30	35	5	1	M
71	47	36	38	2	2	F
72	47	35	47	12	2	M
73	47	46	70	24	2	M
74	48	67	73	6	1	M
75	48	32	44	12	2	F
76	48	28	38	10	1	F
77	48	30	36	6	2	M
78	48	31	36	5	1	M
79	48	39	58	19	2	M
80	48	38	43	5	1	M

TABLE 9. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
81	48	29	31	2	1	M
82	48	42	52	10	2	M

TABLE 10. STUDENT NUMBER, I.Q., PRE-TEST SCORE, POST-TEST SCORE, DIFFERENCE SCORE, FINAL GRADE-9 SCIENCE, AND SEX FOR 113 STUDENTS OF THE ROCHESTER TRADITIONAL GROUP.

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
1	62	39	57	18	2	M
2	62	46	70	24	2	F
3	62	41	63	22	3	F
4	64	31	34	3	2	M
5	64	46	54	8	2	F
6	64	48	57	9	3	F
7	64	51	61	10	4	M
8	64	51	65	14	2	M
9	64	57	72	15	3	M
10	64	40	61	21	3	F
11	64	48	73	25	3	M
12	64	35	62	27	3	M
13	64	21	57	36	2	F
14	66	50	61	11	2	F
15	66	51	64	13	2	M
16	66	50	65	15	4	M
17	67	42	64	22	3	F
18	67	41	52	11	2	F
19	67	45	65	20	4	M
20	67	51	71	20	4	F
21	67	47	67	20	3	M
22	69	45	62	17	3	M
23	69	46	75	29	4	M
24	75	52	62	10	4	M
25	75	49	65	16	4	F
26	75	51	71	20	3	F
27	64	52	63	11	2	F
28	48	35	40	5	2	M
29	48	24	27	3	1	M
30	48	28	31	3	1	F
31	48	51	54	3	2	M
32	48	35	43	8	2	M
33	48	43	52	9	2	F
34	48	40	50	10	2	F
35	48	48	58	10	2	M
36	49	29	35	6	1	M
37	49	43	59	16	2	F
38	51	37	46	9	2	M
39	53	50	61	11	2	M
40	53	46	62	16	3	M

TABLE 10. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
41	53	48	68	20	1	F
42	54	34	38	4	1	M
43	54	23	36	13	1	M
44	54	41	55	14	2	M
45	55	41	60	19	2	F
46	55	23	28	5	1	F
47	55	44	53	9	3	M
48	55	49	60	11	2	F
49	55	37	55	18	1	F
50	56	32	35	3	1	F
51	56	28	32	4	1	F
52	56	44	50	6	2	F
53	56	24	33	9	1	F
54	56	42	52	10	2	F
55	56	37	48	11	2	F
56	56	48	59	11	2	F
57	56	38	50	12	1	F
58	56	31	48	17	1	M
59	56	47	72	25	2	M
60	57	44	50	6	1	F
61	57	44	49	5	2	F
62	57	47	55	8	2	F
63	57	40	50	10	2	F
64	57	42	54	12	1	M
65	57	44	57	13	2	F
66	58	53	60	7	1	M
67	58	47	55	8	2	F
68	58	27	37	10	1	F
69	58	52	65	13	3	F
70	58	31	52	21	1	M
71	58	43	52	9	2	F
72	59	45	54	9	2	F
73	59	54	61	7	2	M
74	59	54	72	18	2	M
75	59	46	59	13	2	M
76	59	43	59	16	2	F
77	62	43	51	8	1	F
78	62	37	48	11	1	M
79	62	49	65	16	2	M
80	62	39	42	3	2	F

TABLE 10. (Continued)

Student Number	I.Q.	Pre-test Score	Post-test Score	Difference Score	Final Grade 9 Science	Sex
81	21	28	38	10	1	M
82	21	27	39	12	1	M
83	28	39	44	5	1	F
84	28	39	45	6	2	F
85	28	28	33	5	1	M
86	28	29	48	19	1	M
87	32	37	39	2	2	M
88	33	32	36	4	1	F
89	34	34	39	5	1	F
90	34	34	41	7	1	M
91	36	34	35	1	1	F
92	36	29	31	2	1	M
93	36	36	39	3	1	M
94	36	30	34	4	1	F
95	36	34	41	7	1	F
96	36	31	40	9	2	F
97	36	30	40	10	2	M
98	36	35	36	1	1	M
99	37	33	41	8	1	M
100	37	38	43	5	1	M
101	39	36	42	6	2	F
102	41	48	57	9	2	M
103	43	36	37	1	1	M
104	43	16	26	10	1	M
105	43	26	47	21	1	M
106	44	29	35	6	1	F
107	44	32	35	3	2	F
108	44	30	31	1	1	M
109	44	28	35	7	2	F
110	44	30	39	9	1	M
111	47	36	40	4	2	F
112	47	42	51	9	1	F
113	47	26	51	25	1	F

Lewis, W. A.
An evaluation of four selected approaches to teaching...

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