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A Comparative Study of Teaching Trends and Practices in the General Biology Laboratory as Offered by the Public Community Colleges of California

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A COMPARATIVE STUDY OF TEACHING TRENDS AND PRACTICES IN THE GENERAL BIOLOGY LABORATORY AS OFFERED BY THE PUBLIC COMMUNITY COLLEGES OF CALIFORNIA

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CHAPTER I

THE PROBLEM

Introduction

Man's curiosity lies at the root of all sciences. In his primitive stages of development he feared natural phenomena and called upon the supernatural to explain the mysterious happenings around him. He had to be something of a biologist to defend himself against nature and to survive. The world was an open laboratory and his varied activities provided biological knowledge founded on observation and eventually on limited experimentation. Overshadowed by superstition and fear, the accumulation of scientific knowledge and the development of concepts proceeded slowly.

The history of biology has been a complex evolution from magic, demons and spirits, through philosophical speculation and intuition to the strictly controlled experiments of today. Once man was willing to look at the physical world as a product of natural forces, he could study it objectively without perceptual biases and emotional barricades. Once man had a new theoretical outlook on the physical world, he was free to develop technology based on that theory, a technology that has profoundly changed human lives in the past three centuries.

This country had its genetic origin in England and its educational system was based on the English model. The strong pioneer spirit which prevailed in the colonies brought about the development of local responsibility and the emergence of the free, tax-supported American common schools. The colonial colleges came into being as liberal arts colleges to educate prospective preachers and to prepare future lawyers, teachers, physicians and businessmen, all from the same common intellectual source.

The curriculum first served as a program for preparing the leadership of society, but the new world had need for a more pragmatic education and a necessity for increased comprehension of the sciences and their practical application.

The community college emerged as the only institution of higher education dedicated to the principle of education for all people. This open-door policy uniquely distinguished the philosophy and role of the two-year colleges in the United States and established the basis for individualized community curricular offerings.

Since the announcement in 1910 of the first junior college in California, these institutions have experienced more than sixty years of rapid expansion and have grown in number to ninety-three in that state. Trends in California probably indicate that the majority of the nation's freshmen and sophomores will soon be educated at two-year colleges. This represents an awesome challenge and responsibility to the junior college faculties.

The impact of modern science and technology demands from the people some basic understanding and fundamental knowledge of the scientific enterprise. It is estimated that scientific information doubles in each decade and a considerable part of modern life is based upon this new understanding of nature. The knowledge acquisition rate is rapid, offers substantial benefits to society but poses numerous problems to the teaching of science.

California community colleges offer a wide variety of introductory biological science courses and increasing numbers of students in higher education will have an opportunity to take them. But the majority will complete only the general education science requirement. Consequently, leading educators are strongly challenging the community college biological science teaching personnel to involve these students in new methods and materials with lasting personal and social relevance.

STATEMENT OF THE PROBLEM

The twentieth century's Scientific Revolution has already produced greater changes than the Agricultural and Industrial Revolutions of the seventeenth, eighteenth, and nineteenth centuries. The natural sciences have attained new meaning for mankind and the biological sciences in the last half of this century stand on the threshold of discoveries and advances that give promise of even more momentous changes. These results are not only important for general knowledge but also determine more and more the hygienic, economic and political development of nations.

While it is a foregone conclusion that science has the potential of presenting society with disturbing problems of many kinds, the future progress of man rests upon the achievements of science. Miller and Blaydes (1962) declare that youth must be thoroughly schooled in scientific principles so that they may properly understand and contribute toward progress. Modern America needs an education in the sciences that is up-to-date and relevant to contemporary life. Hurd (1969) reflects on modern complexities and interdependencies in writing that:

> Man's intellectual outlook changes, human values take on different meanings, and we become increasingly aware the world of today is no longer like that of yesterday. There is the wealth of new knowledge to consider as well as new roles of science in society (p. 1).

Science teaching cannot escape the general challenges to present-day educational endeavors. The teacher of biology has one of the most difficult roles in education as a result of the startling and profound developments that have occurred in science and technology. Biology is something more than a subject in the curriculum. It is a magnificent quest for explanations of the perplexities which beset man as he attempts to adjust to his environment. In his search for answers, new knowledge is inevitably discovered and new patterns of relationships for older knowledge are found. Perception of living things is reorganized and new emphases emerge.

The focal point in teaching biology, for most biologists, is found within the laboratory. In its broadest sense, the biology laboratory has no boundaries and encompasses every environment in which living organisms may be observed and investigated. Setting up a laboratory course with the least common denominators that allows student participation, introduces a variety of pertinent technological resources, involves true scientific investigative techniques, and links the individual with his environment, holds the greatest promise for modern biology teaching and learning.

The tendency by teachers of biology has been to add new content and exercises to existing biological courses without the removal of any traditional material. The student searches for relief and relevance. The instructor selects course content, methods, and equipment, on the basis of very limited experience. Assistance in the form of collective studies or considerations of curricular matters specific to the subject and teaching level are seldom available.

The problem of this dissertation is to make a comparative study of teaching trends and practices in the general biology laboratory as offered by the public community colleges of California.

IMPORTANCE OF THE STUDY

Lanham (1968) would take us back to the beginnings of man when he writes:

> The child of a savage race finds in his human environment purpose and care. He then grows into an awareness of a natural world where animals have structures and abilities that fit them for their ways of life, just as he and his tribe are so gifted as to be able to live as a part of nature. So strong is his appreciation of the purposiveness, the adaptiveness, of living things and their close relationship to their environment that he extends purpose to the non-living world, to the land and the sky... His view is a world view that is hundreds of thousands of years old, as old as the human species.
>
> This unity of man with nature was destroyed in the Western world, by the technological advances made some ten thousand years ago when revolutionary improvements in agriculture made possible the production of surplus wealth, the appearance of cities, and the development of exploiting classes... Civilized man was alienated from nature both by his mode of life - in the world of savage, every man was a biologist - and by the violent distortion and dismemberment of the primitive world view into the ideologies of economic class (pp. 1-2).

The National Academy of Sciences (1970) focuses sharply on the present by stating:

> For several centuries, research in the life sciences has constituted one of the great human adventures. While developing an independent style and value system, biologists have utilized the growing understanding of the physical universe to illuminate man's dim past, establish kinship with all living creatures, and enable comprehension of the nature of life itself. This knowledge and understanding underlie some of the great advances that characterize our civilization: prolific agricultural productivity, a longer span of enjoyable and productive human life, and the potential to ensure the quality of the environment (p. 1).

Today we are dominated by science and technology, according to Marshal and Burkman (1966). Hurd (1969) concludes that the average American, through no fault of his own, is scientifically and technologically illiterate, confuses science with technology, and values the products of science more than scientific inquiry. Dean (1970) predicts a massive reaction against science and the general science laboratory for the prevalence of a know-nothing identification of science with technology and a rejection of both because of the failure to make the best use of technology.

Since the search for knowledge is a major endeavor in our society, ways must be found to solve the science teaching problems created by the production of new knowledge. Unusual as has been the development of the educational system during the past few decades, it has not succeeded in inspiring complete confidence. This was a conclusion of Nelson (1931), and Buchanan (1971) reflects that:

> One of the seriocomic jokes made about members of the educational institution is that they have to run fast to stay 20 years behind. Apparently aware of the lag between where we are and where we need to be, educationists spend a disproportionate amount of time talking about change...
>
> Despite the concerted effort, both physical and intellectual, the classroom seems to be pretty much the same place that it was 40 years ago (p. 614).

We live in a scientific civilization and yet inadequate science-teaching of non-scientists in college has developed mistaken views, dislikes, and misunderstandings. These attitudes, Hurd (1960:19) suggests, "seem to come from a smorgasbord course of snippets of information and from an intensive training course for passing examinations." Neither type of course gives students an understanding of science dynamics or the work of scientists. Perhaps the greatest injustice that can be done to science is to regard it merely as a collection of facts and the practice of science as little more than the routine accumulation of minutiae.

For the past twenty-five years America has been moving more and more from a laboring to a learning society. Undergraduate and graduate students are asking as never before that their studies be meaningful and that they have a chance to deal with a real world and significant aspects of that world. If young people are to live fully and abundantly in a society that is strongly influenced by the forces of science and technology, they must have a real understanding of those two forces and be able to use them to full advantage. The Commission on Undergraduate Education in the Biological Sciences (1970) is convinced that:

> The problem exists not so much in learning itself, but in the fact that what the school imposes often fails to enlist the natural energies that sustain spontaneous learning - curiosity, a desire for competence, aspiration to emulate a model, and a deep-sensed commitment to the web of social reciprocity (p. 103).

As the 1970's demand a change in biological education, it becomes imperative that biologists use the general introductory biology course to provide the non-major student with a basis for developing a rational and intelligent awareness of contemporary scientific knowledge, attitudes, methods, and application. A portion of the uniqueness of college teaching lies in instructor choice of course elements, but articulation with society and other educational institutions requires a certain degree of commonality of content, methods, and equipment. This comparative study of the teaching trends and practices in the general biology laboratory as offered by the public community colleges of California provides a fundamental basis for comparing existing laboratory programs, for developing new courses, and for judging the extent of individual experimentation.

OBJECTIVES OF THE STUDY

The objectives of this comparative study of the teaching trends and practices in the general biology laboratory as offered by the public community colleges of California were to:

1. Search the literature for general biology teaching trends and developments in course objectives, approaches, emphases, exercises, laboratory techniques, and technological equipment.
2. Develop a questionnaire reflecting the major literature teaching trends and developments.
3. Conduct a questionnaire survey of the ninety-three public community colleges of California.
4. Determine from the questionnaire current common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, and the extent to which modern laboratory techniques and technological equipment were utilized in the non-major general biology laboratory.
5. Provide a fundamental basis for comparing existing laboratory programs, for developing new courses, and for judging the extent of individual experimentation.

DELIMITATION OF THE PROBLEM

This study was delimited to the general biology laboratory for non-science majors offered by the ninety-three tax-supported California public community colleges operating in the Spring of 1971. These are community colleges that have met state education code standards and are eligible for the apportionment of state funds.

Statistical analyses of the findings were limited primarily to frequency tabulations and arithmetical mean calculations to reveal and clarify the relationships between trends and practices and to simplify the problem of ultimate course comparison, development, and execution.

Form and Style in Thesis Writing by William G. Campbell (1969) was the basis for the thesis format except that the abbreviated style of the American Psychological Association (1967) was used for documenting references.

DEFINITIONS OF TERMS

For the purposes of this study, the following definitions were used:

Approved. A planned, systematic, and sequential program.

Audio-tutorial Laboratory. The laboratory using programmed materials without formal instruction and available to students at their convenience.

Biology. Those science courses which deal with the origin, development, structure, function, behavior and interrelationships of all living organisms.

Community College. The two-year institution of higher learning whose control is vested in a local board elected by the voting public.

Emphasis. A special stress or coherence throughout the course.

Exercise. Biological material or problem used to arrive at desired conclusions, to attain standard proficiencies, or to furnish the basis for discovery and discussion.

Frequency. The number of occurences.

General Biology. The introductory biological science course offered primarily to non-science majors.

General Education. Those common learning experiences required of all lower-division college students.

Laboratory. The place devoted to experimental study in science and to work experience by the student conducted under the direction of an instructor.

Mean. A statistical term of central tendency calculated by the familiar process of dividing the sum of all quantities by the number of quantities. It is a quantity of the same kind as the members of a set that in some sense is representative of all of them and is located within their range according to a set rule.

Median. A statistical term to designate the value of the middle term when all items are arranged in an order of magnitude.

Mode. The value that occurs most frequently in a statistical distribution.

Non Audio-tutorial Laboratory. The traditional laboratory with a regularly scheduled block of time under the direction of a laboratory instructor.

Objective. A stated purpose which is anticipated as desirable in an activity and which serves to select, direct, and integrate all aspects of the act.

Ranking. The arrangement of items according to value.

Science. A branch of study concerned with the observation and organization of facts to establish verifiable general laws primarily through induction and hypotheses.

Technique. A process, manipulation, or procedure performed as a laboratory activity.

Technological Equipment. The apparatus, more than the supportive cages, glassware, models, charts, and prepared slides, needed to measure some phase of a biological process in the conduct of a biological exercise.

Technology. Applied science.

STATEMENT OF ORGANIZATION

This dissertation is divided into five chapters. The first two chapters introduce, define, and develop the problem. The research part of the paper is contained in the third and fourth chapters where methods, procedures and findings are presented. The last chapter summarizes the preceding material and states the conclusions resulting from the study.

CHAPTER II

REVIEW OF THE LITERATURE

SCIENCE EDUCATION

The thirteen original colonies in America succeeded in founding, establishing, and sustaining a total of nine colleges to the time of the Revolutionary War. By virtue of their colonial origin, they eventually earned the label, the "Venerable Nine" (Wilmarth, 1970). Wilmarth also records that soon after 1790, courses were offered in chemistry, geology, mineralogy, anatomy, and physiology. Sometimes, all were covered under the title of natural history. Gradually, science classroom instruction was improved with more equipment, laboratories, observatories, botanic gardens, field trips, museums, and textbooks especially prepared for the American college student. But according to Wilmarth (1970):

> Most important of all, was the change in the faculty. Young men, nurtured on the elements of the new nationalism began to occupty the professorial chairs. Yet traditionalism was to prevail over the values of the new instruction and the vision of the new faculty. In 1828, President Day of Yale, defended the classical curriculum in the famed "Yale Report." Still later (1850), President Francis Wayland, in his "Report to the Corporation" tried to convince the administration to better serve the educational needs of the nation, by modifying the classical program, especially with respect to the sciences. The most urgent force underlying Wayland's appeal was the intense consequences of the Industrial Revolution...
>
> ...A solution began to develop as early as 1845, through the generous contributions of the new industrialists, who gave large bequests toward the founding of independent Scientific and Engineering Departments (p. 215-A).

The old private American college has been pictured as an aristocratic institution, rigid with an inherited "Oxford curriculum," and unresponsive to the needs of the great democratic majority. However, in the last part of the era, 1845-1860, the college tried to fill some of the middle ground between vocational training and science as an intellectual endeavor by forming special scientific schools and courses. Permanent scientific schools, elective courses, and graduate education had their intellectual origins within the transformed American college rather than as European imports grafted onto an alien system.

The United States Government recognized this rising educational force by commissioning a study of college biological teaching under John P. Campbell (1891). In a cover letter to the study, C. W. Harris, Commissioner of Education, suggested that one of the most striking modifications in the college curriculum made within the previous half century had been the enlargement of the sphere of instruction in the natural sciences. Whereas the older colleges had built their course of study on mathematics, Latin, and Greek, a tributary stream of human learning in the natural sciences was receiving more and more recognition in the course of study.

Since the beginning of the nineteenth century, considerable evolution has taken place in the science curriculum. Some of those changes observable in biology courses have been summarized in chronological order from Hodgson (1938: 52-53):

1. The period of the natural history method, botany, 1800-1860; and zoology, 1825-1870.
2. The period of comparative anatomy and analysis of Asa Gray, 1870-1890.
3. The period of the laboratory study of types, 1890-1900.
4. The period of plant and animal physiology, 1900-1910.
5. The period of correlation, unification, and application of biology, 1910-1920.

Despite the progress of science teaching to this point in time, there was a noticeable bias against science held by the public as asserted by Jordan (1921):

> The public is hostile to science because it lacks familiarity with scientific aims and methods. Our public schools below high school teach almost nothing of science in this age of science, and ninety percent of us do not enter high school. The public fears what it does not understand (p. 22).

The teaching in elementary college biological science courses was challenged sharply by Nelson (1928) when he declared:

> Biology teachers should give more attention to the educational aspect of their subject. Scarcely any effort has been made to advance the teaching of biology during the last two decades although remarkable strides have been made in the science of biology itself (p. 706).

A few years later Webb (1930) was critical of the junior colleges where curricular organization had not kept pace with institutional growth and science departments borrowed methods, content, and textbooks from either the university or the high school.

The strong social impact of science and technology was recognized by Donham (1934) when he remarked that:

> The impact of material progress has lessened, destroyed, or prevented the development of social customs and controls which alone enable mankind to live as a social animal... We have moved millions into the unknown without reestablishing them in social units...
>
> Conflicts between security and progress are always present. The point is that less than 200 years of applied science, just because they brought great progress, have brought great instability. This instability threatens to destroy civilization. It is not a time for despair, nor is it time to stop the quest for knowledge. Rather it is a time for sober thought and plain speaking: for wise direction of progress toward increased knowledge. We need the combined efforts of many groups, particularly in the universities, to bring about social and economic stability. Otherwise our unplanned activities will increase the stresses and strains on an already unstable nation and civilization (p. 233).

Miller and Blaydes (1938) were aware of the material encroachment but were also optimistic in stating the place of science in education:

> Science and scientific thinking have been the key to modern progress in all lines of human endeavor. Science still will be the key to our progress in future generations but out of it there will evolve a new philosophy which will itself be scientific. A new education is imperative and the new education must merely impart the new discoveries of science, it means that education itself must become scientific. We shall demand a new and scientific psychology to supplant the introspective, emotional, and prejudical methods of earlier efforts (p. 6).

The Forty-sixth Yearbook of the National Society for the Study of Education (1947) authoritatively sums up the place of science in education as follows:

> Science is today on a plane of high significance and importance. It is no longer, if indeed it ever was, a mysterious and occult hocus pocus to be known only to a select few. It touches, influences, and molds the lives of every living thing. Science teachers have a great opportunity and responsibility to make a large contribution to the welfare and advancement of humanity. The intellectual aspects of this responsibility are at least equal in importance with the material. Science is a great social force as well as a method of investigation. The understanding and acceptance of these facts and this point of view and their implementation in practice will more than anything else, make science teaching what it can and should be (p. 39).

The ferment and change which occurred in the biological sciences in the 1960's had a close relationship to the changes occurring in biology teaching. Obourn (1960) states the matter for many writers in the following paragraph:

> The rapid advance of science to a position of dominance in the culture of our times has placed new demands on school and college curriculums in science. There is reason to believe that in years to come the influence of science in the lives of people will call for further marked changes in the sequence and offerings of science in the schools of the nation. The current widespread re-examination of the offerings in science at both state and local levels is in response to the forces which will shape science courses for years ahead (p. 196).

The challenge that Robinson (1968) would present to science education in the 1970's is to bring a comprehension of the nature of science as a humanistic enterprise to the full range of young people.

The National Academy of Science (1970) summarizes the great scientific saga as follows:

> For several centuries, research in the life sciences has constituted one of the great human adventures. While developing an independent style and value system, biologists have utilized the growing understanding of the physical universe to illuminate man's dim past, establish his kinship with all living creatures, and enable comprehension of the nature of life itself. This knowledge and understanding underlie some of the great advances that characterize our civilization: prolific agricultural productivity, a longer span of enjoyable and productive human life, and the potential to ensure the quality of the environment (p. 1).

The practical limitations of the individual teacher of biology was recognized and expressed at the Stanford Colloquium of the Commission on Undergraduate Education in the Biological Sciences (1967):

> Whatever problems contemporary biological education faces, they are primarily the result of success and expansion of the field as an academic discipline. New methods, new information, and new problems, all have eroded away the central elements which characterize the earlier systems of thought, and our teaching of biology must mirror these changes...
>
> In the day-to-day routine of teaching, research, and committee meetings, we are slaves to the immediate goals and tasks confronting us. They seem endless and repetitive. All of us welcome the opportunity to back off a bit, ask a few questions of ourselves, and try to gain a larger perspective (p. 12).

New classes, new techniques, an increase in school population demand that we take a constant look into the future so that we may be prepared to share our best with our students. Statler (1969) projects us into the future with the prediction that:

> Biology teaching in 2000 is bound to be more extreme than our wildest dreams. Each learner will likely be his own teacher - but conversely the best way to teach yourself is to help others to learn. Everyone may be a biology teacher (p. 503)!

THE JUNIOR COLLEGES

"Rooted distantly in the educational institutions of England and Western Europe, American higher education has adapted itself to the peculiar social, economic, political and cultural conditions and needs of its own society," wrote Medsker (1960) as he reflected on the progress and prospect of the junior colleges. He further stated that:

> In this process it has created two unique institutions, found nowhere else in the world. They are the two-year junior college and the four-year liberal arts college. These two innovations, the one bringing higher education to the students' own doors, and the other offering a general education instead of the professional studies traditionally associated with the university, have been primarily responsible for the unprecedented expansion of college enrollment in this country (p. v).

The junior college made its initial appearance in American education as early as 1839, and has increased appreciably in numbers since its inception. Houston (1928:408) listed the obvious advantages: first, students can remain longer under home conditions; second, the junior college can easily furnish the semi-professional training which now is required as fundamental to a professional training; third, because of the general nature of the freshman and sophomore work in college, it might well constitute an expanded curriculum of the secondary school, rather than the lower tier of college; fourth, by placing into the secondary school all the work that is appropriate to that unit, the junior college relieves the university to that extent and by such an arrangement the full period of general education is put into the secondary unit; and fifth, the establishment of the junior college makes easy transition from one college unit to the other and from the senior high school to the freshman in college.

The Christian Science Monitor (1927) focused on regional differences in college development by caustically asserting that:

> One hundred years ago education left the settled East, traveled in the covered wagon of the pioneers across the prairies and the Continental Divide to the Pacific and grew up with the country. Today the situation is reversed. The junior-college movement, which has had its largest development in California, has only recently reached the Atlantic coast - New England last of all. The slowness of its progress recalls those processes of mental erosion that necessarily preceded the establishment of coeducation and woman suffrage among a people whose natures have taken on something from the granite hills and rock-bound coasts (p. 784).

The junior college idea was born from the struggle to achieve equality of opportunity and to broaden the scope of higher education. Brick (1967) found that it grew out of the desire to eliminate financial, geographical and social barriers to education and was nurtured by such educational leaders as Henry A. Tappan, William W. Folwell, Alexis F. Lange, "Father of the California junior-college idea," and David Starr Jordan. By 1920, the junior college was accepted as an institution capable of offering the first two years of an approved baccalaureate program.

The rapid development and spread of the junior colleges in California were clear evidence of the vital interest in and the great need for educational institutions. However, the perennial problems of education were evident from a survey of the public junior colleges in California conducted for the academic year 1921-22 in which Proctor (1923) found rapidly increasing enrollments, inadequate instructor academic training, minimum library and laboratory facilities, and meager financial support.

Nicholas Ricciardi (1930), Chief of the Division of City Secondary Schools, California State Department of Education, in an article in the first issue of The Junior College Journal, listed the following curricular functions which had been accepted in California and by national leaders in secondary education:

> A fully organized junior college aims to meet the needs of a community in which it is located, including preparation for institutions of higher learning, liberal arts education for those who are not going beyond graduation from the junior college, vocational training for particular occupations usually designated as semi-professional vocations, and short courses for adults with special interests (pp. 24-25).

Brick declared (1967) that social and economic conditions give insistent and imperative notice that an institution like the junior college is a necessity for our times. The National Science Foundation, NSF, through The Commission on Undergraduate Education in Biological Science, CUEBS, has attempted since 1966 to infuse life and vitality into college biological courses, to bridge the gap between research and the college science curriculum, and to search for an elusive "core curriculum." There are many approaches to biological science education but especially so in California where geography, and hence biology, is varied. It would seem incontrovertable that a course in general biology should be adapted to the region, but proliferation of courses may become a source of weakness in the junior colleges as well as a source of unnecessary expense.

Despite a history of more than sixty years of existence in California, junior colleges have emerged only recently as significant institutions of higher education. Blocker (1965) notes that:

> The two-year college may still be regarded among dowager circles as the "enfant terrible" of American education, but there can be little question that as an institution, it has arrived (p. xi).

Recognizing its responsibility, CUEBS established a Panel on Biology in the Two-Year College. Hertig (1969) makes the following statement in the preface of the Panel's Position Paper:

> Growth brings change, and explosive growth brings precipitous change: change in public demands for meeting needs of society whose complexity is no longer accommodated by twelve years of formal schooling, change in the response of an ivory-towered academia whose demeanor has been unresponsive too long to the vital exigencies of the day, and change in the attitude toward public support for a higher education traditionally reserved for the intellectually elite. In its response, the two-year college has expanded but its influence on the American scene still has not reached its full potential (p. 3).

BIOLOGY LABORATORY OBJECTIVES

All education is a phase of human development and all conscious education is an attempt to develop inner capacities. Conklin (1937:3) succinctly stated that "The essence of all real education is habit formation." At the turn of the century Gruenberg (1909:796) asserted that "Education is effective in proportion as it produces changes in the thoughts or feelings or conduct of people..."

Wood (1913) refused to defend or justify the position of biology in the curriculum because the necessity for such a procedure had passed. He believed that the value of biology in the curriculum should rest upon its constructive value, its utilitarian value, and its setting of high ideals. In its broader aspects, Wood declared, biology teaching would accomplish the following things:

> First, it will give practical and cultural but not technical training in the immature years.
>
> Second, it will instill ideas and ideals to aid the growing boy and girl to attain a wider outlook and larger life.
>
> Third, it will promote ideas of honesty, health, consideration, cooperation...
>
> Fourth, it will develop the mental constructive ability of the pupil who will rely upon his apperception primarily and not upon his memory as such.
>
> Fifth, it will teach only those things worthwhile.
>
> Sixth, it will seek for breadth rather than depth in the treatment of life principles.
>
> Seventh, it will treat life as it now is, together with its possibilities of improvement in all living forms.
>
> Eighth, it will attempt to make the student, first, a good wholesome animal, and, second, a good useful citizen, because he sees himself a real factor as a necessary part of honest and sincere cooperation in the betterment of society - and of the race (p. 247).

Later Wood (1914:6-13) declared that "The most important avowed function of biology in the secondary school is to make every pupil studying it, a good animal... A second function of biology is to prepare the pupil for efficient citizenship... The personal equation is the determining factor - the personality and enthusiasm of the teacher."

The first extensive study dealing with science education in the secondary schools was made by the Science Committee of the Commission on Reorganization of Secondary Education, U.S. Bureau of Education (Caldwell, 1920). The Committee's report attempted to show how science instruction could contribute to the attainment of the seven cardinal principles of education as recommended by the whole Commission (U.S. Bureau of Education, 1918):

1. Health
2. Command of fundamental processes
3. Worthy home membership
4. Vocation
5. Civic education
6. Worthy use of leisure time
7. Ethical character (p. 3)

The U.S. Bureau of Education Commission (1918) reflected the patriotic influence after World War I with the statement that:

> The ideal of any course in biology...both within and without the school, should develop in each individual the knowledge, interests, ideals, habits, and powers whereby he will find himself and society towards ever nobler ends (p. 9).

Ames (1927) also mildly presented the popular nationalistic sentiments:

> If the education in a democracy is to serve the ends for which it has been provided, the spirit of scientific education must be carried out. Scientific education should fit the individual to discharge the duties which he owes to himself, and also equip him to make some contribution toward the betterment of society. The task of the life sciences is to help the student realize his place in the scientific program of the day (p. 1).

The religious influence was strong at this same time as interpreted from a biased summary by Martin (1926) of the issues involved in criticisms of life science content in the secondary schools:

> 1. This study has shown that for ages past there has been on the part of some people a controversy between science and religion. As knowledge has increased, the controversies vanished.
>
> 2. That the controversy over evolution would also disappear as knowledge appeared and that the controversy over evolution would not be between God and not God but between God working with means instead of without means.
>
> 3. That the youth of the land should be taught that this is God's world and all scientific truths are God's truth, that the Bible is God's book, therefore rightly interpreted must agree.
>
> 4. That the lack of scientific knowledge and an unsound philosophy has led to perverted ideas, that if allowed to grow, will cause the conditions of the country to revert to those when plague and pestilence survived (p. 46).

A special committee of the American Association for the Advancement of Science (1928) submitted a report on the place of science in education. According to Blanc (1952), the chief addition which the report made to the list of seven cardinal principles was the recommendation that the scientific method in science be included as a major objective of science teaching.

Of greater significance was the Thirty-First Yearbook of the National Society for the Study of Education published in 1932. This yearbook offered a comprehensive program of science teaching and Powers (1932:42) defined for the committee the aim of education as "Life Enrichment through Participation in a Democratic Social Order."

The meaning of a liberal education had been a subject of frequent discussion. From the works of John Dewey, James H. Robinson, E.D. Martin and many others, Nelson (1931) perceived that a liberal education endeavors:

> 1. To provide a knowledge of the great and fundamental truths of nature.
> 2. To apply learning towards conservative purposes.
> 3. To develop scientific attitudes of thought.
> 4. To develop scientific methods of thought.

5. To develop creativeness.

6. To consider the needs of society as well as those of the individual.

7. To develop the mind in a harmonious fashion instead of giving attention exclusively to just one or two of the above objectives (pp. 227-8).

Nelson (1931) also surveyed one hundred college catalogs and twenty-one widely used college textbooks and reported the following objectives in the most frequently mentioned order:

1. To give information about fundamental facts, principles or essentials of the sciences of life, including the study of structure, physiology, ecology, classification.

2. To survey the plant and animal kingdoms or to study types in detail.

3. To show the relation of plants or animals to our welfare, or to show their economic importance.

4. To acquaint the student with the various theories of the biological sciences.

5. To provide a cultural course, to emphasize the philosophical aspects of the subject.

6. To train the student in the use of scientific methods as applied to biological science.

7. To prepare the student for other related courses (p. 228).

A further comparison by Nelson (1931) of the objectives of instruction stressed in biological courses with the desirable objectives of instruction, closely related to a liberal education, revealed that, in actual practice, attention was almost exclusively directed towards one of the objectives: namely, the acquisition of knowledge of the great and fundamental truths of nature.

The survey courses, originated in the early twenties, increased rapidly in number and contributed toward general rather than specialized education. They represented attempts at broad syntheses within the areas of science represented, instead of being given as only systematic factual surveys. The courses were planned to develop insight into the nature of the scientific enterprise involving the union of logical analysis, critical observation and experiment, and resourceful imagination characteristic of the scientific worker. The endeavor was to go beyond the appreciative stage to provide a practical understanding of the scientific method with an impelling urge to apply it to the problems encountered by the student in his individual and social life.

The most important feature of the organization of the survey course in biological science was to be its dynamic aspect. Isenbarger (1936) briefly stated the aims of one such course:

> 1. To give students a command of such biological information as is most closely related to their welfare as intelligent human beings.
>
> 2. To provide an opportunity to explore the various fields of biological science as vocational and intellectual guidance.
>
> 3. To help students acquire the cause and effect relationship concept.
>
> 4. To give students a background of science which will enable them to appreciate and enjoy literature dealing with biological science.
>
> 5. To aid students in gaining an understanding of fundamental principles common to all living things.
>
> 6. To aid students in acquiring such knowledge of their own bodies and of their relation to the biological and physical environment as may be applied in the conservation of health and the development of physical and social efficiency (pp. 74-75).

Isenbarger (1936) also listed the claims made for laboratory work:

> 1. It furnishes a natural basis for learning through self-activity.
>
> 2. It provides for the development of laboratory techniques and manipulations in biology.
>
> 3. It provides in a concrete way for training in scientific method.

4. It provides a way of clarifying facts not easily understood without concrete illustration and verification.

5. It serves to develop in the student habits of inquiry, initiative, and careful work (p. 75).

The objectives of good teaching in biological subjects are essentially the same objectives of the teaching of all subject matter but with special implications as regards details and applications. These objectives have been stated by various writers in many different terms. Some prefer to divide them into numerous statements, others to condense. Miller and Blaydes (1938: 14-15) grouped objectives into four categories. They believed these general objectives furnished the background of educational philosophy as applied to biology teaching. First among these was the acquisition of information; second, the development of methods of thinking; third, the induction and application of principles; and fourth, the formation of attitudes. They were adamant that, despite all criticism, the acquisition of information must remain a primary aim of all education but allowing this objective to be the dominant, almost the sole objective, was untenable.

From a survey by Lang (1938) sixty-four biology objectives, valuable for social understanding, were ranked according to mean frequency of mention by those surveyed. The top sixteen are given below.

To know about heredity in man.

To know the essential facts about emotions.

To know the meanings of habits.

To know about the inheritance of special effects and abilities.

To know about race differences.

To appreciate the importance of health.

To know how to keep children healthful.

To know the characteristics of the stages in human life from infancy to death.

To understand the reproduction in man.
To know the causes and preventions of diseases.
To know about work, fatigue, and rest.
To understand adaptations.
To understand struggle, selection, and survival.
To know the industrial problems of health.
To know the value of medical treatment.
To know the nature of heredity (pp. 9-10).

Lang indicated an unwillingness to discard any objective, for his stance was that those being stressed in teaching should be stressed more confidently and those not stressed were worthy of serious consideration.

Ebel (1938) demonstrated the extreme in the development of objectives with a statement on the scientific attitude through a listing of "readiness elements" in which he uses the word "readiness" one hundred and fifty-seven times to introduce headings in his meticulous outline.

Ebel (1938:81) had this to say about his monumental work: "The extensiveness of the statement contributes greatly to its value as a guide for the teaching of the scientific attitude. It would be difficult indeed to develop such abstract qualities as openmindedness and accuracy if no specific statements explaining their meaning and application were available."

In 1938 a comprehensive statement of the very broad purposes of science in general education in the secondary school was published by the Progressive Education Association (1938). The report attempted to orient science teaching toward areas of living such as personal living, personal-social relationships, social-civic relationships, economic relationships and the disposition to use reflective thinking in the solution of problems.

The American Council of Science Teachers (1942) prepared a report and added the areas of safety, consumer education, and conservation to the objectives of the Progressive Education Association.

A startling and extremely negative point of view concerning the teaching of the general biology course was expressed in Report Number 15, Adjustment of the College Curriculum to Wartime Conditions and Needs, issued by a committee of the U.S. Office of Education in 1943 (Alexander, 1944). The committee concluded that it should not recommend wartime modifications in the beginning college courses but then stated very positively that, if there were objective evidence or sound subjective evidence that general biology courses had lasting values for the students, it had not been made available to the committee. Alexander (1944) drew attention to that conclusion and reacted strongly to the timing and to the social influence. He stated that more, rather than fewer, introductory courses were needed for the development of a concept by students of a unified science of life.

The purposes of education were restated after World War II with strong democratic and international overtones. From a Report of the President's Commission on Higher Education (1947) the following pronouncements were made:

> Education is an institution of every civilized society, but the purposes of education are not the same in all societies. An educational system finds its guiding prinicples and ultimate goals in the aims and philosophy of the social order in which it functions...
>
> It is a commonplace of the democratic faith that education is indispensable to the maintenance and growth of freedom of thought, faith enterprise, and association...
>
> It is essential today that education come decisively to grips with the world-wide crisis of mankind...

> In a real sense the future of our civilization depends on the direction education takes, not just in the distant future, but in the days immediately ahead...
>
> This crisis is admittedly world-wide. All nations need re-education to meet it...
>
> We must make sure that the education of every student includes the kind of learning and experience that is essential to fit free men to live in a free society...
>
> Present college programs are not contributing adequately to the quality of students' adult lives either as workers or as citizens. This is true in large part because the unity of liberal education has been splintered by overspecialization...
>
> For half a century and more the curriculum of the liberal arts college has been expanding and disintegrating to an astounding degree...
>
> Specialization is a hallmark of our society, and its advantages to mankind have been remarkable. But in the educational program it has become a source of both strength and of weakness...
>
> The crucial task of higher education today, therefore, is to provide a unified general education for American youth. Colleges must find the right relationship between specialized training on the one hand, aiming at a thousand different careers, and the transmission of a common cultural heritage toward a common citizenship on the other...
>
> General education seeks to extend to all men the benefits of an education that liberates...
>
> This purpose calls for a unity in the program of studies that a uniform system of courses cannot supply. The unity must come, instead, from a consistency of aim that will infuse and harmonize all teaching and all campus activities...
>
> Whatever form the community college takes, its purpose is educational service to the entire community, and this purpose requires of it a variety of functions and programs (pp. 5-67).

The Forty-sixth Yearbook of the National Society for the Study of Education (1947) suggested that general education must improve by including convincing and effective personal and community controls of knowledge. Science instruction was reminded not only of a great potential contribution but also a responsibility to develop the qualities of mind and the attitudes that will be of greatest usefulness in meeting the pressing social and economic problems that face the world.

An important part of the Yearbook was devoted to these criteria for the selection of objectives; these should be practicable, psychologically sound, possible of attainment, universal, and indicating the relationship of classroom activity to desired changes in human behavior.

In accordance with the criteria listed, the National Society for the Study of Education (1947) proposed the following types of objectives for science teaching:

(A) functional information or facts;
(B) functional concepts;
(C) functional understanding of principles;
(D) instrumental skills
(E) problem-solving skills;
(F) attitudes;
(G) appreciations;
(H) interests (p. 25).

The Yearbook Committee sounded a note of warning in that the development of science will continue so long as there exist men with courage, curiosity and ability to observe and to experiment to learn the new truth and there can be no stopping of scientific research in order that society may catch up. Man's awareness of changing concepts of individual and universal destinies were clearly indicated by the National Society for the Study of Education (1947:296) in the words: "Science may contribute knowledge and understanding...but educated human character must assume the decisive role in civilization's future."

Powers (1944) proposed the following outcomes of science education to meet the needs of youth in the post war world.

1. Good health and physical fitness.
2. Work experience.

3. Comprehension of the natural resources of the nation.

4. Comprehension of the impact of science and technology on our society.

5. Ability to select and use materials made available by science in solving social problems (pp. 136-41).

The results of a questionnaire sent by Hunter and Ahrens (1947) to 1200 science teachers in junior and senior high schools in California reported the trend that science teachers were shifting their emphasis on objectives away from the strictly functional objectives in favor of those dealing with scientific method and factual knowledge.

In summarizing material contributed by twenty-one leading colleges and universities, McGrath (1948) listed four possible objectives for non-science major students who took general education college science courses. These are condensed as follows:

1. To understand and learn to use the method of science...

2. To become acquainted with some of the more important facts of science...

3. To become aware of the social implications of science...

4. To appreciate the historical development of science (p. 183).

Not all objectives can be realized or even expressed in any particular course. But, by 1950, the social aspects of society and the impact of science on society were constituting problem areas from which material and inspiration were being drawn and leading toward an understanding of science by the general student.

From an analysis and synthesis of over 1800 articles, research studies, committee reports, and yearbooks covering a fifty-year period Paul D. Hurd (1953:245) reported that: "Human adjustment is the major goal of science teaching." He also found that science was regarded more as a way of life or a philosophy of living than as exclusively subject material and method.

B. Lamar Johnson (1952), from a report of the California Study of General Education in the Junior College, found that the general education program aimed to help each student increase his competence in:

> Using methods of critical thinking for the solution of problems and for discrimination among values.
>
> Understanding his interaction with his biological and physical environment so that he may better adjust to improve that environment.
>
> Using the basic mathematic...skills necessary to everyday life.
>
> Understanding his cultural heritage so that he may gain a perspective of his time and place in the world (p. 200).

Even while Weiss (1953) was writing that this is the century of the biological sciences, Harvey (1953) reported the following feeling from the NSF Summer Conference on College Biology held at the University of Oklahoma:

> 1. Biology, in general, is failing to attract the best students and, furthermore, is held in a position of low esteem by laymen. This may be due in part to introductory courses that present biology as a body of doctrine and not as a study of dynamic phenomena that have inherent within them the most fascinating and important problems of the universe.
>
> 2. Recognizing that biology courses are failing to meet the objectives set for them, there is need for serious re-evaluation of materials and organization of the courses. The facts that are presented need to be selected carefully so that they will best illustrate causal relationships and thus present the dynamic or cause-and-effect viewpoint that is desired.
>
> 3. Although biology is compartmentalized into various fields, e.g., genetics, comparative anatomy, bacteriology, for convenience, these are artificial barriers. A real effort must be made to present living organisms as products of their evolution, heredity, physiology, anatomy, ecology, and behavior, if biology is not to be sadly and severely misrepresented.
>
> 4. There must be no separation of structure and function in the study of living organisms, but structure and function must be presented as inescapably dependent upon each other.
>
> 5. The use of a dynamic descriptive approach to biology will entail constant understanding and employment of the scientific method. From this will accrue an appreciation of the theoretical aspects of biology and a way of thinking that is an absolute

> requirement in our society today if our lives and our civilization are to be ruled by reason rather than by superstition, prejudice, or self-interest.
>
> Although these five ideas have been stated many times before, their constant reiteration indicates that they have not yet been incorporated successfully into the majority of introductory college biology courses and that this incorporation is necessary if such courses are to fulfill their purpose (p. 290).

The major recommendations of that conference concerning the objectives of the biology program were reported by Breukelman and Armacost (1955) as follows:

> 1. An understanding of the basic principles of biology.
> 2. An understanding of themselves (man) and of human life.
> 3. An understanding of how the organism and physical environment in a given situation form a community with many complex interrelationships.
> 4. An understanding of how biology can be used in later life.
> 5. An understanding of scientific methods and attitudes through experiences in the biology courses.
> 6. A positive approach to physical and mental health.
> 7. Avocational interests and appreciations related to living things (p. 36).

The advent of the general ferment in biological education, the explosion of knowledge, the rise of molecular biology, and advances in the psychology of learning caused the American Institute of Biological Science, AIBS, to form a Committee on Education in 1955 to study education in the biological sciences. The Biological Sciences Curriculum Study, BSCS, was organized by the Committee on Education of the AIBS in 1959 and ceases to function in 1971.

General policy for the BSCS was provided by a twenty-seven member Steering Committee, which included research biologists, high school biology teachers, science supervisors, education specialists, medical and agricultural educators and university administrators. The specific objectives that were tentatively accepted to serve as a guide in preparing the preliminary courses of study were summarized by Voss and Brown (1968) as:

> 1. An understanding of man's own place in the scheme of nature; namely that he is a living organism and has much in common with all living things.
>
> 2. An understanding of his own body; its structure and function.
>
> 3. An understanding of the diversity of life and of the interrelations of all creatures.
>
> 4. An understanding of what man presently knows and believes regarding the basic biological problems of evolution, development, and inheritance.
>
> 5. An understanding of the biological basis of many of the problems and procedures in medicine, public health, agriculture and conservation.
>
> 6. An appreciation of the beauty, drama, and tragedy of the living world.
>
> 7. An understanding of the historical development and examples to show that these are dependent on the contemporary techniques, technology and the nature of society.
>
> 8. An understanding of the nature of scientific inquiry; that science is an open-ended intellectual activity and what is presently "known" or believed is subject to "change without notice;" that the scientist in his work strives to be honest, exact, and part of the community devoted to the pursuit of truth; that his methods are increasingly exact and the procedures themselves are increasingly self correcting (p. 51).

The BSCS biology was influenced by the theoretical considerations of Jerome Bruner. It is Bruner's thesis that children should be taught in such a way as to have a clear understanding of the underlying principles which give structure to the subject. This is characterized as a spiral curriculum.

There was a renewal of interest in the concept of educational objectives starting around 1960. There was a re-defining of the rules and principles governing the structures of objective statements. The resistance of the protectors of educational traditions was being shaken by the humanists, the behaviorists, and the educational technologists to allow for practical experimentation within the major curriculum development movement.

In 1966 the National Science Teachers Association, NSTA, listed objectives for science in general education for non-science majors as:

> 1. To help students see and comprehend the scientific phenomena about them.
>
> 2. To show how scientists arrive at their views and to instill in students the means of applying these methods to daily problem solving, questioning, and inquiry.
>
> 3. To present the effect of science upon our society.
>
> 4. To recognize the basic unity of science by introducing inter-disciplinary approaches whenever possible.
>
> 5. To show and to develop an appreciation for the esthetic values inherent in the field of science (Eiss, 1966:35).

A position paper of a Commission on Undergraduate Education in the Biological Sciences, CUEBS, Panel on the Laboratory in Biology stated that the laboratory has had several long standing traditional functions:

> The commonest use of the laboratory is to illustrate objects and experiments that have been introduced elsewhere...
>
> A second function of the laboratory has been to provide training in laboratory techniques...
>
> A third function...is that of intellectually stimulating the student and developing appreciation for biology and for living things...
>
> A fourth function...is that the laboratory serves primarily to stimulate discussion (Holt, et al, 1965:1104).

There is general agreement among science educators, according to Lee and Steiner (1970), that goals are important in any institutional program of science. An important part of the methodology of the 1970's is the development and use of behavioral objectives which are defined as educational goals stated in terms of observable learner outcomes (Hernandee, 1971).

Thomas (1965) writes that recent research suggests that when objectives are written in a behavioral form, the following results are attained: (1) learning is facilitated; (2) retention rate is higher; and (3) the student becomes highly motivated.

Educators write many objectives; the literature shows them in over-abundance. The writing of behavioral objectives may be but another wave on the vast sea of education, the latest but not the last.

Pribadi (1960), after a long adventurous journey of ideas, formulates the general aim of education as the facilitation of creating the personal maximum condition for self-realization.

Perhaps the most important single point to be made is that each student (Medsker, 1960) brings a set of emotional and mental characteristics which in a sense are the raw materials to process.

In a historical search Del Giorno (1968) found that the impact of changing scientific knowledge on science education has increased as the years have progressed. Science entered the field of education when the public became cognizant of its importance to the industrial and economic growth of the country. Science was placed in the curriculum but educators struggled continuously with problems germane to the aims and objectives of science teaching, the type of science courses that should be given to everyone, and the type of science courses that should be offered to the science major. On the whole, Del Giorno (1968) found, that the impact of new developments in science education lag behind some ten to thirty years.

Something radical must be done to cope with the ever-widening disparity between what is known and what is taught in science. H. Bentley Glass (1962), President of the National Association of Biology Teachers, stated that our educational system is poorly organized to transmit to the next generation even the core of a body of knowledge which is increasing at an exponential rate.

The crisis in higher education is chronic and Hurd (1961) would remind us that this has ever been so by quoting Aristotle's observation in 300 B.C. after visiting the schools of Athens:

> There are doubts concerning the business of education since all people do not agree on those things which they would have a child taught, both with respect to improvement in virtue and a happy life: nor is it clear or whether the object of it should be to improve the reason or rectify the morals. From the present mode of education we cannot determine with certainty to which men incline, whether to instruct a child in which will be useful to him in life, or what tends to virtue, or what is excellent; for all these things have their separate defenders (p. 4).

BIOLOGY LABORATORY APPROACHES

Nature was the harsh teacher of all creatures who inhabited natural surroundings. Primitive man acquired his biological learning through a series of vivid experiences and gained his skills through the effective but perilous process of trial and error. He observed biological phenomena and products in natural surroundings and throughout history paid dearly in disease and death for his lack of biological knowledge.

At the end of the nineteenth century Campbell (1891) wrote that most of the students in the college had received no training or instruction in the sciences before entering college and "by so many years of exclusive attention to other subjects, their powers of observation and of imagination of physical phenomena are well-nigh atrophied; and the loving interest in nature, innate in every normal child, instead of being systematically developed, is well-nigh extenguished" (pp. 120-121).

Biology began in 1500 A.D., according to Wood (1913) and was not a study of life, but rather of structure. The biologists did not see the principle behind the form.

In the old city of Nuruberg, Germany, there was a famous carving which represented a schoolmaster holding a funnel to an opening in the top of the head of a luckless school boy into whom the schoolmaster was supposedly pouring knowledge. This traditional classroom lecture method of presentation gradually evolved into lecture-demonstrations and finally into the separate student-participation laboratory periods. Most biologists today regard the laboratory as essential, the "heart of biology."

In the nineteenth century, Agassiz, Gray and Bailey were outstanding proponents and practioneers of the investigative laboratory. This type of practical application of biology (Wood, 1914:9) seemed of vital interest to a student because "it would (1) allow him to organize his own ideas; (2) provoke him to serious thought; (3) develop his limited individuality; (4) enhance his power of expression; (5) give him growing confidence in himself; and (6) end in real accomplishment."

Years later, the standard trend in the development of general education college science laboratory courses was toward the illustrative type laboratory with routine work, laboratory manuals filled with blanks requiring "right answers," and rote learning.

Roberts (1914:467) complained that "...the laboratory time is all too short, and the sensation throughout on the part of the instructor, is one of haste...and to cram...into the limited time...enough observational work to give the student...a comprehensive survey of the subject matter of science. The result...is...a swiftly appearing and disappearing series of natural (or unnatural) objects."

Robinson (1968) recognized the same problem while re-thinking the science curriculum:

> For while new developments have been accumulating, the tendency in science teaching has been to add new factual material to the traditional courses...courses have become overcroweded with masses of...often unrelated data, and teaching procedures have become hurried and frequently unrewarding (p. 12).

The audio-tutorial, programmed, or independent study laboratory was a natural development out of school space limitations, increased enrollments, shortages of personnel, voluminous subject material, and a wide variety of available audio-visual aids. This laboratory, an extension of the demonstration-museum arrangement, was made available to the students at their convenience without formal instruction.

The Biological Science Curriculum Study, BSCS, program for the improvement of biology instruction in secondary schools was moving forward with apparent success (Hutto, 1965) and then the Committee on Undergraduate Education in the Biological Sciences, CUEBS, was organized to help with the real problem of the college biology teacher. The laboratory was a point of weakness in many freshman biology courses. The approaches varied from almost complete devotion of time to demonstrations by the instructor to the endless traditional activities of observation, dissection, and drawing.

The most important element lacking was genuine experimentation, an opportunity for the student to participate in the approaches to the scientific method in a real scientific investigation. Voss and Brown (1968) recorded that the value of laboratory work had been investigated intensely yet the effectiveness of the biology laboratory in learning was not clear. Dearden reported (1960:241) that research "to date in the literature indicates that no one type of laboratory is clearly superior in developing all of the outcomes desired from the science laboratory."

The position taken by Soule (1970) was that science for non-majors has progressed from what it would be nice to know, to what students ought to know, to what society absolutely must know if man is to survive. A problem-centered approach illuminates the problems of individuals and those of society and nature which are of biological origins or might have biological solutions.

The term "investigative laboratory" has been used by the Committee on Undergraduate Education in the Biological Sciences, CUEBS, to designate "courses in which students are carefully prepared to select and handle individual research problems and then freed from rigid schedules to pursue investigations on their own" (Thornton, 1971:1). The initiation of the investigative laboratory is considered by CUEBS as an essential part of a radical restructuring of teaching. The initial phase of the "new" investigative laboratory still has a traditional approach through the use of film loops, guided readings, audio-tutorial techniques as developed and produced by Postlethwaite (1969), and programmed instruction as discussed at length in the Sixty-sixth Yearbook of the National Society for the Study of Education (1967).

Anyone who professes to teach the sciences cannot become "involved with students, their views and thoughts toward science, and their attitudes toward education without being stimulated to look deeper into himself and the course he is teaching" (Carter, 1971:9). The "ultimate" laboratory approach may change but must always remain one in which the student is stimulated by curiosity, guided by knowledge, and rewarded by discovery.

BIOLOGY LABORATORY EMPHASES

The year 1846 was an eventful one for the teaching of biology in this country, for in that year Louis Agassiz left the home of his youth in Switzerland and came to America. From an address by Dr. G. B. Emerson, delivered before the Boston Society of Natural History shortly after Agassiz's death, the following passages are quoted:

> One of the secrets of his success as a teacher was that he brought in nature to teach for him... He appealed at once to the eye and to the ear, thus naturally forming the habit of attention, which is so difficult to form by the study of books (Campbell, 1891:127-8).

In 1876 Professor H. Newell Martin entered upon the duties of the chair of biology in the John Hopkins University, and one of the first innovations which he introduced was the establishment of a "general biology" course (Campbell, 1891:122). General education science courses continued to grow in popularity. They were designed for the non-science student rather than the science specialist and were most often called survey courses. They generally stressed breadth instead of depth of content and drew subject matter from two or more established science fields.

From the period of the natural history method; botany, 1800-1860; and zoology, 1825-1870; and the period of botanical comparative anatomy and analysis, 1870-1890, developed a synthesis of botany and zoology into the general biology laboratory study of types, 1890-1900 (Harvey, 1940).

Laboratory work was generally regarded as the highest value and the character of the courses differed only by the orders of study, higher forms before lower forms and animal or vegetable forms of life first, strictly a tandem presentation.

During the period of plant and animal physiology, 1900-1910, Professor William S. Johnson (1904), of the University of Chicago wrote that:

> Within the lifetime of biology teachers now living, the methods of teaching the subject have changed completely... The textbook was discarded, to be succeeded by the laboratory and the scientific treatise...
>
> Progress is the study of plants and animals in their wider relationships has been retarded by ancient customs...
>
> Questions relating to material and method in biology are now treated with intelligence and skill, but the question of motive has scarcely been touched...
>
> In the pre-Darwinian period, plants and animals were studied largely from the side of their usefulness to man...
>
> ...With the advent of Darwinism, men of science broke loose from creed bondage and began to look for the facts regardless of their significance...
>
> ...Science...must go deeper than form... The lesson of concession and adaptation is taught both by the roadside weed and the glorified soul...the new morality...supported by modern science ...will furnish the soil from which the ethical code of the twentieth century will grow (p. 60).

This period was followed by one of correlation, unification and application of biology, 1910-1920 (Harvey, 1940). The changes were not remarkable, however, and there were usually three distinct course sections - animals, plants, and human anatomy and physiology. The conventional or taxonomic sequence for a course usually began with the lower groups of animals and progressed successively to the higher types, the Mammalia occupying the center of the stage. Attention was given to human relations with the phyla species and then human anatomy and physiology, particularly of the nervous and circulatory systems and of the endocrine glands. Addition of plant biology made the course of general biology unwieldy and added to the complexity of an already overburdened curriculum.

Hurd (1953) surveyed trends in science teaching and found that within the past half-century of science teaching many changes in philosophy and curriculum had occurred. General biology had become more general with the integration of physics and chemistry to meet the major goal of science teaching, human adjustment.

An analysis by Davis (1962) of the existing programs in Texas Junior Colleges showed a typical botany-zoology combination, teaching methods largely descriptive and laboratories involving mainly dissections and drawings of preserved plant and animal specimens.

Science not only grows but it develops. As new data is uncovered and new knowledge is formed, reorganization connects old with new. One of the most conspicuous ways in which biology reorganizes its knowledge is by changing the emphases that are put on different levels of organization. Ancient biology would largely begin with gross anatomy. With the development of tools, techniques, and experience, biology entered an era of anatomizing. The emphasis shifted to the organization of tissues and organs. With the knowledge from this and further development of skills and techniques, physiology made an impressive appearance.

Around 1960 the development of biology has been in a downward direction from organs and tissues to the cellular level and finally the molecular level. With the advancement of biology on many fronts came the inevitable reorganized knowledge of organs and tissues, understanding the relations of one level of organization to another and a return to the ancient center of interest - the whole organism.

The Biological Sciences Curriculum Study, BSCS, developed three new biology curricula. About 70% of the content of the three high school biology curricula is identical. The difference between the versions is essentially in the emphasis. For purposes of clarity the three versions are known as yellow, green, and blue biology, corresponding to the textbook cover color. The "green version" introduces biology from the ecological point of view. The "blue version" approaches biology as a molecular study. The "yellow version" is a cellular or evolutionary treatment.

The British Nuffield Teaching Project of the early 1960's aimed at producing a set of documents which would achieve much the same ends as the BSCS publications. Like the American scheme, the course is to be built around a number of fundamental concepts which will be woven throughout its whole fabric (Tracy, 1965).

There are over a million different kinds of plants and animals but whatever we decide about life in the general biology laboratory must be based on the consdieration and examination of only a tiny segment of life. For this reason conceptual generalizations are used by biologists to unify statements about life. The five major concepts of biology are listed by Carlson (1967) as cell doctrine, heredity, development, genetic control, molecular biology, and evolution.

Hankins (1969) made a recent determination of significant course content for a freshman level general education course in biology from twenty leading textbooks and one hundred and fifty competent research biologists, college and university teaching biologists, science educators, and science historians. He drew the following pertinent major conclusions from the data: (1) a general education course in biology should lead the student primarily to appreciate the place and significance of biology in human culture; (2) no attempt should be made to acquaint the non-science major with the fund of biological knowledge; (3) the major content emphsis of the course should focus primarily on environmental biology; (4) the second largest segment of the course should be equally distributed between (a) evolution and (b) energetics and metabolism; and (5) a laboratory should accompany the course.

Classical biology is built upon observation and experiments with living organisms and insists life is inherently associated with the complexity of at least one cell. Molecular biology assumes that life could reside in a cellular constituent and permits the notion of a living molecule. Barry Commoner (1964) asserts that the classical studies of living things and the molecular studies have steadfastly converged for over 200 years toward their present collision. Biology is, therefore, in a crisis and the outcome will determine which of the two streams of biological science will survive and form the mainstream of our future understanding of life.

BIOLOGY LABORATORY EXERCISES

Most courses in general biology taught before 1900 were not organized around a biological theme or presented as an integration of the biological sciences. The popular writings of the day (Hurd, 1961:28) contained numerous disparaging remarks on the "fish-fern" and the "bale of hay and pail of frogs" course syntheses and the favorite by certain botanists that "biology was botany taught by a zoologist."

The typical laboratory contained botanical exercises on the classification of algae, fungi, mosses, ferns, gymnosperms, and angiosperms and on plant structure, physiology, and reproduction. The biology course taught by a botanist might well contain little else. Biology taught by a zoologist would be composed predominately of exercises illustrating Protozoa, Porifera, Coelenterata, Echinodermata, Vermes, Mollusca, Arthopoda, Insecta, Vertebrata and comparing the groups. All instructors required "quality work" through laboratory notebooks.

During the decade 1910-1920 (Hurd:1961) textbooks and laboratory manuals appeared on the academic book market with the title of "biology" in contrast to the texts on elementary botany, zoology, and physiology. The actual titles reflected the growing emphasis upon the applied aspects of biology. The laboratory exercises were heavy with classification and morphology but some began to emphasize application to human activities, observation of life phenomena accurately, enrichment of life through aesthetic appeal of plants and animals, and demonstration of the study of biological science as a means of scientific progress.

The period 1920-1930 was one of cultural refinement during which biology curriculum makers attempted to implement education theory developed earlier. In 1923 the Committee on the Reorganization of Science listed 98 biological topics developed to encompass the interests of 2,500 high school students. These topics were organized into the following nine teaching units:

1. Living things in relation to their environment.
2. Interdependence of living things.
3. Life processes in plants and animals.
4. Green plants as living organisms.
5. Animals as living organisms.
6. Responses of plants and animals.
7. Reproduction of plants and animals.
8. Evolution.
9. Man's control of his environment (Hurd, 1961:44).

The depression years, 1930-1940, in America constituted a period of questioning of educational practices that characterize a time of economic and social crisis. The major criterion for the selection of course content was "to meet the needs of students." Health information and consumership (Hurd, 1961) loomed large in the biology curriculum. However, the U.S. Office of Education (Beauchampt, 1932) published a survey of science teaching practices and found that in forty of forty-five courses of biology examined, the content was still divided into three major divisions: botany, zoology, and physiology. The Committee making the report was primarily interested in finding laboratory procedures that would integrate concepts, exemplify the scientific method and encourage students to devise personal experiments.

In 1941, the National Commission on Cooperative Curriculum Planning formulated and recommended the following biological areas for study:

1. History of the past.
2. Relation of man and his communities to earth.
3. Plants and animals and their classification.
4. The place of man among living things.
5. Organic evolution.
6. Heredity.
7. Nutritional processes and relationships.

8. Cycles of materials in the organic world.
9. Plant and animal communities.
10. Reproduction in plants and animals.
11. The human life cycle from reproduction to death.
12. General anatomy of the human body.
13. Basic biological functions.
14. Internal adjustments of the body.
15. Dietary needs of man.
16. Natures and varieties of human diseases and their control in the individual.
17. The nervous system, sense organs and sensations.
18. Nature and methods of learning.
19. Emotions and their place in human behavior.
20. Individual differences - mental and physical.
21. Mental and emotional conflicts and their control.
22. Nature of knowledge (Hurd, 1961:25-26).

The importance of laboratory work with experience in observation and experimentation was regarded by the committee as self-evident in biological science teaching.

The decade from 1950 to 1960 has been described as one of "confusion and crisis" in science education (Hurd, 1961:108). The National Science Foundation took the leadership in stimulating and supporting the development of new materials and teaching resources in the sciences and mathematics. Hundreds of institutes were organized to assist in realizing the potentialities of new curricula through a retraining of teachers for most of us "teach as we have been taught."

The Committee on Educational Policies of the National Academy of Sciences, National Research Council, in 1954 established a Subcommittee on Instructional Materials and Publications. One of the first concerns of this subcommittee was to consider the problem of laboratory instruction and field work in biology. The subcommittee noted "in a distressingly large number of high schools and even some colleges, the pressures of mounting enrollments and inadequate facilities, the ineptitude and lack of enthusiasm of some teachers, the notion that students learn as well from demonstrations and films as from laboratory work they do themselves, have led to drastic reduction or even total abandonment of laboratory and field study. Elsewhere, through 'laboratory' remains on the schedule, what is offered is so pedestrian and unimaginative, so unlikely to challenge the student's powers, as to be almost worse than no laboratory work at all" (Hurd, 1961:125-126).

The subcommittee finally accepted the major function of laboratory ana field studies as the showing of students that biology is a living science full of interesting and intriguing questions. It also stated that the course in biology should develop in students confidence in science as a dependable aid to the solution of many human problems and that biology must be presented as a serviceable and dependable intellectual tool to solve many of the world's practical problems and to gain for humanity as a whole an intellectual understanding of the nature of things not achievable without it.

The subcommittee material developed for the secondary school biology laboratory and field work was organized to fit the following course outline:

1. Organisms living in their particular environment are the primary objects of biology.
2. The diversity of organisms.
3. Some essential chemistry.
4. The organism as a dynamic open system: introduction to the basic organismic functions.
5. Maintenance of the individual.
6. Maintenance of the species.
7. The organism in its ecological setting.
8. Evolution of organisms and their environments (Hurd, 1961:128-129).

The founding members of the Commission on Undergraduate Education believed that the content of curricula had fallen far behind the spectacularly advancing front of biological investigation and subscribed to the notion that something could be done about narrowing the gap. A commission panel considered the writing of an ideal core curriculum but chose instead to analyze the existing core programs of four high quality universities. The Report of the Panel on Undergraduate Major Curricula (1967) is presented in Publication No. 18 of CUEBS entitled Content of Core Curricula in Biology. The report is lengthy, detailed but becomes meaningful with patient and persistent perusal.

At the University of Illinois an attempt is being made to communicate the concept of "biological awareness" to students in the general education biology sequence (non-major) within the School of Life Sciences (Kieffer, 1970). Conventional lecture, laboratory, discussion and quizzing have been abandoned in favor of the independent study or audio-tutorial method. Listed below is an abbreviated description of topics presently covered in the two-semester sequence:

Semester I - Biology 100

Unit I - Introduction.
Unit II - How Unique is Living Matter?
Unit III - This is Living?
Unit IV - Life in its Organization.
Unit V - The Concept of Appropriate Size.
Unit VI - What Do We Inherit?
Unit VII - How Like Begets Like - The Genes at Work.
Unit VIII - Science, Sex...and Other Things.
Unit IX - More About Other Things - How Large Organisms are Built.
Unit X - Changes.
Unit XI - Terrestrialization.
Unit XII - Homeostatis and Cybernetics in Animals.
Unit XIII - Cybernetics and Homeostasis in Plants and Cells.
Unit XIV - The Meaning of Biology to Modern Man.

Semester II - Biology 101

Unit I - Radiation Biology
Unit II - The History of Life: From Atoms to Adam.
Unit III - Is Evolution Directed?
Unit IV - Man's Changing View of Himself.
Unit V - Behavior - Mostly Human (Part I).
Unit VI - Behavior - Mostly Human (Part II).
Unit VII - Chemical and Biological Warfare.
Unit VIII - New Horizons - Oceans and Space.
Unit IX - Cybernetics of Animal and Plant Populations.
Unit X - Cybernetics of Animal and Plant Populations.
Unit XI - Is There Intelligent Life on Earth?
Unit XII - Can the World Be Saved?
Unit XIII - Immunobiology.
Unit XIV - The Relationship of Biology to Human Thought.
Unit XV - Biology and the Future of Man (Kieffer, 1970:4-5).

The appeal of the whole course at the University of Illinois is epitomized in the verse:

> I am only one,
> But still I am one.
> I cannot do everything,
> But still I can do something;
> And because I cannot do everything,
> I will not refuse to do something
> That I can do.
>
> - Edward Everett Hale (Kieffer, 1970:6)

In the CUEBS Publication Biology for the Non-Major, by the Committee on Biology for a Liberal Education (1967), the vast number of respondees to the request for biological course opinions favored absolute freedom for the teacher in structuring his course. One person expressed himself in a rather specific manner:

> "...Topics? There is a surfeit of these. The problems of selecting from among them are fantasically difficult and exciting. Selection always demands artistry; therefore, it follows that no two people will make the same selection, and that many good courses are possible (p. 20).

F. W. Smith, Jr., writing in The American Biology Teacher speaks to the present with these words:

> The increasing disenchantment with science by the young seems to be directly related to the increasing failure of the traditional activities of science teachers, science courses, and science-teacher organizations to prepare them to solve the problems of a science-oriented society. Science, to our young, creates but never seems to solve societal problems. The need here is imperative. Science must become humanized or it will be increasingly rejected (p. 178).

TECHNIQUES AND TECHNOLOGICAL EQUIPMENT FOR THE BIOLOGY LABORATORY

Whatever the biology curriculum developed, there were always questions about the learning values and the best means for conducting class and laboratory work. What to teach and how to teach is a large and complex field.

The education of primitive man was as simple as the relatively unsocialized life he lived. The education of modern man must be of a degree of complexity with the high specialization of the society in which he lives. Truth, old and new, is always beautiful, but life is short and knowledge increasing exponentially. Each generation must crystalize for the next generation exact and useful information, through all available means, which will contribute most to its happiness, prosperity and success. Keppel admitted (1967) that circumstances almost always make this more convenient to do for the next generation than for our own.

Biology began largely as a descriptive science in which systematics, morphology, and anatomy were primary, proceeding from the natural and direct application of man's senses. With the development of the microscope, the gross features of plants and animals were seen indirectly as the normal consequence of an internal structure based on a universal unit, the cell. According to Commoner (1964), when the first compound microscopes were built, the embryologists discovered that even an animal as marvelously contrived as man, began life as a single cell. The cell appeared to be the "unit of life." Separated from the organisms, certain features of vitality were retained; but dismembered cells lost most of their original capabilities.

With the development of tools and techniques each generation finds the "new biology" somewhat strange and unfamiliar. However, the incorporation of every pertinent device into the instructional program makes for enjoyable experimentation. Roberts (1914) proposed abolishing the recitation as a formal exercise and having all work done in the laboratory which would:

> ...be equipped with stereopticon and projectoscope, blackboards and charts, aquaria, and a small conservatory or greenhouse opening immediately out of it on the same floor. I would have four laboratory periods a week instead of two, and during those periods, with a limit of twenty students in the section, I would undertake to make the laboratory work as far as possible become a personal development in observation by each individual student. I should take more time for the study of each form of life considered, and should endeavor to get at the subject from more angles. I should feel free to vary the work at any time by the use of the stereopticon or charts or blackboard, in order to illustrate special phases, or by conference to develop or summarize the results of the observations (p. 467).

Investigations of life constituents began in the nineteenth century when chemists turned their attention increasingly to living things. Analysis of chemicals found in body fluids and in the juices of crushed cells revealed the elaborate world of organic chemistry, of molecules based on the carbon atom. Sugars, proteins, enzymes, vitamins, and hormones were discovered in brews of plant and animal tissues and in microorganisms. Gradually, piece after piece of the cell's structure and chemical machinery were isolated, purified and meticulously studied as to size, shape, composition and chemical reactivity. Since the turn of the century, these efforts culminated in the formation of a new science, biochemistry, with special and unique techniques and tools for replication of results and continued research.

From the time of Rutherford and Curie to Fermi and Lawrence, the science of physics has had a unique role in probing the ultra-microscopic world and the production of sensing and recording devices such as x-ray machines and particle accelerators. Molecular biology has emerged but there remains an interdependency of all three sciences - biology, chemistry, and physics - in the areas of techniques and technological equipment.

The policies and operations of our colleges and universities have been characterized traditionally by extreme institutional individualism (Donham, 1934). Intense loyalty to a single institution rather than higher education as a whole has opened the way to expansion of functions and facilities. So long as the American aspiration for education was fulfilled, ambitious institutional individualism policy served the country well.

Professor Loehwing (1944) of the State University of Iowa wrote that current public interest tended to center increasingly in those phases of biology underlying legislation on health, housing, nutrition, conservation, agriculture, and medicine. Proposed and existing federal legislation concerned with education provided a good index of a heavy emphasis upon technical education. Battle-hardened veterans and mature war workers were ready to enter college after 1946, mentally conditioned in favor of technical and functional, as opposed to liberal education. New vistas were opening out and inviting active leadership from the colleges and universities in general education programs. Existing knowledge was decades ahead of educational practices, according to Brimble (1941), but the opportunity for relevancy and modernization was like the proberbial "cry in the wilderness" and went unheeded by most institutions of higher learning.

By 1953 there was a tendency to organize the content of science courses around broad areas of human concern and the laboratory exercises (Hurd, 1953) included many basic techniques of research and usages of equipment. The National Science Teachers Association Committee on Science Facilities (Richardson, 1954) stressed that well-qualified teachers should have available numerous facilities for the purposes of educating all citizens in science in order that there shall be a public that understands, uses wisely, and encourages the achievements of scientists, engineers and technicians and of developing scientists, engineers and technicians to keep our society continuously at the forefront of scientific and technological developments.

The investigator is dependent upon his experimental tools. As more precise and sophisticated instruments have been developed for gathering scientific information, the quality of the research product has improved (Handler, 1970). Indeed, the history of science, including the life sciences, is the history of the manner in which major problems have been attacked as more powerful and definitive tools have become available. Living cells, invisible to the naked eye, exhibit an elaborate wealth of structural detail through electron microscopy. Techniques for isolation of pure proteins were developed in the 1930's and 1940's but understanding their structure seemed impossibly remote. Analytical tools such as electrophoresis, ultracentrifugation, chromatography, and appreciation of action specificity of certain enzymes permitted resolution of the linear sequences of amino acids in the protein chain. X-ray crystallography provided infinite data on the three-dimensional structures of smaller molecules but the calculations required to convert the data into a model of a protein molecule were not accomplished until the appearance of the high-speed computer. Until all the stones had been laid, the apex was invisible and unattainable.

Biology has become a mature science as it has become quantifiable. The biologist is no less dependent upon his apparatus and techniques than the physicist. For tools the biologist is an opportunist. He is always grateful to the physicists, chemists, and engineers who have provided the tools adapted to biological investigation.

The scientific instrument industry is generally rather fragmented with small and medium-sized firms competing successfully with bigger firms in the following groups of instruments: (1) analytical instruments, (2) electronic test and measuring instruments, (3) nuclear instruments, (4) biomedical instruments and (5) microscopes. Almost no fundamental research is done on instruments as they never constitute a research objective *per se* but are tools for obtaining other research objectives. This group of experts (Organization for Economic Opportunity and Development, 1968) stressed the need for low-cost standardized instruments and standardization in the instrument field of basic standards of measurements.

The problems of original cost, constant maintenance, rapid obsolescence, changing standards and variable measurement scales help to make laboratory sciences expensive of time, effort, and money. The economics of program administration may account somewhat for the finding by Condell (1966) that the "equipment in eighty-two percent of the colleges failed to meet the BSCS Checklist criteria" (p. 6526).

The literature of the late 1960's reflects individual attempts to expose students to the techniques and technological equipment of the times. Holt, et al, (1965) reported on investigative laboratories in which carefully planned exercises were used to introduce the students to selected techniques and instrumentation, such as radioisotopic usage, spectrophotometry, microscopy, and pure culture techniques. An effort was made early to anticipate the greater independence expected of the student later in the program on basic laboratory techniques and technological equipment.

Voss and Brown (1968) listed the pieces of equipment in one extremely well-equipped high school biology laboratory -- electron microscope, Warburg respirometer, radiation scaler, analytical balance, photomicrographic microscope, phase-contrast microscope, automatic autoclave, electrophoresis apparatus, incubators, microtome, and closed environmental chamber. They also noted that some laboratories also have chromatography jars, oscilloscopes, and recording polygraphs. Biology has progressed beyond the scope of the dissecting kit and the simple light microscope.

Monaco (1965), in discussing the role of junior colleges in "the new biology," was convinced that even the most balanced curriculum cannot be effective without proper equipment and facilities. In order to develop an understanding of today's experimental approaches, the undergraduate student in biology must be introduced to equipment that not long ago was found only in the large universities and research institutions. Consequently, equipment such as plant growth chambers, chromatographic and electrophoresis units, phase-contrast microscopes and spectrophotometers are necessary for teaching as well as for research purposes.

Twentieth century biology must have a multi-disciplinary laboratory which would include not only the standard utilities of hot and cold water, gas and multiple circuits of 110-volt electricity, but also

220-volt circuits, air line, vacuum line, walk-in cold room, walk-in growth chamber, and hoods. Monaco (1965) also declares that, if biology is to be taught in the two-year college, a greenhouse, an animal house, and a culture room would be future additions for living materials to interest and to teach the student.

There is a current trend toward amalgamating the various scientific disciplines. Courses in biochemistry, biophysics, and sociobiology are illustrative of this trend and cause the biologist to reflect that he must be informed in a number of fields in addition to that of biology.

The Report of the Panel on Undergraduate Major Curricula (1967) has listed the sequence of items presented in the biology laboratories of Purdue University, Stanford University, North Carolina State University, and Dartmouth College. The numerous biological and chemical techniques expose the students to a vast array of basic modern research technological equipment.

During the 1964-65 academic year the faculty of the Department of Biology at Ball State University undertook a major re-evaluation, modernization, and reorganization of the department's course offerings. During 1965-66, plans were made for the development of facilities needed for the newly organized courses. Nesbitt and Mertens (1971) wrote that "in addition to microscopes, our basic equipment for one laboratory includes two climate-control chambers, a refrigerator-freezer, two low-temperature incubators, two spectroscopes, three colorimeter-spectrophotometers, a console centrifuge, an ice-maker, three pH meters, seven balances, and six hot plates. Miscellaneous items include standard laboratory glassware, molecular-model kits, alcohol lamps, hand lenses, thermometers, ultraviolet lamps, and dessicators" (p. 35).

From Goucher College, a small college in Towson, Maryland, Lacy and Funk (1970) would point out that too many research-oriented laboratory programs at larger colleges and universities are dependent upon graduate students to do much of the work in starting the labs, answering routine questions, finding equipment, teaching techniques and otherwise freeing the professor to discuss only experimental problems and results. The Department of Biology at Goucher College first included an investigative laboratory in the introductory biology course in 1958-59 and have offered it ever since with various modifications. The experimental organisms are limited to four or five microorganisms and the general stock of equipment is relatively simple. Major items include pipettes, pipette discard jars, test tubes with plastic caps, transfer loops, prescription bottles with screw caps, chemicals, compound microscopes, spectrophotometers, incubators, refrigerator, autoclave and balance.

In speaking of "The Duty of Biology" Professor T. D. A. Cockrell (1926), President, Southwestern Division, American Association for the Advancement of Science, stated that "There is no single or certain way to produce the most fruitful scientific research, but we can at least pay attention to the conditions under which it has been accomplished... We have not yet created what might be called a scientific atmosphere... Certainly, we must concentrate on the arts of presentation, and remember learning does not cease on leaving school" (pp. 367-371).

More recently, Sir Harold Himsworth (1961), in his introduction to the Surgical Research Society, defined an instrument as a device for extending the range of natural ability and concluded his presentation with the reminder that "Instruments can never be more than a means to an end. They are...the servants of ideas. The progress of knowledge depends...on the assessment of data and the formulation of precise questions for investigation. And in this operation all the skills joined in any endeavor have each their particular contribution to make" (pp. ix-xii).

SUMMARY AND DISCUSSION OF THE LITERATURE FINDINGS

The thirteen original colonies in America succeeded in founding, establishing, and sustaining a total of nine colleges to the time of the Revolutionary War. The old private American college has been pictured as an aristocratic institution with a rigid curriculum and unresponsive to the needs of the great democratic majority. The junior college movement made an initial appearance in 1839 because of the adaptation of higher education to the peculiar social, economic, political, and cultural conditions of its own society. It is a unique institution with two innovations, the one bringing higher education to the students' own doors and the other offering a general education instead of the traditional professional program.

Whereas the older colleges had built their course of study on mathematics, Latin, and Greek, after 1845 a tributary stream of human learning in the natural sciences was receiving more and more recognition. Science instruction improved with more equipment, laboratories, observatories, botanic gardens, field trips, museums, and textbooks especially prepared for the American college student.

The science survey courses that originated in the early 1920's contributed toward general rather than specialized education and represented broad syntheses of science areas. The courses were planned to be dynamic, to develop insight into the nature of the scientific enterprise, and to provide a practical understanding of the scientific method with an impelling urge to apply it to the problems encountered by the student in his individual and social life.

The literature indicated that the rapid advance of science to a position of dominance in the culture of our times has placed new demands on the college science curriculum. The life sciences have developed an independent style and value system, especially in biological science education. The effective biology teacher selects pertinent methods and materials and combines them into a pattern particularly suited to his own talents and objectives and the needs and concerns of the community. The teaching trends in the general biology laboratory seem to be those of establishing a wide range of objectives, organizing around a few selected central emphases, employing a variety of instructional methods, putting students into problematical situations to open new vistas of interest and opportunity, extending students' experiences through the use of technological equipment and community resources, and making imaginative efforts to evaluate outcomes.

The objectives of good teaching in the biological subjects are essentially the same as for the teaching of all subject matter but with special implications in regards to details and implications. The literature indicated that all objectives should be feasible, psychologically sound, attainable, universal, and related to desired changes in human behavior.

The biological sciences have never suffered from a lack of objectives. They have periodically emphasized religion, morals, ethics, health, citizenship, and patriotism. Through the years there has been the gradual ascendancy of the scientific method and the adherence to the acquisition of knowledge. Current objectives for the general biology laboratory have evolved into stress upon whole organisms, common life processes, organismic inter-relationships, reservation of judgment, life enrichment, and intelligent participation in a contemporary world.

The general ferment in biological education, the explosion of knowledge, the rise of molecular biology, and the advances in the psychology of learning caused the American Institute of Biological Science to mount a massive study in the biological sciences commencing in 1955 and culminating in 1971. There was a renewal of interest in the concepts of educational objectives. The resistance of the protectors of educational traditions was being shaken by the humanists, the behaviorists, and the educational technologists to allow for practical experimentation within the major curriculum revision movement.

Even though the crisis in higher education is widespread and there is growing dissatisfaction amongst students and faculty with the results achieved from the laboratory work in general biology, introductory biological science courses are needed to develop the concepts of a unified science of life and the laboratory is essential to any course in biology.

Educators have written many goals for the general biology laboratory. The literature shows them in over-abundance. An important part of the methodology of the 1970's is the development and use of behavioral objectives which are educational goals stated in terms of observable learner outcomes. This is the latest, but not necessarily the last, attempt to write educational objectives designed to cope with the ever-widening disparity between what is known and what is taught in science by creating the maximum conditions for student development and self-realization. A separate study beyond the scope of this dissertation could be the extent of development and effect of behavioral objectives in the college biological science courses.

The traditional classroom lecture method of presentation gradually evolved into the science lecture-demonstration and finally the separate student-participation laboratory. In the nineteenth century there were outstanding proponents and practioneers of the investigative laboratory. Years later, the approach to the general biology laboratory was usually an illustrative type laboratory with routine work, laboratory manuals filled with blanks requiring "right answers," and rote learning. There were common complaints by students that courses were crowded with factual material and by science instructors that teaching procedures had become hurried and frequently unrewarding.

The audio-tutorial, programmed, or independent study laboratory was a natural development out of school space limitations, increased enrollments, personnel shortages, voluminous subject-matter, and a wide variety of procurable audio-visual aids. This laboratory was an extension of the demonstration-museum arrangement but was available to the students at their convenience without formal instruction and placed learning responsibility upon the individual student.

The Committee on Undergraduate Education in the Biological Sciences, CUEBS, was organized in the middle 1960's to help with the problems of the college biology teacher. The laboratory was a point of weakness in many freshman biology courses. The approaches varied from almost complete devotion of time to demonstrations by the instructor to the endless traditional activities of observations, dissection, and drawing.

The most important element lacking was genuine experimentation, an opportunity for the student to participate in the approaches to the scientific investigation. The return to the investigative laboratory approach is considered by CUEBS as an esstential part of the complete restructuring of the general biology laboratory.

The literature indicates that no one type of laboratory is clearly superior in developing all of the outcomes desired from the science laboratory. The ultimate laboratory approach changes but always remains one in which the student is stimulated by curiosity, guided by knowledge, and rewarded by discovery.

Science not only grows but develops. Reorganization connects new knowledge with the old. The history of biology teaching is one of changing emphases on different levels of organization. Ancient biology began with gross anatomy. With the development of tools, techniques, and experience, the emphasis shifted to organs and tissues. Around 1960 the downward trend continued through the cellular to the molecular level. With the advancement of biological science on many fronts came new understanding of the relationships of one level of organization to another and a return to the ancient center of interest - the whole organism.

The Biological Science Curriculum Study, BSCS, developed three new biology curricula in the late 1950's. About 70% of the content of the three curricula is identical. The difference between the versions is esstentially in emphasis - ecological, molecular, or evolutionary.

The conclusions about life in the general biology laboratory are based upon the consideration and examination of only a tiny segment of plants and animals. For this reason conceptual generalizations are utilized to unify and extend statements about life. The literature reveals that there are five major concepts in modern biology - cell doctrine, heredity, development, genetic control, molecular biology, and evolution, with the molecular emphasis being dominant.

Most courses in general biology taught before 1900 were not organized around a biological theme or presented as an integration of the biological sciences. The typical laboratory was an endless array of classification exercises and all instructors required "quality work" through laboratory notebooks. During the decade 1910-1920 separate biology textbooks and laboratory manuals appeared on the academic book market. The laboratory exercises were still heavy with taxonomy and morphology but some began to emphasize application to human activities, observation of life phenomena, enrichment of life, and biological science as a means of scientific progress. The period 1920-1930 was one of cultural refinement and the depression years, 1930-1940, in America constituted a period of questioning of educational practices. The major criterion for course content was "to meet the needs of the students." Health information and consumership loomed large in the biology curriculum. From 1940 to 1950 the importance of laboratory work with experience in observation and experimentation was regarded as self-evident in biological science teaching.

The decade from 1950 to 1960 has been described as one of "confusion and crisis." In 1954 the National Academy of Sciences noted that a large number of colleges had abandoned the laboratory and those that remained were so pedestrian and unimaginative as to be almost worse than no laboratory work at all. The National Science Foundation, NSF, took the leadership in stimulating and supporting the development of new materials and teaching in the sciences and mathematics.

The literature would have the laboratory show that biology is a living science full of interesting and intriguing questions and that biology is a serviceable and dependable intellectual tool to solve many of the world's practical problems. Every published biological textbook and laboratory manual has the author's particular objectives, approach, and exercises for developing confidence in science. There is clearly no shortage of topics. The problems of selection are fantastically difficult and exciting. Selection always demands artistry; therefore, it follows that no two people will make the same selection and that many good courses are possible.

Biology began largely as a descriptive science in which systematics, morphology, and anatomy were primary, proceeding from the natural and direct application of man's senses. The development of the microscope and microscopic techniques ultimately revealed the cell as the "unit of life." With the continued development of laboratory techniques and technological equipment, each generation finds the "new biology" somewhat strange and unfamiliar. The investigator is dependent upon his experimental tools. The history of the life sciences is the history of the manner in which major problems have been attacked as more powerful and definitive tools and techniques have become available.

Biology has become a mature and quantifiable science and the laboratory is expensive of time, effort, and money. Condell found in 1966 that 82% of the junior colleges in Minnesota failed to meet the Biological Sciences Curriculum Study Checklist criteria. The literature of the late 1960's reflects individual attempts to expose students to the techniques and technological equipment of the times. Monaco in 1965 was convinced that even the most balanced junior college curriculum in the "new biology" could not be effective without proper equipment and facilities. In order to develop an understanding of today's experimental approaches, the undergraduate in biology must be introduced to equipment that once was found only in the large universities and research institutions.

Some college investigative laboratory programs have been initiated because the number of experimental organisms could be limited and the general stock of equipment made simple and inexpensive. The literature stressed that there is no single or certain way to produce the most fruitful scientific research or teaching, but we can at least create a scientific atmosphere and concentrate on the arts of presentation.

In summary, the literature indicated that the teaching trends in the general biology laboratory would:

1. Enroll the student in a year-course with unique arrangements such as audio-tutorial or open laboratory situations for the development of basic background and techniques.
2. Engage the student through an inquiry-type laboratory for a minimum of three hours per week in one or more long investigations toward which all his efforts would be concentrated.
3. Allow student selection of the area of emphasis which would usually be in the major areas of cell biology, heredity and genetics, animal behavior, or ecology.
4. Limit objectives to the behavioral objectives designed to give order and purpose throughout the investigation but with personal and social applicability.
5. Make available technological equipment necessary for the laboratory techniques as needed in a limited but unfolding personal investigative problem.

CHAPTER III

METHODS AND PROCEDURES

THE LITERATURE SEARCH

A thorough literature search, pertaining to the general education biological science offered at the junior college level, was conducted at the major institutions of higher education in the San Diego and Los Angeles areas - San Diego State College, University of San Diego, United States International University - California Western and Elliott Campuses, University of California at San Diego, University of California at Los Angeles and University of Southern California. Material was also utilized from a personal library of scientific magazines, biological textbooks, and laboratory manuals and from the files of the Department of Life Sciences at San Diego Mesa College.

Most information dealing with the history and development of general education, science education, biological science education and the junior or community college came from books, periodicals, dissertations, theses, governmental documents and published findings of professional societies. Chronological data on trends in course objectives, approaches, empases, exercises, laboratory techniques, and supportive technological equipment were summarized from books, periodicals, dissertations, reports by governmental agencies and yearbooks by learned societies.

Paul D. Hurd was clearly the outstanding contributor to biology education in America and trends in science teaching during the twentieth century. <u>School Science and Mathematics</u>, <u>Science</u>, and <u>Science Education</u> provided basic historical records. Many of the more recent trends and practices were developed by a spectrum of writers in <u>The American Biology</u>

Teacher and numerous publications by CUEBS, Committee for Undergraduate Education in the Biological Sciences. Dissertation Abstracts and Dissertation Abstracts International were worthwhile sources of pertinent and succinct data from the U.S. Office of Education and the Yearbooks by the National Society for the Study of Education were invaluable for depth coverages on science education in American schools.

Additional coverage on laboratory exercise topics and arrangements came through perusals of the table of contents of forty-eight laboratory manuals from current science education publishers. The same manuals were meticulously surveyed page by page for the newer techniques involved in biological laboratory exercises. The list of the larger and more expensive available technological equipment was prepared from a methodical searching in the catalogues of some thirty-nine larger firms that serve college, university and commercial biological laboratories.

Separate card files were prepared from the literature for course objectives, approaches, emphases, exercises, laboratory techniques, and technological equipment. Repetitious items were eliminated easily from all card files except for course objectives where some subjectively was exercised. The basic criterion for objectives was to have but one different or differently expressed thought in each statement.

THE PILOT STUDY

The first formal draft of an evaluative instrument, a questionnaire, was prepared and distributed at San Diego Mesa College to the other eleven teaching members of the Department of Physical Sciences and the Dean of Arts and Sciences. These persons were asked to serve as a panel of experts, to mark the questionnaire as though they actually were "Chairman, Department of Biology," and to offer any suggestions as to form, style depth, dimension, and direction with regard to the planned survey.

Over a two-week period the questionnaires were collected and personal interviews held with each person to read and understand written comments, to allow for verbal amplification of remarks, and to probe for additional suggestions on consolidation, clarity, and definition of the survey. In formulating the final questionnaire, the panel of experts was of appreciable help in reducing the size, restructuring the form, simplifying the rating scales, improving the clarity of thought, and strengthening the purpose.

Two recent doctoral dissertations were consulted for guidance in questionnaire development and to avoid duplication of research. Rundall (1970) with "An Analysis of the Freshman Biological Curriculum in the State Colleges of California" recommended criteria for the organization and presentation of a worthwhile program of biological science for the non-biology major at the California State Colleges. Schechter (1970) in "Biology in the California Public Junior Colleges" determined, analyzed, and evaluated the "actual" practices and recommended "desirable" practices for California junior colleges regarding biological science courses for non-science majors obtained from data based on the judgment of experienced junior college administrators.

THE QUESTIONNAIRE

The evaluative instrument developed from the literature search for this comparative study of the teaching trends and practices in the general biology laboratory as offered by the public community colleges of California was kept as short as possible but complete enough for a composite survey. The questionnaires were mailed with stamped self-addressed envelopes enclosed and a request "to return the questionnaire when completed." The respondents selected for this study were biology department chairmen in the ninety-three community colleges of California.

The returned questionnaires were separated into appropriate sections and made ready for tabulation and analysis. According to Creager and Ehrle (1971), "rare indeed is the questionnaire survey in which the sample is known to be an unbiased, random sample of the population" (p. 120). A copy of the questionnaire comprises Appendix A of this dissertation.

CHAPTER IV

THE QUESTIONNAIRE FINDINGS

INTRODUCTION

A total of 64 questionnaires, or 68.8% of the 93 questionnaires distributed to the community colleges of California, were returned for tabulation and analysis. Not all questionnaires were completed but the percentage participation was considered sufficient for a valid study.

Each section of this chapter is introduced by the corresponding questionnaire preface, instructions, and rating scale. The first table in every section generally presents the data in the form of the frequency of rating and the mean of the total rating points of the individual item in the order in which that item appeared in the questionnaire. The second table in each section is an alternate arrangement of the items ranked according to the mean rating or the total rating points. The mean rating of each item was calculated by dividing the sum of the products of the frequencies times the ratings by the total number of frequencies. The total rating points were determined from the sum of the frequencies times the corresponding ratings. Total rating points were substituted for mean ratings whenever total utilization was under consideration, the range of total frequencies was wide, and mean ratings would have false emphases with the lower frequencies. Determinations were made from the data in most tables of the mean frequency of rating for each column as well as the mean rating or mean total rating points of all the items.

Statistical analysis of the findings was limited primarily to frequency tabulations, arithmetical mean calculations, and point totalizations to reveal and clarify the relationships between trends and practices and to simplify the problem of ultimate course comparison, development, and execution by the concerned individual.

OBJECTIVES OF THE BIOLOGY LABORATORY

The questionnaire gave the following introduction, instructions, and rating scale for judging objectives of the general biology laboratory as offered by the public community colleges of California:

> Man's curiosity lies at the root of all sciences. In its broadest sense the biology laboratory has no boundaries. But in the general ferment of biological education, the limitation of time necessitates the careful selection of material along with the establishment of specific objectives. Please mark each of the listed objectives according to the indicated scale:
>
> 1 - not an objective in your laboratory.
> 2 - a secondary objective in your laboratory.
> 3 - a primary objective in your laboratory.

From the data tabulated in Table 1 (Frequency of Rating and Mean Rating of Objectives) the following observations and determinations were made:

1. Objective number 14, "To understand the life processes common to all organisms," had the highest mean rating at 2.94.
2. Objective number 27, "To pass an examination," had the lowest mean rating at 1.39.
3. The overall mean rating for all 28 objectives was 2.35.
4. No single objective was rated the same by all 64 chairmen.
5. Only objective number 27, "To pass an examination," was not listed as a primary objective by any of the survey participants.
6. Seven of the 28 objectives listed in the questionnaire (numbers 1, 3, 5, 7, 14, 15, and 20) were either a primary or a secondary objective in the general biology laboratory of all respondents.

7. The objectives were rated "1 - not an objective in your laboratory" by 13.1%, of all the chairmen, mean = 8.28.

8. The rating of "2 - a secondary objective in your laboratory" was given by 38.1%, of the respondees, mean = 24.1.

9. The objectives were marked as "3 - a primary objective in your laboratory" by 48.8%, of the participants, mean = 30.9.

All 28 objectives were ranked by means in Table 2. This rearrangement verified the relative positions of the objectives and permitted the following group analyses:

1. Twelve objectives had a mean over 2.50 which is approaching "3 - a primary objective in your laboratory."

2. Twenty-three objectives had a mean of 2.00 or slightly higher, which was for a secondary objective.

3. Five objectives were under a mean of 2.00.

4. Only objective number 27, "To pass an examination," had a mean less than 1.50, the closest to "1 - not an objective in your laboratory."

TABLE 1

Frequency of Rating and Mean Rating of Objectives

Objective	Frequency of Rating			Mean Rating
	1	2	3	
1. To engage the student in the process of investigation.	0	14	50	2.78
2. To detect and state a problem.	9	28	24	2.25
3. To develop the power of observation through carefully directed study of the common biological problems and materials in the local environment.	0	16	48	2.75
4. To learn to use scientific equipment.	8	40	16	2.13
5. To learn to organize facts obtained from observations and experiments.	0	16	46	2.74
6. To develop a willingness to suspend judgment until sufficient facts are gathered.	3	19	41	2.60
7. To recognize true cause-and-effect relationships.	0	22	40	2.65
8. To satisfy the student urge for activity.	31	23	5	1.55
9. To learn to transfer the method of scientific thinking to individual and social problems.	4	38	22	2.28
10. To give a command of biological information related to the welfare of intelligent human beings.	2	26	36	2.53
11. To correct common superstitions, unfounded and ignorant practices.	18	30	16	1.97
12. To acquire a knowledge and understanding of the individual organism.	6	24	34	2.44
13. To understand the relation of structure to function.	2	22	40	2.60
14. To understand the life processes common to all organisms.	0	2	62	2.94
15. To acquire a knowledge and understanding of cooperative and competitive interrelationships among plants and animals.	0	24	40	2.63
16. To provide scientific knowledge basic to understanding the great problems facing mankind.	2	30	32	2.47

TABLE 1 (continued)

Objective	Frequency of Rating 1	2	3	Mean Rating
17. To motivate and guide the student in the development of an active interest in his position in the biological world.	4	16	44	2.63
18. To make the student into a creative instead of an imitative being.	7	31	23	2.26
19. To prepare students for intelligent participation in a contemporary world.	4	12	48	2.69
20. To enrich the lives of young people by making them more aware of the biological phenomena taking place in themselves and their surroundings.	0	16	48	2.75
21. To develop a knowledge of specific organisms that effect man directly.	10	24	30	2.31
22. To appreciate the place and significance of biology in human culture.	6	26	32	2.41
23. To cultivate an appreciation of the scientist and his work.	9	41	13	2.06
24. To develop lasting esthetic values realizing the orderliness and intricacies existing in nature.	6	26	32	2.41
25. To give students a background of science which will enable them to appreciate and enjoy literature dealing with biological sciences.	16	26	22	2.09
26. To become acquainted with the nature and extent of the professional fields of biology.	22	26	16	1.91
27. To pass an examination.	38	24	0	1.39
28. To satisfy the general education science requirement.	25	33	5	1.68
Total	232	676	864	65.90
Mean	8.28	24.1	30.9	2.35
Percentage	13.1	38.1	48.8	

TABLE 2

Ranking of Objectives by Mean Rating

Objective	Mean Rating	Ranking
14. To understand the life processes common to all organisms.	2.94	1
1. To engage the student in the process of investigation.	2.78	2
3. To develop the power of observation through carefully directed study of the common biological problems and materials in the local environment.	2.75	3.5
20. To enrich the lives of young people by making them more aware of the biological phenomena taking place in themselves and their surroundings.	2.75	3.5
5. To learn to organize facts obtained from observations and experiments.	2.74	5
19. To prepare students for intelligent participation in a contemporary world.	2.69	6
7. To recognize true cause-and-effect relationships.	2.65	7
15. To acquire a knowledge and understanding of cooperative and competitive interrelationships among plants and animals.	2.63	8.5
17. To motivate and guide the student in the development of an active interest in his position in the biological world.	2.63	8.5
6. To develop a willingness to suspend judgment until sufficient facts are gathered.	2.60	10.5
13. To understand the relation of structure to function.	2.60	10.5
10. To give a command of biological information related to the welfare of intelligent human beings.	2.53	12
16. To provide scientific knowledge basic to understanding the great problems facing mankind.	2.47	13
12. To acquire a knowledge and understanding of the individual organism.	2.44	14
22. To appreciate the place and significance of biology in human culture.	2.41	15.5

TABLE 2 (continued)

Objective	Mean Rating	Ranking
24. To develop lasting esthetic values realizing the orderliness and intricacies existing in nature.	2.41	15.5
21. To develop a knowledge of specific organisms that effect man most directly.	2.31	17
9. To learn to transfer the method of scientific thinking to individual and social problems.	2.28	18
18. To make the student into a creative instead of an imitative being.	2.26	19
2. To detect and state a problem.	2.25	20
4. To learn to use scientific equipment.	2.13	21
25. To give students a background of science which will enable them to appreciate and enjoy literature dealing with biological sciences.	2.09	22
23. To cultivate an appreciation of the scientist and his work.	2.06	23
11. To correct common superstitions, unfounded and ignorant practices.	1.97	24
26. To become acquainted with the nature and extent of the professional fields of biology.	1.91	25
28. To satisfy the general education science requirement.	1.68	26
8. To satisfy the student urge for activity.	1.55	27
27. To pass an examination.	1.39	28

APPROACHES TO TEACHING THE BIOLOGY LABORATORY

The information in this section of the findings is minimal in quantity but was designed to survey the current status of the audio-tutorial laboratory approach, the length of the community college general biology course, and the amount of weekly laboratory time actually allowed for student experimentation. The following paragraph preceded the fill-in blanks:

> The CUEBS publication Biology for Non-Majors makes the statement that the feelings of the majority of biologists, whether for or against the laboratory, are best summarized by the respondee who wrote "I support all of the pious platitudes about labs, both for and against, but especially the one about poor labs being worse than none at all." The approach is part of the development and organization of a worthwhile laboratory which is not any easy task for any teacher. Please indicate your type of laboratory, the number of semesters or quarters in your school year biology program, the number of hours per week required in laboratory and the approximate percent of time that is scheduled for each of the indicated activities.

TABLE 3

FREQUENCY AND PERCENTAGE OF TYPE OF GENERAL BIOLOGY LABORATORY

Laboratory	Frequency	Percentage
Audio-tutorial	8	12.5
Non Audio-tutorial	56	87.5

Table 3 (Frequency and Percentage of Type of General Biology Laboratory) showed that 87.5% of sampled California public community colleges offer a non audio-tutorial general biology laboratory course to non-majors.

The tabulations in Table 4 (Frequency and Mean of Yearly and Weekly Lengths of the General Biology Laboratory) showed that some 60 out of 64, or 93.8%, of the community colleges were on the semester system, 56.7% offering biology to non-majors in a one-semester program and 43.3% organized into a two-semester course. The 4 colleges on the quarter system were equally divided between the one-quarter and the three-quarter arrangement. The three-hour laboratory period was operative at 69.7% of the institutions and the mean length of the weekly biology laboratory period was 3.33 hours.

TABLE 4

Frequency and Mean of Yearly and Weekly Lengths of the General Biology Laboratory

Item	Frequency						Mean
	1	2	3	4	5	6	
Number of Semesters	34	26	0	0	0	0	1.43
Number of Quarters	2	0	2	0	0	0	2.00
Number of Hours per Week	0	4	46	7	3	4	3.33

The mean percentage of time scheduled for the various general laboratory activities recorded in Table 5 showed that 11.5% of the laboratory time was given to introductory lectures, 5.7% to introductory demonstrations, and 6.8% for summary discussions. The bulk of laboratory time, a mean of 76.0%, was allowed for student activities but, subtracting the 15.1% spent observing displays and exhibits and the 11.5% for analysis of data in class, left only 49.4% of the time for actual student experimental work.

One instructor gave his approach to the laboratory as one of dividing into teams, sharing the various tasks, and reporting to the group near the end of the period. Another school tried to solve the problem of too little student experimental time by doing much of the introductory and summary work in lecture and having students prepare in advance and evaluate the data outside the laboratory.

TABLE 5

Mean Percentage of Time Scheduled for Laboratory Activities

Laboratory Activity	Mean Percentage of Time
1. Introductory lecture on tape or by instructor.	11.5
2. Introductory demonstration directed by tape or given by instructor.	5.7
3. Student activities	76.0
a. Observation of displays or exhibits.	15.1
b. Actual experimentation time.	49.4
c. Analysis of data in class.	11.5
4. Summary discussion by tape or with instructor.	6.8

EMPHASES IN THE BIOLOGY LABORATORY

The section of the questionnaire that dealt with course emphases had the following introductory paragraph:

> As biology has advanced on many fronts, knowledge of living things has undergone a reformation. Biology reshapes its teaching of that knowledge by changing the emphases that are put on different levels of biological organization. Please mark each of the following according to the scale as you analyze your own emphases in the general biology laboratory:
>
> 1 - little or no stress.
> 2 - frequently stressed.
> 3 - strongly stressed throughout.

The frequency of responses to this section are shown in Table 6 along with the mean ratings. From this data the following observations can be made:

1. The highest ranking (shown in Table 7) was given by the respondees to the ecological emphasis with a mean of 2.56.
2. Cellular and genetic emphases were ranked (Table 7) second and third, respectively, with means of 2.45 and 2.44 in that order, Table 6.
3. Emphasis number 8, "pathological," had the lowest mean rating at 1.39. No one rated it as "3 - strongly stressed throughout."
4. The overall mean rating of the 11 emphases was 2.11.
5. All chairmen gave a rating of "2 - frequently stressed" or "3 - strongly stressed throughout" to the ecological, cellular, genetic, and physiological emphases in the biology laboratory.
6. The emphases were rated "1 - little or no stress" by 17.4% of the participants, a mean of 10.9 out of 64.

7. The rating of "2 - frequently stressed" was marked on 53.2% of the questionnaires or a mean of 33.3.

8. The emphases were rated as "3 - strongly stressed throughout by 29.4% of the respondents or a mean of 18.4 participants.

TABLE 6

Frequency of Rating and Mean Rating of Emphases in the General Biology Laboratory

Emphasis	Frequency of Rating			Mean Rating
	1	2	3	
1. anatomical	20	36	6	1.77
2. cellular	0	34	28	2.45
3. developmental	8	42	12	2.06
4. ecological	0	28	36	2.56
5. evolutionary	9	23	31	2.35
6. genetic	0	36	28	2.44
7. molecular	15	37	11	1.94
8. pathological	38	24	0	1.39
9. physiological	0	40	22	2.36
10. reproduction	4	34	24	2.26
11. taxonomical	26	32	4	1.64
Total	120	366	202	23.20
Mean	10.9	33.3	18.4	2.11
Percentage	17.4	53.2	29.4	

The emphases were rearranged in Table 7 to permit perusal by rank order of mean rating. This value ranking showed that:

1. Only the ecological emphasis at 2.56 was over the mid-point of 2.50 between the ratings "2 - frequently stressed" and "3 - strongly stressed throughout."
2. Seven of the 11 emphases in the questionnaire had ratings exceeding 2.00.
3. Only the pathological emphasis was less than the mid-point of 1.50 between "2 - frequently stressed" and "1 - little or no stress."

TABLE 7

RANKING OF EMPHASES BY MEAN RATING
IN THE GENERAL BIOLOGY LABORATORY

Emphasis	Mean Rating	Ranking
4. ecological	2.56	1
2. cellular	2.45	2
6. genetic	2.44	3
9. physiological	2.36	4
5. evolutionary	2.35	5
10. reproduction	2.26	6
3. developmental	2.06	7
7. molecular	1.92	8
1. anatomical	1.77	9
11. taxonomical	1.64	10
8. pathological	1.39	11

EXERCISES FOR THE GENERAL BIOLOGY LABORATORY

The section of the questionnaire dealing with exercises was the longest and most complex since it was concerned with the voluminous subject matter available to biologists. The paragraph preceding the exercises was as follows:

> To many biologists the laboratory is the heart of biology where students are stimulated by curiosity, guided by knowledge, and rewarded by discovery. Please mark each of the following according to the indicated scale:
>
> 1 - those topics not included in your laboratory.
> 2 - those topics included with others in a laboratory period.
> 3 - those topics given a full laboratory period to develop and consider.

The comparisons that can be made from the data on exercises are astronomical in number. It is intended to deal with the relationships that are obvious and applicable to the ultimate objective of this dissertation which was to provide a fundamental basis for comparing existing laboratory programs, for developing new courses, and for judging the extent of individual experimentation.

Table 8 has the data for the general biology laboratory exercises organized according to frequency of rating and total rating points which are the sums of the frequencies times the corresponding ratings. For laboratory exercises, the concept of total rating points is closer to actual exercise practice than mean rating. Table 8 disclosed that:

1. Exercise number 1 on the microscope had the highest total number of rating points at 170.
2. Exercise number 9 on ecology had the second highest total points at 168.
3. The exercises on metabolism, cell biology, reproduction, and genetics and heredity (numbers 5, 12, 19, and 21, respectively) were grouped at a total of 160 points each.

TABLE 8

FREQUENCY OF RATING AND TOTAL RATING POINTS OF EXERCISES

Exercise	Frequency of Rating 1	2	3	Total Rating Points
1. The Microscope	0	22	42	170
2. The Scientific Method	1	47	15	140
3. Characteristics of Life	8	26	30	150
4. Nutrition	14	28	22	136
5. Metabolism	2	28	34	160
6. Animal Behavior	8	34	22	142
7. Symbiosis	8	48	8	128
8. Health	34	26	2	92
9. Ecology	4	16	44	168
10. Embryology	12	22	30	146
11. Evolution	9	29	21	130
12. Cell Biology	0	14	44	160
a. Enzymes	3	23	21	112
b. Organelles	0	22	20	104
c. Processes	0	20	24	112
d. Structure	3	21	19	102
13. Taxonomy - Monera	8	28	24	136
a. Bacteria	3	21	15	90
b. Blue-green Algae	5	27	9	86
14. Taxonomy - Protista	6	30	22	132
a. Algae	2	22	14	88
b. Fungi	4	22	12	84
c. Protozoa	2	24	12	86
15. Taxonomy - Metaphyta	7	19	29	132
a. Non-vascular plants	4	22	10	78
b. Vascular plants	4	20	12	80
c. Seed plants	4	16	16	84
d. Flowering plants	4	20	12	80
16. Taxonomy - Metazoa	9	23	29	142
a. Porifera	6	24	12	90
b. Coelenterata	5	23	13	90
c. Plateyhelminthes	7	25	11	90
d. Aschelminthes	6	22	14	92
e. Annelida	4	20	18	98
f. Arthropoda	4	24	14	94
g. Mollusca	3	25	13	92
h. Echniodermata	4	24	14	94

TABLE 8 (continued)

Exercise	Frequency of Rating			Total Rating Points
	1	2	3	
i. Chordata	4	18	18	94
j. Non-vertebrates	7	19	15	90
k. Vertebrates	6	20	16	94
l. Mammals	6	24	12	90
17. Plant anatomy and physiology	5	15	39	152
a. Roots	2	26	12	90
b. Stems	2	24	14	92
c. Leaves	2	24	14	92
d. Flowers, fruits, seeds	2	20	18	96
e. Tropisms	8	24	8	80
18. Plant anatomy and physiology	5	15	35	140
a. Non-mammalian dissection	8	14	18	90
b. Mammalian dissection	10	12	20	94
c. Circulatory system	4	22	18	102
d. Diegestive system	1	25	17	102
e. Endocrine system	10	22	12	90
f. Excretory system	10	18	16	94
g. Integumentary system	10	26	6	80
h. Muscular system	10	22	12	90
i. Nervous system	5	21	17	98
j. Reproductive system	2	26	16	102
k. Respiratory system	6	26	12	94
l. Skeletal system	12	20	12	88
19. Reproduction	3	11	45	160
a. Animal	2	22	18	100
b. Plant	4	22	14	90
c. Meiosis	2	22	22	112
20. Growth and Development	1	21	33	142
a. Differentiation	4	22	18	102
b. Homeostasis	6	24	8	78
c. Mitosis	3	11	31	118
d. Regeneration	4	32	2	74
21. Genetics and Heredity	0	14	44	160
a. Classical genetics	2	18	26	116
b. Molecular genetics	6	24	12	90
c. Population genetics	7	29	9	92
Total	388	1662	1382	7858
Mean	5.3	22.8	19.0	107.6
Percentage	11.3	48.4	40.3	

4. Exercise number 8 on health had the lowest total of rating points with 92.
5. All respondees gave a full or partial laboratory period to only 3 out of the 21 major numbered questionnaire exercises, the microscope, cell biology, and genetics and heredity (numbers 1, 12, and 21, respectively). The major numbered exercises are presented separately in Table 9.
6. There was a mean of 5.3 responses per exercise topic on the questionnaire for the rating of "1 - those topics not included in your laboratory." This figure represented 11.3% of the total responses.
7. A mean of 22.8 responses was made per exercise topic for the rating of "2 - those topics included with others in a laboratory period." This was 48.4% of all ratings.
8. The rating of "3 - those topics given a full laboratory period to develop and consider" was given by 40.3% of the participants on each of the exercises for a mean of 19.0 respondents.
9. The mean frequency of rating for all 73 exercise topics and sub-topics was 2.95.
10. The mean frequency of rating for the 21 major numbered exercises was 2.35.
11. Within the exercise number 12 on cell biology almost equal consideration was given to the sub-topics of enzymes, organelles, processes, and structure.
12. Under exercise number 13 on "Taxonomy - Monera" only slightly more consideration was given to bacteria than to blue-green algae.

13. The algae, protozoa, and fungi in exercise number 14 on "Taxonomy - Protista" were closely rated in that sequence.
14. In the development of exercise 15 on "Taxonomy - Metaphyta" the seed plants were emphasized most frequently.
15. The Phylum Annelida was considered more often with 98 total rating points than all the other categories listed under "Taxonomy - Metazoa" in exercise 16. That phylum was closely followed by 4 groups of organisms with 94 total rating points each, Arthropoda, Echinodermata, Chordata, and Vertebrata.
16. Exercise number 17 on plant anatomy and physiology indicated a slight preference for "flowers, fruits, and seeds" over "stems, roots, and leaves" as laboratory presentations.
17. In exercise number 18 on animal anatomy and physiology the circulatory, digestive, and reproductive systems were equally considered with the same highest total of rating points of 102. This exercise has been separately considered in Table 10.
18. Under reproduction in exercise 19, the sub-exercise on meiosis rated highest.
19. Exercise number 21 on genetics and heredity indicated a more frequent presentation of classical genetics over molecular and population genetics.

The 21 major numbered questionnaire exercises are presented in Table 9 in rank order according to total rating points. This consolidation and simplification of the data from Table 8 permitted the consideration of the major exercises from a one-page table. Exercise number 1 on the microscope ranked at the top of all the exercises with 170 points and exercise number 8 on health ranked last with 92 points. This was a range of 78 points or a mean separation of 3.71 points between the 21 exercises. The second lowest exercise was number 7 on symbiosis with a total of 128 rating points. Thus, the 20 top-ranked exercises had a range of 42 points or a mean separation of only 2.1 total rating points. Table 9 also showed relative positions in which:

1. Exercise 7 on plant anatomy and physiology ranked 7th over exercise 18 on animal anatomy and physiology at 13.5 in the list of 21 topics.
2. Exercise 2 on the scientific method only ranked 13.5 as a separate exercise in the biology laboratory.
3. The taxonomic exercises (numbers 13, 14, 15, and 16) ranked as 11 or lower in total rating points. Only the exercises on evolution, symbiosis, and health ranked lower than the taxonomic considerations of Monera, Protista, and Metaphyta.
4. The mean total rating points for all major exercises was 143.7. Table 9 revealed that 9 out of 21 exercises ranked above that total of rating points.

TABLE 9

Ranking of Exercises by Total Rating Points

Exercise		Total Rating Points	Ranking
1.	The microscope	170	1
9.	Ecology	168	2
5.	Metabolism	160	4.5
12.	Cell biology	160	4.5
19.	Reproduction	160	4.5
21.	Genetics and heredity	160	4.5
17.	Plant anatomy and physiology	152	7
3.	Characteristics of life	150	8
10.	Embryology	146	9
6.	Animal behavior	142	11
16.	Taxonomy - Metazoa	142	11
20.	Growth and development	142	11
2.	The scientific method	140	13.5
18.	Animal anatomy and physiology	140	13.5
4.	Nutrition	136	15.5
13.	Taxonomy - Monera	136	15.5
14.	Taxonomy - Protista	132	17.5
15.	Taxonomy - Metaphyta	132	17.5
11.	Evolution	130	19
7.	Symbiosis	128	20
8.	Health	92	21

The components of exercise number 16 on "Taxonomy - Metazoa" were extracted from Table 8 and rearranged into Table 10 by total rating points. The phylum of Annelida ranked at the top with 98 points while the Porifera, Coelenterata, Platyhelminthes, Non-vertebrates, and Mammals were grouped at the bottom with 90 total rating points each. The range of only 8 points separating the top and bottom categories represented a mean of 0.67 points between each sub-exercise. The vertebrates were emphasized over the non-vertebrates and 4 of the top 5 rankings in the general biology survey course for non-science majors were the taxonomically higher organisms, Arthropoda, Echinodermata, Chordata, and Vertebrata.

TABLE 10

Exercise Number 16
Taxonomy - Metazoa
Ranking by Total Rating Points

Exercise	Total Rating Points	Ranking
e. Annelida	98	1
f. Arthropoda	94	4.5
h. Echinodermata	94	4.5
i. Chordata	94	4.5
k. Vertebrates	94	4.5
d. Aschelminthes	92	5.5
g. Mollusca	92	5.5
a. Porifera	90	10
b. Coelenterata	90	10
c. Platyhelminthes	90	10
j. Non-vertebrates	90	10
l. Mammals	90	10

Table 11 was constructed to allow a separate overview of animal anatomy and physiology as presented in the general biology laboratory. Clearly, the circulatory, digestive, and reproductive systems were emphasized. Intermediate consideration was given the nervous, excretory and respiratory systems. Far less attention was centered on the endocrine, muscular and skeletal systems.

The integumentary system ranked at the bottom with the greatest separation of total rating points in the whole table. Mammalian dissection was included more frequently in the laboratory than non-mammalian dissection.

The comments to this section of the questionnaire indicated that certain topics appeared in varying density in numerous laboratory periods during the course, that morphology and physiology were primary over classification; and, that new areas for the laboratory should be radiation biology, population biology, and pollution problems.

TABLE 11

Exercise Number 18
Animal Anatomy and Physiology
Ranking by Total Rating Points

Exercise	Total Rating Points	Ranking
c. Circulatory system	102	2
d. Digestive system	102	2
j. Reproductive system	102	2
i. Nervous system	98	4
b. Mamalian dissection	94	6
f. Excretory system	94	6
k. Respiratory system	94	6
a. Non-mammalian dissection	90	9
e. Endocrine system	90	9
h. Muscular system	90	9
l. Skeletal system	88	11
g. Integumentary system	80	12

TECHNIQUES IN THE BIOLOGY LABORATORY

The section of the questionnaire that dealt with basic biological laboratory techniques had the following introductory paragraph:

> There is no one best course, just a constant development through trial, feedback, revision and utilization of techniques to achieve objectives. Please mark each of the following techniques according to the indicated scale:
>
> 1 - not a necessity for students in general biology laboratory.
> 2 - of secondary importance to students in general biology laboratory.
> 3 - a must for every student in general biology laboratory.

The frequency of rating and the total rating points, obtained by adding frequency times rating for each technique, are shown in Table 12. From the tabulations the following determinations were made:

1. Technique number 1 on microscopy ranked the highest with 148 total rating points.
2. The general interpretive techniques of gross and graphing (items 13 and 17) ranked 2nd and 3rd with 136 and 129 total rating points, respectively.
3. Technique number 15 on electroencephalography ranked the lowest with 58 total rating points.
4. The mean for all techniques was 93.1 total rating points.
5. The techniques were rated "1 - not a necessity for students in the general biology laboratory" by a mean of 28.8 respondents or 50.4% of the participants.
6. The techniques were rated as "2 - of secondary importance to students in the general biology laboratory" by 20.8 chairmen or 36.4% of the respondees.

TABLE 12

Frequency of Rating and Total Rating Points of Techniques

	Technique	Frequency of Rating 1	2	3	Total Rating Points
1.	analysis, blood	33	21	5	90
2.	analysis, fat	30	22	6	92
3.	analysis, protein	30	24	4	90
4.	analysis, starch	27	21	9	96
5.	analysis, sugar	28	22	8	96
6.	analysis, air pollutants	32	24	2	86
7.	analysis, soil pollutants	32	24	2	86
8.	analysis, water pollutants	32	24	2	86
9.	biometry	32	18	8	92
10.	blood smearing	24	24	8	96
11.	blood typing	14	28	15	115
12.	chromatography	8	36	12	116
13.	dissection, gross	9	23	27	136
14.	dissection, microscopic	28	22	8	96
15.	electroencephalography	54	2	0	58
16.	electrophoresis	36	20	2	82
17.	graphing	10	28	21	129
18.	hybridization	26	22	6	88
19.	hydroponics	40	14	2	74
20.	microscopy	7	9	41	148
21.	photomicrography	36	20	0	76
22.	plastic embedding	48	12	0	72
23.	radiation	34	18	4	82
24.	sectioning	43	9	3	70
25.	squashing, cells	24	28	4	92
26.	staining	21	31	5	98
27.	tissue culture	40	16	0	72
	Total	778	562	204	2514
	Mean	28.8	20.8	7.6	93.1
	Percentage	50.4	36.4	13.2	

7. Some 7.6 of the participants, or 13.2% of the total, rated the techniques as "3 - a must for every student in general biology laboratory."

8. The mean frequency of rating was 1.63 for all techniques presented in the questionnaire.

9. There was complete rejection by all respondents of 4 techniques as "3 - a must for every student in general biology laboratory. These techniques were electroencephalography, photomicrography, plastic embedding, and tissue culture, items 15, 21, 22, and 27, respectively.

The rearrangement of techniques by total rating points in Table 13 developed a ranking of techniques which revealed that:

1. The total rating points were distributed in such a way that only 10 out of 27 techniques were above the mean of 93.1.

2. There was a mean difference between the 27 techniques of 3.33 total rating points.

3. The first 5 techniques of microscopy, gross dissection, graphing, chromatography, and blood typing stood out as a group from 115 to 148 total rating points and a mean of 6.60 points separating the items.

4. The remaining 22 techniques ranged from 58 to 98 total rating points with a mean of 1.82 points between adjacent items.

TABLE 13

Ranking of Techniques by Total Rating Points

Technique	Total Rating Points	Ranking
20. microscopy	148	1
13. dissection, gross	136	2
17. graphing	129	3
12. chromatography	116	4
11. blood typing	115	5
26. staining	98	6
10. blood smearing	96	8.5
4. analysis, starch	96	8.5
5. analysis, sugar	96	8.5
14. dissection, microscopic	96	8.5
25. squashing, cells	92	12
2. analysis, fat	92	12
9. biometry	92	12
1. analysis, blood	90	14.5
3. analysis, protein	90	14.5
18. hybridization	88	16
6. analysis, air pollutants	86	18
7. analysis, soil pollutants	86	18
8. analysis, water pollutants	86	18
23. radiation	82	20.5
16. electrophoresis	82	20.5
21. photomicrography	76	22
19. hydroponics	74	23
27. tissue culture	72	24.5
22. plastic embedding	72	24.5
24. sectioning	70	26
15. electroencephalography	58	27

TECHNOLOGICAL EQUIPMENT IN THE BIOLOGY LABORATORY

The last portion of the questionnaire was introduced by a brief statement and instructions for marking as follows:

> The study of biology necessitates the utilization of a variety of human resources. Pedagogic and monetary values of facilities and equipment cannot be equated but the general biology laboratory can mirror something of modern research. Please mark each of the following according to the indicated scale:
>
> 1 - available at your college
> 2 - demonstrated to the students.
> 3 - actually used by the students.

The compilation of questionnaire data on technological equipment into Table 14 on the basis of frequency of rating was essential to assess the utilization of items in the conduct of the general biology laboratory. The last portion of the table had the frequency of rating columns totaled and the individual totals divided by the number of participating colleges to give the mean number of items either available at the college, demonstrated to the students, or used by the students. Those means were also converted to the percentages of mean items per college. Table 14 reveals that:

1. One piece of equipment, the autoclave (item number 3), was marked as available at all participating California community colleges.
2. The basic laboratory tool, the flat field microscope (item number 24), was rated as available in only 47 out of the 64 colleges of the respondents, causing one to suspect the questionnaire instructions and technological equipment terminology.

TABLE 14

Frequency of Rating of Technological Equipment

Technological Equipment	Frequency of Rating		
	1	2	3
1. adding machine	55	0	11
2. auxanometer	17	0	0
3. autoclave	64	21	14
4. bacteria colony counter	58	8	26
5. balance	60	1	48
6. blender	60	8	33
7. calculator	53	2	18
8. calorimeter	39	4	18
9. centrifuge	60	8	40
10. chromatograph, paper	60	5	48
11. chromatograph, thin layer	36	6	18
12. colorimeter	51	8	37
13. electrophoresis apparatus	40	11	10
14. electrocardiograph	46	14	14
15. environmental chamber	34	8	14
16. freeze drying equipment	19	4	4
17. Geiger counter	48	16	8
18. hemocytometer	52	11	26
19. incubator	58	2	44
20. kymograph	60	7	39
21. lights, ultra-violet	56	8	33
22. microscope, electron	6	3	0
23. microscope, dark field	32	10	10
24. microscope, flat field	47	0	47
25. microscope, phase contrast	44	11	22
26. microscope, interference	8	0	0
27. microscope, polarizing	18	8	6
28. microscope, stereoscopic	57	0	57

TABLE 14 (continued)

Technological Equipment	Frequency of Rating		
	1	2	3
29. microtome	52	7	32
30. nuclear minigenerator	10	0	0
31. opthalmoscope	29	8	15
32. oscilloscope	56	10	26
33. osmometer	42	6	34
34. pH meter	62	6	46
35. physiograph	45	6	34
36. pneumograph	42	7	28
37. potometer	32	2	28
38. refractometer, hand	16	2	10
39. respirometer	48	2	40
40. scaler	28	5	12
41. spectrophotometer	36	7	22
42. sphygmomanometer	61	2	45
43. sterilizer	54	12	23
44. stethoscope	63	0	50
45. stimulator, electric	44	9	29
46. transpirometer	34	3	29
47. TV, closed circuit	23	11	8
48. vitalometer	24	2	16
49. water bath, thermostatic	53	4	36
50. Warburg apparatus	34	7	10
Total	2126	302	1212
Mean	33.2	4.7	18.9
Percentage	66.4	9.4	37.9

3. The electron microscope (item 22) was the lowest in availability.

4. There was a mean availability of 33.2 items, or 66.4%, of technological equipment at each community college.

5. The autoclave (item 3) was demonstrated most frequently to students.

6. A mean of 4.7 items, or 9.4%, of the technological equipment was demonstrated to the students.

7. There were 7 items (numbers 1, 2, 24, 26, 28, 30, and 44) not demonstrated to students at any college but only 3 of those items, the auxanometer, interference microscope, and nuclear minigenerator (items number 1, 26, and 30, respectively) were neither "2 - demonstrated to the students" or "3 - actually used by the students."

8. The stereoscopic microscope (item 28) was rated the laboratory equipment item most frequently used by students.

9. A mean of 18.9 items, or 37.9%, of the technological equipment was rated as "3 - actually used by the students."

10. About 47.3% of the equipment, a mean of 23.6 of the 50 listed items, was either demonstrated to or used by students in the general biology laboratory.

Table 15 represented a ranking of technological equipment according to frequency of availability in the community colleges. This rearrangement gave a different perspective and revealed that:

1. The top 4 available technological equipments were the autoclave, stethoscope, pH meter, and sphygmomanometer (items 3, 44, 34, and 42 in that order).

TABLE 15

Ranking of Technological Equipment According to Frequency of Availability at College

	Technological Equipment	Frequency of Availability at College	Ranking
3.	autoclave	64	1
44.	stethoscope	63	2
34.	pH meter	62	3
42.	spygmomanometer	61	4
5.	balance	60	7
6.	blender	60	7
9.	centrifuge	60	7
10.	chromatograph, paper	60	7
20.	kymograph	60	7
4.	bacteria colony counter	58	10.5
19.	incubator	58	10.5
28.	microscope, stereoscopic	57	12
21.	lights, ultra-violet	56	13.5
32.	oscilloscope	56	13.5
1.	adding machine	55	15
43.	sterilizer	54	16
7.	calculator	53	17.5
49.	water bath, thermostatic	53	17.5
18.	hemocytometer	52	19.5
29.	microtome	52	19.5
12.	colorimeter	51	21
17.	Geiger counter	48	22.5
39.	respirometer	48	22.5
24.	microscope, flat field	47	24
14.	electrocardiograph	46	25
35.	physiograph	45	26
25.	microscope, phase contrast	44	27.5
45.	stimulator, electric	44	27.5
33.	osmometer	42	29.5

TABLE 15 (continued)

	Technological Equipment	Frequency of Availability at College	Ranking
36.	pneumograph	42	29.5
13.	electrophoresis apparatus	40	31
8.	calorimeter	39	32
11.	chromatograph, thin layer	36	33.5
41.	spectrophotometer	36	33.5
15.	environmental chamber	34	36
46.	transpirometer	34	36
50.	Warburg apparatus	34	36
23.	microscope, dark field	32	38.5
37.	potometer	32	38.5
31.	opthalmoscope	29	40
40.	scaler	28	41
48.	vitalometer	24	42
47.	TV, closed circuit	23	43
16.	freeze drying equipment	19	44
27.	microscope, polarizing	18	45
2.	auxanometer	17	46
38.	refractometer, hand	16	47
30.	nuclear minigenerator	10	48
26.	microscope, interference	8	49
22.	microscope, electron	6	50

2. The 4 lowest ranked items were 38, 30, 26, and 22, the hand refractometer, nuclear minigenerator, interference microscope, and the electron microscope, last and least in frequency of availability at the colleges.
3. There never was more than a frequency difference of 4 colleges between any two adjacent items.
4. The mean difference of frequency of availability between the 50 items of technological equipment was 1.16 colleges.
5. The stereoscopic microscope ranked as number 12 but the flat field microscope only ranked as number 24 out of the 50 items of equipment.
6. Some 37 of the items, or 74.0%, were available at half of the participating colleges.

Table 16 represented another rearrangement of technological equipment through ranking according to frequency of student use. A few respondents commented in their questionnaires that the process of science for the non-major can be conducted with a minimum of specialized equipment. The data in Table 16 disclosed that:

1. The stereoscopic microscope (item 28) was ranked first in frequency of use by students at the most number of colleges, 57 in number.
2. The stethoscope (item 44) ranked as number 2, being used by students at 50 colleges, some 7 less than the stereoscopic microscope for the largest difference in the table.
3. The balance and paper chromatograph (items 5 and 10, respectively) had a frequency of student use at 48 each and shared the 3.5 ranking.

TABLE 16

Ranking of Technological Equipment
According to Frequency of Student Use

Technological Equipment	Frequency of Student Use	Ranking
28. microscope, stereoscopic	57	1
44. stethoscope	50	2
5. balance	48	3.5
10. chromatograph, paper	48	3.5
24. microscope, flat field	47	5
34. pH meter	46	6
42. sphygmomanometer	45	7
19. incubator	44	8
9. centrifuge	40	9.5
39. respirometer	40	9.5
20. kymograph	39	11
12. colorimeter	37	12
49. water bath, thermostatic	36	13
33. osmometer	34	14.5
35. physiograph	34	14.5
6. blender	33	16.5
21. lights, ultra-violet	33	16.5
29. microtome	32	18
45. stimulator, electronic	29	19.5
46. transpirometer	29	19.5
36. pneumograph	28	21.5
37. potometer	28	21.5
4. bacteria colony counter	26	24
18. hemocytometer	26	24
32. oscilloscope	26	24
43. sterilizer	23	26
25. microscope, phase contrast	22	27.5
41. spectrophotometer	22	27.5
7. calculator	18	30

TABLE 16 (continued)

	Technological Equipment	Frequency of Student Use	Ranking
8.	calorimeter	18	30
11.	chromatograph, thin layer	18	30
48.	vitalometer	16	32
31.	opthalmoscope	15	33
3.	autoclave	14	35
14.	electrocardiograph	14	35
15.	environmental chamber	14	35
40.	scaler	12	37
1.	adding machine	11	38
13.	electrophoresis apparatus	10	40.5
23.	microscope, dark field	10	40.5
38.	refractometer, hand	10	40.5
50.	Warburg apparatus	10	40.5
17.	Geiger counter	8	43.5
47.	TV, closed circuit	8	43.5
27.	microscope, polarizing	6	45
16.	freeze drying equipment	4	46
2.	auxanometer	0	48.5
22.	microscope, electron	0	48.5
26.	microscope, interference	0	48.5
30.	nuclear minigenerator	0	48.5

4. The flat field microscope (item 24) was marked as "3 - actually used by students" by only 47 participants and ranked fifth.

5. The stereoscopic and flat field microscopes were the only items of technological equipment that were available at the same number of colleges as permitted student utilization of the microscopes.

6. The auxanometer, electron microscope, interference microscope, and nuclear minigenerator (items number 2, 22, 26, and 30, respectively) were the only 4 equipments not actually used by students at any community college and had a common ranking of 48.5.

7. There were 18 items of technological equipment, or 36.0%, that were actually used by students at one-half of the colleges in the execution of the general biology laboratory exercises for the non-major.

SUMMARY AND DISCUSSION OF THE QUESTIONNAIRE FINDINGS

The questionnaire reflecting the major literature teaching trends was developed for a survey of the 93 public community colleges in California to determine the current common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, and the extent to which modern laboratory techniques and technological equipment were utilized in the non-major general biology laboratory. A total of 64 questionnaires, 68.8%, were returned for tabulation and consideration. Statistical analysis of the findings was limited primarily to frequency tabulations, arithmetical mean calculations, and point totalizations to reveal and clarify the relationships between trends and practices and to simplify the problem of ultimate course comparison, development, and execution by the concerned individual.

All objectives had some degree of importance. None were completely rejected and 48.8% were primary objectives in the general biology laboratory. Some 23 out of 28 questionnaire objectives had mean ratings above a secondary objective in the laboratory. The expression of so many objectives can dilute and obscure the effectiveness of the unifying purposes of a teaching program. However, the broad goals seem to be accomplished through the execution of specific aims inherent in every laboratory exercise.

"To understand the life processes common to all organisms" was the most highly rated objective. This represented a return to a study of whole organisms and to a consideration of their interrelationships as predicted by the literature. The second ranking objective "to engage the student in the process of investigation" correlated positively with the urgings of the literature for rapid development of the inquiry-type laboratory. The remainder of the objectives, ranking downward to the mean, clearly indicated a stress upon the development of the powers of observation, the organization of experimental facts, and intelligent participation in a contemporary world. "To learn to transfer the method of scientific thinking to individual and social problems "ranked only 18 as a separate objective but it is an integral procedure for the accomplishment of all the other objectives.

There was not a strong expression of factual acquisition which the literature found to be a constant practice or a recurrent trend. Those objectives that exhibited the tendency toward transfer of academic knowledge were grouped just below the mean frequency of rating.

The literature emphasized the need for laboratory objectives dealing with the use of scientific equipment, the enjoyment of the literature in the biological sciences, and the appreciation of the scientist and his work. These were, however, well below the mean of all objectives in the questionnaire.

The participants in this study rated "to satisfy the general education science requirement," "to satisfy the student urge for activity," and "to pass an examination" as the last three objectives in that order. Some respondents indicated that these may well be the precise goals of many students. A further extension of this study of objectives could most certainly include a survey of student opinion. A combination of staff and student estimations should provide much material for earnest consideration and develop into a laboratory situation with greater common interest, intellectual exchange, mutual learning, and student personal and social applicability.

A large majority, 87.5%, of the California public community colleges offered a traditional nonaudio-tutorial general biology laboratory to non-majors. The causes for this, such as financial problems, scheduling difficulties, limited facilities, academic preparation, personnel preferences, transfer articulation, or community control, could constitute a separate study beyond this survey.

The assignment of an instructor at a certain time does not negate a strong audio-tutorial teaching approach but it limits material availability at student convenience. The literature urged the use of modern audio-visual adis to repeat fundamentals and to free instructors and knowledgeable students for more advanced biological efforts.

Despite the exponential expansion of biological knowledge, adjustments to the general education requirements have shortened many general biology programs from one year to one semester. The community colleges showed an almost equal division between the one-semester and the two-semester general biology course with a mean of slightly over three hours per week of laboratory instruction. The course length differences have a direct relationship to the frequency of course objectives, emphases, exercises, laboratory techniques, and technological equipment as rated by the participants. The application of this data, therefore, requires individual consideration of program length and weekly laboratory time for any course comparison, development, and execution.

The nonaudio-tutorial teaching approach allowed 49.4% of the laboratory time for actual student experimentation. That means estimated allowance can be further reduced in actual practice by student problems of lateness, absence, lack of preparation, and biological background differences and by the sheer mechanics of modern college organization, such as large classes, equipment accounting, and attendance procedures. The audio-tutorial laboratory approach stresses student responsibility for preparation, initial conduct of exercises, and repetition for understanding. It also permits the instructor to concentrate with students in the mutual construction of behavioral objectives for investigations in the inquiry-type laboratory.

As biology has advanced on many fronts, knowledge of living things has undergone a reformation. Biology reshapes its teaching of that knowledge by changing the emphases that are put on different levels of organization. The Biological Sciences Curriculum Study, BSCS, developed materials which stressed evolution, molecular biology, and ecology. This survey of current teaching trends and practices showed that ecology, cell biology, and genetics are emphasized in that order but the mean rating of the emphases at 2.11 indicated the multiple stresses necessary for understanding the concept of life. Some respondents stated that the multiplicity resulted from the need for specific concepts for specific exercises.

The top ranking of the ecological emphasis correlates positively with the current public concern toward balance of nature, conservation of natural resources, food chains, population explosion, and pollution of air, soil, and water. The cellular and genetic emphases were next in accentuation and are strong areas of research hose findings make startling public news and crowd the pages of contemporary textbooks. These timely and ready-made factors undoubtedly have some influence on biology instructors in developing laboratory course objectives, approaches, and emphases.

The physiological and evolutionary emphases were next in order and are basic to the understanding and application of the ecological, cellular, and genetic concepts. The molecular stress is not as strong in the laboratory as in the lecture presentations. Anatomy and taxonomy have been progressively superceded through the years as other biological areas have developed. The taxonomical emphasis was far below the mean and had a lower relative ranking than the objectives concerned with the acquisition of phylogenetic knowledge. Pathology ranked the lowest of the course emphases and this was substantiated by the literature findings which never showed a strong stress on the study of diseases in the general biology laboratory.

There was a high acceptance at 88.7% of the exercises presented in the questionnaire for a full or partial laboratory period. This would correlate positively with the objectives of a general education survey course and with the philosophy of the inquiry laboratory - unfolding and expanding development through investigation.

The microscope ranked as the most frequent general biology exercise. It was followed by ecology, metabolism, cell biology, reproduction, and genetics and heredity, in that order. The three highest ranked emphases of ecological, cellular, and genetic are to be found in the same sequence amongst the top six exercises.

The students usually prefer animals to plants and yet plant anatomy and physiology ranked over animal anatomy and physiology. There is probably much of the animal emphasis through other exercises on metabolism, reproduction, characteristics of life, embryology, animal behavior, and growth and development, all of which ranked over the specific and separate exercise on animal anatomy and physiology. Whenever animal anatomy and physiology was offered as a separate exercise, the circulatory, digestive, reproductive, and nervous systems were examined most frequently. There is a strong tendency in the laboratory toward conceptual considerations which cut across the traditional exercise headings of the questionnaire.

The scientific method as a distinct exercise was ranked below the mean at 13.5 out of 21 major laboratory exercises but it is an integral part of the approach to every scientific problem. The four taxonomical exercises ranked a mean of 15 out of the 21 major exercises and reflected the de-emphasis on systematics which was definitely a trend in the literature. The taxonomy of the Kingdoms Monera, Protista, and Metaphyta were only ranked over exercises on evolution, symbiosis, and health. The symbiotic relationships have seldom been presented to the students in the general biology laboratory as a separate exercise but they have been inherent in other exercises, especially the larger contemporary topic of ecology. The subject of health has its separate considerations in health education and hygiene courses. It was the last of the laboratory course emphases and was the lowest ranking biological exercise.

Exercise choice requires constant finesse and adaptability. The laboratory is not a permanent set of stagnating procedures but a foundation with constant variations. A worthwhile doctoral study would be the historical examination of the influences on instructor choice of exercise topics. Another survey could well contrast staff and student expressions on laboratory organization, conduct, and evaluation procedures.

Microscopy ranked as the number one technique which correlated positively with the top ranking given the exercise on the microscope.

The three most common techniques of microscopy, gross dissection, and graphing are basic tools for investigation of material or interpretation of data in the biology laboratory. Slightly over one-half of the laboratory techniques were rated by the participants as not a necessity for non-major students. Only a mean of 13.2% of the laboratory techniques were considered as a must for every student in the general biology laboratory. Most of the top one-third of the techniques were inexpensive and quickly accomplished. Roughly the bottom one-third of the techniques, such as electro-encephalography, sectioning, tissue culture, and hydroponics, were time-consuming and required expensive equipment.

Some of the techniques of analysis had the same total rating points, such as starch and sugar, blood and protein, and air, soil, and water pollutants. The mathematic groupings were caused by exercise groupings in the questionnaires. Those who analyzed starch also analyzed sugar. Those who analyzed blood extended it to proteins and similarly for the pollutants of air, soil, and water. Even though ecology was ranked as the number one emphasis in the general biology laboratory and second to the microscope in the exercises, the analysis of air, soil, and water pollutants were only grouped at ranking 18 out of 27 laboratory techniques. The concern for ecology has evidently not reached the stage of quantification by students.

Some respondees felt that not too much could be done in the general biology laboratory for non-majors beyond the very simple and inexpensive techniques. The reasons given centered on the need for development and demonstration of each exercise topic by the instructor and the lack of student background, capability, motivation, and responsibility at the community colleges.

The utilization of technological equipment is a many-faceted problem of scheduled purchasing, regular maintenance, obsolescence, uncertain replacement, and laboratory application and supervision. The equipment at each college, beyond an initial group of basic instruments, depends upon the selection of exercises by the individual instructor. There is a sequence of related and dependent decisions that follows naturally from the development of objectives, approaches, and emphases to the selection of exercises, laboratory techniques, and technological equipment.

None of the 50 items of technological equipment was available at all community colleges but every item was available at 6 or more institutions. There was a mean availability of 33.2 items, or 66.4%. The top 4 available laboratory tools were the autoclave, stethoscope, pH meter, and sphygmomanometer. Optical equipment comprises the basic laboratory instrumentation and yet the stereoscopic microscope and flat field microscope ranked 12 and 24, respectively, in availability out of a total of 50 instruments. The questionnaire instructions and technological equipment terminology may have been at fault since the top exercise on the microscope should have had a positive correlation with equipment availability.

The 4 least available items were the hand refractometer, nuclear minigenerator, interference microscope, and electron microscope. The inexpensive technological equipment ranked near the top in both availability and use, except for the stereoscopic and flat field microscopes.

The more expensive items, like the nuclear minigenerator, interference microscope, and electron microscope, were the least available at community colleges and used least by the students.

The steroscopic microscope was ranked first in frequency of use by students and was followed by the stethoscope, balance, and paper chromatograph. There were 19.0 items of technological equipment, or a mean of 38.0%, that were actually used by the students at the colleges in the execution of the general biology laboratory exercises for the non-major. About 47.4% of the technological equipment, a mean of 23.7 items, was either demonstrated to or used by students. The total usage of technological equipment is not nearly as important as the manner of utilization. Pedagogic and monetary values of facilities and equipment cannot be equated but the general biology laboratory can mirror something of modern science. It can also engender an understanding of the time, effort, and money necessary to the structure and quests of the life sciences.

Some rankings showed that relative simple instruments have been replaced by more versatile and accurate devices; the hand refractometer ranked 40.5 and the spectrophotometer had a ranking of 27.5 out of the 50 items used by students. Yet a few participants indicated a movement toward a utilization of simple and inexpensive equipment in the investigative approach to the laboratory.

Grants for laboratory equipment tempt departments of life sciences to develop paper programs needing expensive and sophisticated biometric machines. Applications usually require plans for the in-service training of staff. Another doctoral study could well consider the relationships between grant applications, the depth of in-service training, and the event al extension to classroom demonstration by staff and the ultimate use by students.

In brief, the questionnaire findings revealed that the teaching practices in the general biology laboratory as offered by the public community colleges of California are quite variable, but the typical program would:

1. Enroll the student in a one-semester or two-semester course with the traditional nonaudio-tutorial laboratory.
2. Engage all students for three hours per week in the same basic museum-demonstration situation with an equal amount of time for experimentation that culminated weekly with the assigned period.
3. List many course objectives, probably a different one for each exercise, unified by the central aim to understand the life processes common to all organisms.
4. Emphasize the ecological, cellular, and genetic levels or concepts of biological organization.
5. Provide separate exercises on the microscope, ecology, metabolism, cell biology, reproduction, genetics and heredity, and plant anatomy and physiology.
6. Present combination exercises on the characteristics of life, embryology, animal behavior, taxonomy, growth and development, animal anatomy and physiology (circulatory, digestive, reproductive, and nervous systems), and evolution.
7. Integrate into the exercises pertinent laboratory techniques of microscopy, gross dissection, graphing, chromatography, blood typing, and perhaps staining, blood smearing, starch analysis, microscopic dissection, and cell squashing.

8. Incorporate student utilization of about 19 items of technological equipment, such as the stereoscopic microscope, stethoscope, balance, paper chromatograph, flat field microscope, pH meter, sphygmomanometer, and incubator into the experimental portions of specific laboratory exercises.

9. Demonstrate throughout the laboratory phase of the general biology course a mean of 5 items of technological equipment, such as the autoclave, Geiger counter, electrocardiogram, sterilizer, electrophoresis apparatus, hemocytometer, phase contrast microscope, closed circuit TV, dark field microscope, oscilloscope, and electric stimulator, for the accomplishment of the stated objectives.

CHAPTER V

SUMMARY AND CONCLUSIONS

A form of biology began when man became aware of himself as different from the unfeeling earth. Progress toward a science of biology was slow as long as the natural was felt to be subordinate to the supernatural. The history of biology has been a complex evolution from demons and magic through philosophical speculation and intuition to the strictly controlled experiments of today.

While it is a foregone conclusion that science has the potential of presenting society with disturbing problems of many kinds, the future progress of man rests upon the achievements of science. The impact of modern science and technology demands from the people some basic understanding and fundamental knowledge of the scientific enterprise so that they may properly comprehend and contribute toward that progress. Although large numbers of students in higher education take biology courses, only a small fraction of them major in biology. Consequently, biological science educators are being strongly challenged to select subject matter, methods, and materials for the non-major general biology programs with personal and social applicability.

The focal point for teaching biology, for most biologists, is found in the laboratory. Setting up a biology laboratory course that has the least common denominators, allows maximum student participation, introduces a variety of pertinent technological resources, involves true scientific investigative techniques, and links the individual with his environment, holds the greatest promise for modern biology teaching and learning.

The problem of this study was to determine the common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, and the extent to which modern laboratory techniques and technological equipment are utilized as an aid to instruction and for the fulfillment of course objectives in the general biology laboratory of the public community colleges in California.

This study is important for today we are dominated by science and technology and the average American is scientifically and technologically illiterate. He confuses science with technology and rejects both because of the failure of society to make the best use of technology. We live in a scientific civilization and yet inadequate science-teaching of non-scientists in college has developed mistaken views, dislikes, and misunderstandings. The 1970's demand changes in biological education such as the use of general introductory biology courses to provide the student with a basis for developing rational and intelligent awareness of applicable scientific knowledge, attitudes, and procedures.

A questionnaire was developed after a survey of the literature for common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, modern laboratory techniques, and available technological equipment. The questionnaire was submitted to the 93 public community colleges of California to determine the core of elements from each of the questionnaire categories that through common practice are typical of the general biology laboratory for non-majors.

Rooted distantly in the educational institutions of England and Western Europe, American higher education adapted itself to the peculiar social, economic, political, and cultural conditions and needs of its own society. Colonial college science courses under the title of natural history were offered soon after 1790. Science classroom instruction improved with more equipment, laboratories, observatories, botanic gardens, field trips, museums, and textbooks especially prepared for the American college student. Since the beginning of the nineteenth century, considerable evolution has taken place in the science curriculum. Today it is on a plane of high significance and important, a great social force as well as a method of investigation.

The junior college idea was born from the struggle to achieve equality of opportunity and to broaden the scope of higher education. The junior college made its initial appearance in the United States as early as 1839 and has increased appreciably in number and size since its inception. Despite a history of more than sixty years of existence in California, community colleges have emerged only recently as significant institutions of higher education.

The first extensive study dealing with science education in the secondary schools was made in 1920 by the U.S. Bureau of Education's Science Committee of the Commission on Reorganization of Science Education. The Committee report attempted to show how science instruction could contribute to the attainment of the seven cardinal principles or objectives of secondary education as recommended by the Commission - health, command of fundamental processes, worthy home membership, vocation, civic education, worthy use of leisure time, and ethical character.

The early objectives of instruction in biological courses were laced with morality, religion, patriotism and educational liberalism. In actual practice, attention was almost exclusively directed toward the acquisition of knowledge and the great and fundamental truths of nature. The biological survey courses originated in the early twenties and represented attempts at broad syntheses of biology instead of systematic factual surveys. The courses were to develop insight into the nature of the scientific enterprise, to go beyond the appreciative stage, to provide a practical understanding of the scientific method, and to apply it to the problems encountered by the student in his individual and social life. The most important feature of the organization of the survey course was to be its dynamic aspect.

In summarizing material contributed by twenty-one leading colleges and universities McGrath in 1948 listed four possible objectives for non-science major students who took general education college science courses: (1) to understand and learn to use the method of science; (2) to become acquainted with some of the more important facts of science; (3) to develop awareness of the social implications of science; and (4) to appreciate the historical development of science.

The advent of the general ferment in biological education, the explosion of knowledge, the rise of molecular biology, and the advances in the psychology of learning caused the American Institute of Biological Sciences (AIBS) to form a Committee on Education in 1955 to study education in the biological sciences. The Biological Sciences Curriculum Study (BSCS) was organized by the AIBS Committee on Education in 1959 and ceases to function in 1971. The BSCS biology specific objectives and courses of study were influenced by the theoretical considerations of Jerome Bruner who stressed that children should be taught in such a way as to have a clear understanding of the underlying principles which give structure to the subject.

A position paper of the Commission on the Education of Teachers of Science, National Science Teachers Association, stressed the importance of the laboratory in biological teaching and stated that the laboratory has several long standing traditional functions: (1) to illustrate objects and experiments that have been introduced elsewhere; (2) to provide training in laboratory techniques; (3) to stimulate the student intellectually; (4) to develop appreciation for living things; and (5) to stimulate discussion.

Science entered the field of education when the public became cognizant of its importance to the industrial and economic growth of the country. Science was placed in the curriculum and educators have struggled continuously with problems germane to objectives and content. The impact of new developments in science or science education usually lags behind some ten to thirty years. The crisis in higher education is chronic but something radical must be done to cope with the ever-widening disparity between what is known and what is taught in science.

In the nineteenth century, Agassiz, Gray and Bailey were outstanding proponents and practioneers of the investigative laboratory which allowed the student to organize his own ideas, provoked him to serious thought, developed his limited individuality, and ended in real accomplishment. Years later, the general trend in the development of general education college science laboratory courses was toward routine work, laboratory manuals, and rote learning. The result in the biology laboratory was a swift appearing and disappearing series of natural and unnatural objects.

The laboratory has been a point of weakness in many freshman biology course. The approaches have varied from almost complete devotion to demonstrations by the instructor to the endless traditional activities of observation, dissection, and drawing. The audio-tutorial, programmed or independent-study laboratory was a new development but genuine experimentation was lacking, an opportunity for the student to participate in the approaches to the scientific method through a real scientific investigation. The initiation of this investigative laboratory is considered by the Commission on Undergraduate Education in the Biological Sciences (CUEBS) to be an essential part of a radical restructuring of teaching. The ultimate laboratory approach is one in which the student is stimulated by curiosity, guided by knowledge, and rewarded by discovery.

Science not only grows but it develops. As new data is uncovered and new knowledge is formed, reorganization connects old with new. One of the most conspicuous ways in which biology reorganizes its knowledge is by changing the emphases that are put on different levels of organization.

Ancient biology was taxonomic and built upon observation and experimentation with whole living organisms. With the development of tools, techniques, and experience, biology emphasized the organization of tissues and organs. Around 1960 there was a downward direction to the cellular level and then the molecular level. With the advancement of biology on many fronts came the inevitable understanding of the relations of one level of organization to another and a return to the whole organism.

The Biological Sciences Curriculum Study (BSCS) developed three new biology curriculums in which about 70% of the content is identical. The difference between the versions was essentially in emphasis - ecological, molecular and cellular or evolutionary - to allow for individual instructional preference.

Most courses in general biology taught before 1900 were not organized around a biological theme or presented as an integration of the biological sciences. The popular educational writings of the day referred to the "fish-fern" and the "bale of hay and pail of frogs" course syntheses. During the decade 1910-1920, textbooks and laboratory manuals were published specifically for biology. The laboratory exercises were heavy with classification and morphology but some began to emphasize application to human activities, observation of life phenomena, enrichment of life, and demonstration of the study of biological science as a means of scientific progress.

The U.S. Office of Education in 1932 published a survey of science teaching practices and found the content was still generally divided into botany, zoology and physiology. In 1941 the National Commission on Cooperative Curriculum Planning formulated and recommended some twenty-two biological areas for study and stressed the importance of laboratory work with experience in observation and experimentation.

The decade from 1950 to 1960 has been described as one of confusion and crisis in science education. The National Science Foundation (NSF) took the leadership in stimulating and supporting the development of new materials and teaching resources in the sciences and mathematics and the retraining of teachers. The thrust of these efforts was toward the humanizing and personalizing of science.

With the development of tools and techniques each generation finds the new biology somewhat strange and unfamiliar but the incorporation of every pertinent procedure and device into the instructional program makes for more complete and enjoyable experimentation. The investigator is dependent upon his experimental tools. As more precise and sophisticated instruments have been developed for gathering scientific information, the quality of the research product has improved.

The literature of the late 1960's reflected attempts to expose students to the biological laboratory techniques and technological equipment of the times. It stressed that instruments are simply devices for extending the range of natural ability but necessary for the assessment of data, the formulation of precise questions for investigation, and the ultimate progress of knowledge.

In summary, the literature indicated that the teaching trends in the general biology laboratory would:

1. Enroll the student in a year-course with unique arrangements such as audio-tutorial or open laboratory situations for the development of basic background and techniques.
2. Engage the student through an inquiry-type laboratory for a minimum of three hours per week in one or more long investigations toward which all his efforts would be concentrated.
3. Allow student selection of the area of emphasis which would usually be in the major areas of cell biology, heredity and genetics, animal behavior, or ecology.
4. Limit objectives to the behavioral objectives designed to give order and purpose throughout the investigation but with personal and social applicability.
5. Make available technological equipment necessary for the laboratory techniques as needed in a limited but enfolding personal investigative problem.

A questionnaire reflecting the major literature trends was developed for a survey of the 93 public community colleges in California to determine the current common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, and the extent to which modern laboratory techniques and technological equipment were utilized in the non-major general biology laboratory.

All objectives in this study had some degree of importance and almost one-half were primary objectives in the general biology laboratory. The expression of so many objectives can dilute and obscure the effectiveness of the unifying purposes of a teaching program but the broad goals seem to be accomplished through the execution of specific aims inherent in every laboratory exercise.

To understand the life processes common to all organisms was the most highly rated objective and represented a return to a study of the whole organism as predicted by the literature. To engage the student in the process of investigation, the second ranking objective, was urged by the literature for rapid development of the inquiry-type laboratory. The remainder of the objectives above the mean stressed development of the powers of observation, organization of experimental facts, and intelligent participation in a contemporary world.

There was not a strong expression of factual acquisition which the literature found to be a constant practice or a recurrent trend. Those objectives that exhibited the tendency toward the transfer of academic knowledge were grouped just below the mean.

A further extension of this study could well be a comparison of staff and student objectives. Such expressions should provide much material for earnest consideration and should develop into a laboratory situation with greater common interest, freer intellectual exchange, more mutual learning, and better student personal and social applicability.

A vast majority of 87.5% of the California public community colleges maintain the traditional nonaudio-tutorial general biology laboratory for the non-major. The causes for the strong continuance of the museum-demonstration arrangements, such as financial problems, scheduling difficulties, academic preparation, personnel preferences, transfer articulation, or community control, could constitute a penetrating and insightful study beyond this survey. The assignment of an instructor at a certain time does not negate a strong audio-tutorial approach, but it limits student latitude and access to laboratory materials. The literature urged the maximum utilization of modern audio-visual aids and the constant availability of museum-demonstration arrangements to permit the individual student to relate need to repetition of fundamentals and to free instructors and knowledgeable students for more advanced biological efforts.

Despite the exponential expansion of biological knowledge, adjustments to the general education requirements have shortened many general biology programs. The community colleges showed an almost equal division between the one-semester and the two-semester general biology course with a mean of slightly over three hours per week of laboratory instruction. The course length differences, as marked by the participants, have a direct relationship to the frequency of course objectives, emphases, exercises, laboratory techniques, and technological equipment. The application of this data, therefore, requires individual consideration of program length and weekly laboratory time for any course comparison, development, and execution.

The nonaudio-tutorial teaching approach allowed only 49.4% of the laboratory time for actual student experimentation. That time allowance can be further reduced in actual practice by student lateness, absence, lack of preparation, and biological background and by the shear mechanics of modern college organization such as large classes, equipment accounting, and attendance procedures. The audio-tutorial approach stresses student responsibility for preparation, repetition toward a set level of understanding, and permits the instructor to concentrate on the investigations of the inquiry-type laboratory.

As biology has advanced on many fronts, knowledge of living things has undergone a reformation. Biology reshapes its teaching of that knowledge by changing the emphases that are put on different levels of organization. This survey of current teaching trends and practices indicated that ecology, cell biology, and heredity are the primary stresses but that specific exercises need specific emphases to develop an understanding of the concept of life.

The top ranking of the ecological emphasis correlates positively with the current public concern toward the balance of nature, conservation of natural resources, food chains, population explosion, and pollution of air, soil, and water. The cellular and genetic emphases were next in accentuation and are strong areas of research whose findings make startling public news and crowd the pages of contemporary textbooks. These timely and ready-made factors undoubtedly have some influence on biology instructors in developing laboratory course objectives, approaches, and emphases.

Anatomy and physiology have been progressively superseded through the years as other biological areas have been developed. The taxonomical emphasis was far below the mean and had a lower relative ranking than the objectives concerned with the acquisition of phylogenetic knowledge. Pathology ranked the lowest of course emphases and this was substantiated by the literature findings which never showed a strong stress on the study of diseases in the general biology laboratory.

There was a high acceptance at 88.7% of the many exercises for a full or partial laboratory period. That reflects the traditional broad shallow coverage of the survey course. The microscope ranked as the most frequent general biology exercise and was followed by ecology, metabolism, cell biology, reproduction, and genetics and heredity. The three highest ranked emphases of ecological, cellular, and genetic were in the same sequence amongst the top six exercises.

The scientific method as a distinct exercise was ranked below the mean but is an integral part of the approach to every scientific problem. The four taxonomical exercises ranked a mean of 15 out of the 21 major exercises and reflected the de-emphasis on systemics in the literature. There was a strong tendency in the laboratory toward conceptual considerations in the reorganization of traditional exercises.

Exercise choice requires finesses and adaptability. The laboratory is not a permanent set of stagnating procedures but a foundation with constant variations. A worthwhile doctoral study would be the historical examination of the influences on instructor choice of exercise topics. Another survey could well contrast staff and student expressions on laboratory organization, conduct, and evaluation procedures.

Microscopy ranked as the number one technique which correlated positively with the top ranking given the exercise on the microscope. The three most common techniques of microscopy, gross dissection, and graphing are basic tools for investigation or interpretation of data in the biology laboratory. Slightly over one-half of the laboratory techniques were rated by the participants as not a necessity for non-major students. Only a mean of 13.2% of the laboratory techniques were considered as a must for every student in the general biology laboratory. Most of the top one-third of the techniques were inexpensive and quickly accomplished. Roughly the bottom one-third of the techniques, such as electroencephalography, sectioning, tissue culture, and hydroponics, were time-consuming and required expensive equipment.

Even though ecology was ranked as the number one emphasis in the general biology laboratory and second to the microscope in the exercises, the analysis of air, soil, and water pollutants were only grouped at ranking 18 out of the 27 laboratory techniques. The concern for ecology has evidently not reached the stage of quantification by students.

Some respondees felt that not too much could be done in the general biology laboratory for non-majors beyond the very simple and inexpensive techniques. The reasons given centered on the need for development and demonstration of each topic by the instructor and the lack of student background, capability, motivation, and responsibility at the community college level.

The utilization of technological equipment is a many-faceted problem of scheduled purchasing, regular maintenance, obsolescence, uncertain replacement, and laboratory application and supervision. The equipment at each college, beyond an initial group of basic instruments, depends upon the selection of exercises by the individual biology instructor. There is a sequence of related and dependent decisions that follows naturally from the development of objectives, approaches, and emphases to the selection of exercises, laboratory techniques, and technological equipment.

None of the 50 items of technological equipment was available at all community colleges but every item was available at 6 or more institutions. There was a mean availability of 33.2 items or 66.4%. The top four available laboratory tools were the autoclave, stethoscope, pH meter, and sphygmomanometer. Optical equipment comprises the basic laboratory instrumentation and yet the stereoscopic microscope and flat field microscope ranked 12 and 24, respectively, in availability out of a total of 50 instruments. The questionnaire instructions and technological equipment terminology may have been at fault since the top exercise on the microscope should have had a positive correlation with equipment availability.

The inexpensive technological equipment tended to rank high in both availability and use, except for the stereoscopic and flat field microscopes. The more expensive items, like the nuclear minigenerator, interference microscope, and electron microscope, were least available at the community colleges and least used by students.

The stereoscopic microscope was ranked first in frequency of use by students and was followed by the stethoscope, balance, and paper chromatograph. There were 19.0 items of technological equipment, or a mean of 38.0%, that were actually used by the students at the colleges in the execution of the general biology laboratory exercises for the non-major. About 47.4% of the technological equipment, a mean of 23.7 out of 50 items, was either demonstrated to or used by students.

The total usage of equipment is not nearly as important as the manner of utilization. Pedagogic and monetary values of facilities and equipment cannot be equated but the general biology laboratory can mirror something of modern science. It can also engender an understanding of the time, effort, and money necessary to the structure and quests of the life sciences.

Grants for laboratory equipment tempt departments of life sciences to develop paper programs needing expensive and sophisticated biometric machines. Applications usually require plans for the in-service training of staff. Another doctoral study could well consider the relationships between grant applications, the depth of in-service training, and the eventual extension to classroom demonstration and student use.

In brief, the questionnaire findings revealed that the teaching practices in the general biology laboratory as offered by the public community colleges of California are quite variable but the typical program would:

1. Enroll the student in a one-semester or two-semester course with the traditional nonaudio-tutorial laboratory.
2. Engage all students for three hours per week in the same basic museum-demonstration situation with an equal amount of time for experimentation that culminated weekly with the assigned period.
3. List many course objectives, probably a different one for each exercise, unified by the central aim to understand the life processes common to all organisms.
4. Emphasize the ecological, cellular, and genetic levels or concepts of biological organization.
5. Provide separate exercises on the microscope, ecology, metabolism, cell biology, reproduction, genetics and heredity, and plant anatomy and physiology.

6. Present combination exercises on the characteristics of life, embryology, animal behavior, taxonomy, growth and development, animal anatomy and physiology (circulary, digestive, reproductive, and nervous systems), and evolution.
7. Integrate into the exercises when pertinent the laboratory techniques of microscopy, gross dissection, graphing, chromatography, blood typing, and perhaps staining, blood smearing, starch analysis, sugar analysis, microscopic dissection, and cell squashing.
8. Incorporate student utilization of about 19 items of technological equipment, such as the stereoscopic microscope, stethoscope, balance, paper chromatograph, flat field microscope, pH meter, sphygmomanometer, and incubator, into the experimental portions of specific laboratory exercises.
9. Demonstrate throughout the laboratory phase of the general biology course a mean of 5 items of technological equipment, such as the autoclave, Geiger counter, electrocardiogram, sterilizer, electrophoresis apparatus, hemocytometer, phase contrast microscope, closed circuit TV, dark field microscope, oscilloscope, or electric stimulator, for the accomplishment of the stated purposes.

There seems to be no one best biology laboratory course, just a constant development through trial, feedback, and revision to achieve objectives. The literature urged new methods and materials, reported some experimentation but generally conceded that changes come slowly. The survey disclosed strong traditionalism and a wide gap between teaching trends and practices in the general biology laboratory as offered by the public community colleges of California. The differences can be lessened through rich exploitation of diversity in science education and the generation into introductory biological science courses of the spirit of independent research.

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APPENDIX A.

LETTER OF TRANSMITTAL FOR THE QUESTIONNAIRE

May 10, 1971

Dear Colleague:

The teacher of biology probably has one of the most challenging roles to play in education as a result of the startling and profound developments that have occurred in science and technology. Donald S. Dean wrote in the December, 1970, issue of The American Biology Teacher that "There is abroad today a know-nothing identification of science with technology and a rejection of both because of our failure, as a society, to make the best use of technology." Laboratory sciences have a magnificant structure and quest which belong to the people and provide a basis for other intellectual endeavors. The biology laboratory is a unique opportunity to feel science as an act of investigation and discovery and, as such, is a vital part of general education.

I would appreciate your cooperation in a survey of the non-major general biology laboratories in the public community colleges of California. I am gathering data as to course objectives, approaches, emphases, exercises and the extent to which modern techniques and technological equipment are used to accomplish the objectives. It is hoped that this doctoral study will contribute to improvement in instruction and qualifications of college students to be more effective and thinking persons in a scientifically-oriented society.

The enclosed questionnaire is designed to take only 15 to 20 minutes of your time. Please use the stamped, self-addressed envelope to return the questionnaire when completed.

Sincerely,

Frank L. Bonham, Teacher
Life Sciences Department
San Diego Mesa College
7250 Artillery Drive
San Diego, California 92111

APPENDIX B.

THE QUESTIONNAIRE

A. Objectives

Man's curiosity lies at the root of all sciences. In its broadest sense the biology laboratory has no boundaries. But in the general ferment of biological education, the limitation of time necessitates the careful selection of material along with the establishment of specific objectives. Please mark each of the listed objectives according to the indicated scale:

1 - not an objective in your laboratory.

2 - a secondary objective in your laboratory.

3 - a primary objective in your laboratory.

____ 1. To engage the student in the process of investigation.

____ 2. To detect and state a problem.

____ 3. To develop the power of observation through carefully directed study of the common biological problems and materials in the local environment.

____ 4. To learn to use scientific equipment.

____ 5. To learn to organize facts obtained from observations and experiments.

____ 6. To develop a willingness to suspend judgment until sufficient facts are gathered.

____ 7. To recognize true cause-and-effect relationships.

____ 8. To satisfy the student urge for activity.

____ 9. To learn to transfer the method of scientific thinking to individual and social problems.

____10. To give a command of biological information related to the welfare of intelligent human beings.

____11. To correct common superstitions, unfounded and ignorant practices.

____12. To acquire a knowledge and understanding of the individual organism.

____13. To understand the relation of structure to function.

____14. To understand the life processes common to all organism.

____15. To acquire a knowledge and understanding of cooperative and competitive interrelationships among plants and animals.

____16. To provide scientific knowledge basic to understanding the great problems facing mankind.

____17. To motivate and guide the student in the development of an active interest in his position in the biological world.

____18. To make the student into a creative instead of an imitative being.

____19. To prepare students for intelligent participation in a contemporary world.

____20. To enrich the lives of young people by making them more aware of the biological phenomena taking place in themselves and their surroundings.

____21. To develop a knowledge of specific organisms that effect man most directly.

____22. To appreciate the place and significance of biology in human culture.

____23. To cultivate an appreciation of the scientist and his work.

____24. To develop lasting esthetic values by realizing the orderliness and intricacies existing in nature.

____25. To give students a background of science which will enable them to appreciate and enjoy literature dealing with biological sciences.

____26. To become acquainted with the nature and extent of the professional fields of biology.

____27. To pass an examination.

____28. To satisfy the general education science requirement.

Other objectives and/or comments:

B. Approaches

The CUEBS publication Biology for Non-Majors makes the statement that the feelings of the majority of biologists, whether for or against the laboratory, are best summarized by the respondee who wrote "I support all of the pious platitudes about labs, both for and against, but especially the one about poor labs being worse than none at all." The approach is part of the development and oraniza-tion of a worthwhile laboratory which is not an easy task for any teacher. Please indicate your type of laboratory, the number of semesters or quarters in your school year biology program, the number of hours per week required in laboratory and the approximate percent of time that is scheduled for each of the indicated activities.

____Audio-tutorial laboratory ____Nonaudio-tutorial laboratory

____Number of semesters in the general biology laboratory program.

____Number of quarters in the general biology laboratory program.

____Number of hours per week scheduled for the biology laboratory.

____1. Introductory lecture on tape or by instructor.

____2. Introductory demonstration directed by tape or given by instructor.

____3. Student activities.

____a. Observation of displays or exhibits.

____b. Actual experimentation time.

____c. Analysis of data in class.

____4. Summary discussion by tape or with instructor.

Other approaches and/or comments:

C. Emphases

As biology has advanced on many fronts, knowledge of living things has undergone a reformation. Biology reshapes its teaching of that knowledge by changing the emphases that are put on different levels of biological organization. Please mark each of the following according to the scale as you analyze your own emphases in the general biology laboratory:

1 - little or no stress.

2 - frequently stressed.

3 - strongly stressed throughout.

____1. anatomical

____2. cellular

____3. developmental

____4. ecological

____5. evolutionary

____6. genetic

____ 7. molecular

____ 8. pathological

____ 9. physiological

____10. reproduction

____11. taxonomical

Other emphases and/or comments:

D. Exercises

To many biologists the laboratory is the heart of biology where students are stimulated by curiosity, guided by knowledge and rewarded by discovery. Please mark each of the following according to the indicated scale:

1 - those topics not included in your laboratory.

2 - those topics included with others in a laboratory period.

3 - those topics given a full laboratory period to develop and consider.

____1. The microscope

____2. The scientific method

____3. Characteristics of life

____4. Nutrition

____5. Metabolism

____ 6. Animal behavior

____ 7. Symbiosis

____ 8. Health

____ 9. Ecology

____10. Embryology

____11. Evolution

____12. Cell biology

____a. Enzymes

____b. Organelles

____c. Processes

____d. Structure

____13. Taxonomy - Monera

____a. Bacteria

____b. Blue-green algae

____14. Taxonomy - Protista

____a. Algae

____b. Fungi

____c. Protozoa

____15. Taxonomy - Metaphyta

____a. Non-vascular plants

____b. Vascular plants

____c. Seed plants

____d. Flowering plants

____16. Taxonomy - Metazoa

____a. Porifera

____b. Coelenterata

____c. Platyhelminthes

____d. Aschelminthes

____e. Annelida

____f. Arthropoda

____g. Mollusca

____h. Echinodermata

____i. Chordata

____j. Non-vertebrates

____k. Vertebrates

____l. Mammals

____17. Plant anatomy and physiology

____a. Roots

____b. Stems

____c. Leaves

____d. Flowers, fruits, seeds

____e. Tropisms

____18. Animal anatomy and physiology

____a. Non-mammalian dissection

____b. Mammalian dissection

____c. Circulatory system

____d. Digestive system

____e. Endocrine system

____f. Excretory system

____g. Integumentary system

____h. Muscular system

____i. Nervous system

____j. Reproductive system

____k. Respiratory system

____l. Skeletal system

____19. Reproduction

____a. Animal

____b. Plant

____c. Meiosis

____20. Growth and development

____a. Differentiation

____b. Homeostasis

____c. Mitosis

____d. Regeneration

____21. Genetics and Heredity

____a. Classical genetics

____b. Molecular genetics

____c. Population genetics

Other exercises and/or comments:

E. Laboratory Techniques

There is no one best course, just a constant development through trial, feedback, revision and utilization of techniques to achieve objectives. Please mark each of the following techniques according to the indicated scale:

1 - not a necessity for students in general biology laboratory.

2 - of secondary importance to students in general biology laboratory.

3 - a must for every student in general biology laboratory.

____ 1. analysis, blood

____ 2. analysis, fat

____ 3. analysis, protein

____ 4. analysis, starch

____ 5. analysis, sugar

____ 6. analysis, air pollutants

____ 7. analysis, soil pollutants

____ 8. analysis, water pollutants

____ 9. biometry

____10. blood smearing

____11. blood typing

____12. chromatography

____13. dissection, gross

____14. dissection, microscopic

____15. electroencephalography

____16. electrophoresis

____17. graphing

____18. hybridization

____19. hydroponics

____20. microscopy

____21. photomicrography

____22. plastic embedding

____23. radiation

____24. sectioning

____25. squashing, cells

____26. staining

____27. tissue culture

Other techniques and/or comments:

F. Technological Equipment

The study of biology necessitates the utilization of a variety of human resources. Pedagogic and monetary values of facilities and equipment cannot be equated but the general biology laboratory can mirror something of modern science research. Please mark each of the following according to the indicated scale:

1 - available at your college.

2 - demonstrated to the students.

3 - actually used by the students.

____ 1. adding machine

____ 2. auxanometer

____ 3. autoclave

____ 4. bacteria colony counter

____ 5. balance

____ 6. blender

____ 7. calculator

____ 8. calorimeter

____ 9. centrifuge

____10. chromatograph, paper

____11. chromatograph, thin layer

____12. colorimeter

____13. electrophoresis apparatus

____14. electrocardiograph

____15. environmental chamber

____16. freeze drying equipment

____17. Geiger counter

____18. hemocytometer

____19. incubator

____20. kymograph

____21. lights, ultra-violet

____22. microscope, electron

____23. microscope, dark field

____24. microscope, flat field

____25. microscope, phase contrast

____26. microscope, interference

____27. microscope, polarizing

____28. microscope, stereoscopic

____29. microtome

____30. nuclear minigenerator

____31. opthalmoscope

____32. oscilloscope

____33. osmometer

____34. pH meter

____35. physiograph

____36. pneumograph

____37. potometer

____38. refractometer, hand

____39. respirometer

____40. scaler

____41. spectrophotometer

____42. sphygmomanometer

____43. sterilizer

____44. stethoscope

____45. stimulator, electronic

____46. transpirometer

____47. TV, closed circuit

____48. vitalometer

____49. water bath, thermostatic

____50. Warburg apparatus

Other technological equipment and/or comments:

APPENDIX C.

ABSTRACT OF DISSERTATION

The focal point for teaching biology, for most biologists, is found in the laboratory. Setting up a biology laboratory course that has the least common denominators, allows maximum student participation, introduces a variety of pertinent technological resources, involves true scientific investigative techniques, and links the individual with his environment, holds the greatest promise for modern biology teaching and learning.

The problem of this study was to determine the common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, and the extent to which modern laboratory techniques and technological equipment are utilized as an aid to instruction and for the fulfillment of course objectives in the general biology laboratory of the public community colleges in California.

This study is important for today we are dominated by science and technology and the average American is scientifically and technologically illiterate. He confuses science with technology and rejects both because of the failure of society to make the best use of technology. We live in a scientific civilization and yet inadequate science-teaching of non-scientists in college has developed mistaken views, dislikes, and misunderstandings. The 1970's demand changes in biological education such as the use of general introductory biology courses to provide the student with a basis for developing rational and intelligent awareness of applicable scientific knowledge, attitudes, and procedures.

A questionnaire was developed from a survey of the literature for common course objectives, usual methods of instruction, prevalent unifying emphases, typical laboratory exercises, modern laboratory techniques, and available technological equipment. The questionnaire was submitted to the 93 public community colleges of California to determine the core of elements from each of the above six categories that through common practice are typical of the general biology laboratory for non-majors.

The literature indicated that the teaching trends in the general biology laboratory would:

1. Enroll the student in a year-course with unique arrangements such as audio-tutorial or open laboratory situations for the development of basic background and techniques.
2. Engage the student through an inquiry-type laboratory for a minimum of three hours per week in one or more long investigations toward which all his efforts would be concentrated.
3. Allow student selection of the area of emphasis which would usually be in the major areas of cell biology, heredity and genetics, animal behavior, or ecology.
4. Limit objectives to the behavioral objectives designed to give order and purpose throughout the investigation but with personal and social applicability.
5. Make available technological equipment necessary for the laboratory techniques as needed in a limited but unfolding personal investigative problem.

The questionnaire findings revealed that the teaching practices in the general biology laboratory as offered by the public community colleges of California are quite variable but the typical program would:

1. Enroll the student in a one-semester or two-semester course with a traditional nonaudio-tutorial laboratory.
2. Engage all students for three hours per week in the same basic museum-demonstration situation with an equal amount of time for experimentation that culminated weekly with the assigned period.
3. List many course objectives, probably a different one for each exercise, unified by the central aim to understand the life processes common to all organisms.
4. Emphasize the ecological, cellular, and genetic levels or concepts of biological organization.
5. Provide separate exercises on the microscope, ecology, metabolism, cell biology, reproduction, genetics and heredity, and plant anatomy and physiology.
6. Present combination exercises on the characteristics of life, embryology, animal behavior, taxonomy, growth and development, animal anatomy and physiology (circulatory, digestive, reproductive, and nervous systems), and evolution.
7. Integrate into the exercises when pertinent the laboratory techniques of microscopy, gross dissection, graphing, chromatography, blood typing, and perhaps staining, blood smearing, starch analysis, sugar analysis, microscopic dissection, and cell squashing.
8. Incorporate student utilization of about 19 items of technological equipment, such as the stereoscopic microscope, stethoscope, balance, paper chromatograph, flat field microscope, pH meter, sphygmomanometer, and incubator, into the experimental portions of specific laboratory exercises.

9. Demonstrate throughout the laboratory phase of the general biology course a mean of 5 items of technological equipment, such as the autoclave, Geiger counter, electrocardiogram, sterilizer, electrophoresis apparatus, hemocytometer, phase contrast microscope, closed circuit TV, dark field microscope, oscilloscope, or electric stimulator, for the accomplishment of the stated purposes.

There seems to be no one best biology laboratory course, just a constant development through trial, feedback, and revision to achieve objectives. The literature urged new methods and materials, reported some experimentation, but generally conceded that changes come slowly. The survey disclosed strong traditionalism and a wide gap between teaching trends and practices in the general biology laboratory as offered by the public community colleges of California. The differences can be lessened through rich exploitation of diversity in science education and the generation into introductory biological science courses of the spirit of independent research.