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ABSTRACT

The investigator taught all experimental classes during the 12 days of instruction, utilizing ten units of a locally-developed text, a test based on the materials, and a series of slides and related discussion. The experimental group included 97 subjects enrolled in three classes studying second-year biology and one class studying tenth-grade social studies; the control group included 108 students enrolled in five classes studying second-year biology. Three subscores (biological concepts, nature of the scientific enterprise and the work of scientists, and social implications of the concepts) and a total score were obtained from the 90-item multiple-choice test administered to experimental and control classes as both a pretest and a posttest. Significant achievement gain on the three subscores and the total score was found for all classes in the experimental group. The control group showed no significant gains. In responding to a student questionnaire, a majority of the students (73 percent) expressed a positive opinion about the interest potential of the reading material, and a majority (57 percent) also indicated that the reading material was less difficult than that ordinarily experienced in biology classes. It was concluded that the performance of the experimental classes met the criteria under which the socio-historical approach was to be judged acceptable. (Author/CP)

THE FEASIBILITY OF TEACHING BIOLOGY VIA THE SOCIOHISTORICAL APPROACH

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Technical Report No. 66

THE FEASIBILITY OF TEACHING BIOLOGY VIA THE SOCIOHISTORICAL APPROACH

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Report from the Science Concept Learning Project

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PREFACE

Contributing to an understanding of cognitive learning by children and youth—and improving related educational practices—is the goal of the Wisconsin R & D Center. Activities of the Center stem from three major research and development programs, one of which, Processes and Programs of Instruction, is directed toward the development of instructional programs based on research on teaching and learning and on the evaluation of concepts in subject fields. The staff of the science project, initiated in the first year of the Center, has developed and tested instructional programs dealing with major conceptual schemes in science to determine the level of understanding children of varying experience and ability can attain.

The exploratory study described in this Technical Report was an attempt to determine the feasibility of teaching science concepts to high school students through instruction on the relationship of science and society or the social implications of science. Gain scores earned by students enrolled in biology and social studies classes who had been instructed utilizing the sociohistorical approach were greater than those receiving the regular instruction. In addition, gain was shown to be independent of IQ. Students reported that the instructional materials, to be made available in a Practical Paper from the Center, were very interesting and less difficult than other science materials.

Herbert J. Klausmeier
Director

CONTENTS

CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

ABSTRACT

This study was designed to test the feasibility of teaching biology via a sociohistorical approach utilizing the ideas of biogenesis and spontaneous generation with emphasis on the social implications of the two ideas. The criteria under which the approach was to be judged as acceptable were:

1. A significant increase in subject matter knowledge possessed by students of average ability and above.
2. No significant differences between the levels of achievement of students enrolled in a biology course and students enrolled in a social studies course when both receive instruction utilizing the approach.
3. A high level of student interest as indicated by student responses to an interest questionnaire.
4. A low level of difficulty encountered by students as indicated by their responses to items on a questionnaire.

Instruction utilized 10 units of locally developed text, a test based on the material, and a series of slides and related discussion. The investigator, who used a presentation-discussion technique during the 12 days of instruction, taught all experimental classes. The experimental group included 97 subjects enrolled in three classes studying second-year biology and one class studying tenth-grade social studies; the control group included 108 students enrolled in five classes studying second-year biology.

Three subscores—biological concepts, nature of the scientific enterprise and the work of scientists, and social implications of the concepts—and a total score were obtained from the 90-item multiple-choice test administered to experimental and control classes as both a pretest and a posttest. Statistical tests for significance were applied to gains in achievement as indicated by differences between pretest and posttest mean scores.

Significant achievement gain was found for all classes in the experimental group on the three subscores and the total score. The uninstructed classes of the control group showed no significant gains. There was no significant difference between the performance of the three classes studying second-year biology and the class studying tenth-grade social studies when adjustment was made for IQ. A correlation coefficient of .311 was obtained between individual gain scores and individual IQ's.

In responding to a student questionnaire a majority of the students (73%) expressed a positive opinion relative to the interest potential of the reading material and a majority (57%) also indicated that the reading material involved was less difficult than material ordinarily experienced in biology classes.

It was concluded that the performance of the experimental classes met the criteria under which the sociohistorical approach was to be judged acceptable.

I
THE PROBLEM

INTRODUCTION

Science instruction for the purpose of providing information of practical value became a part of the secondary school curriculum in the academies initiated by Benjamin Franklin in 1751 (Woodburn and Oburn, 1965, and Richardson, 1957). From 1821 on, the number of high schools increased and the number of academies declined. The early high school not only had the teaching of practical information as an objective but also meeting the need for the children to have a better understanding of the glories of God. The attempt to meet this need was here conceived to be through a study of nature. It can be said that the high school was planned to "meet the functional needs of young people" (Richardson, 1957).

As time passed, the objectives of science teaching began to change; science became a means to achieving "mental discipline" at the same time it was trying to meet the needs of young people in an era of industrial expansion. Underhill (1941) explained that the competition that existed between the classical and utilitarian or functional education during the 1870's led to an interest in agriculture and other related subjects of practical importance. This became a part of what was known as the nature study movement that reached its peak in the elementary school at the turn of the century. There was concern that the child should know his place in the world, be able to conserve his health and make use of his leisure time (Underhill, 1941). Nature study was also a means of helping the child to understand agriculture and its relation to nature. At about the same time, there was a shift in the secondary school from the natural history approach to one of botany and zoology with a major emphasis on morphology (Hurd, 1961). From 1900 to 1930 there was a change from the "mental discipline" approach in biology to one of "humanizing biology." The NEA Committee on Reorganization of Secondary Schools (1918) felt that the objectives of the organized science curriculum should center about the teaching of social goals. Near the end of this period there was some emphasis on "science as science." The AAAS (1927) suggested that the development of scientific thinking should be an objective of science teaching. The NSSE Thirty-first Yearbook (1932) suggested that all science instruction should be organized around broad principles or concepts, an idea that was to become widely popular some 20 years later.

During the period from 1930 to 1950 there was some conflict between the ideas of science for general education and science as preparation for careers. In *Science in General Education*, the Progressive Education Association (1938) tried to relate science teaching to such areas as (1) personal living, (2) immediate personal-social relationships, (3) social-civic relationships, and (4) economic relationships. The great stress in biology just prior to 1950 was that it should meet the needs of the individual (Hurd, 1961). Some of the slogans found in science education during the first half of this century were "science for understanding social environment," "science to help meet the needs of the democratic life," "science for citizenship," "science for family life," and "science for life adjustment."

Only recently has "science for the sake of understanding science" emerged as a main objective for teaching science. This objective has led to a number of new phrases related to science teaching such as "science as inquiry," "the inquiry approach to science teaching," "teaching science through discovery," "knowledge of the scientific enterprise," "the process approach to science teaching," "conceptual schemes as unifying themes," and the "concept-centered curriculum." Also consequent to this activity has been the development of a number of "modern" science courses, i.e., BSCS biology, PSSC physics, and CBA and CHEMS chemistry, largely through the support of federally funded agencies, with understanding science as an objective. The desire appears to be the production of scientists and probably a promotion of the understanding and utilization of the methods of science. The human and/or societal relationship is generally absent.

In this study the belief is nourished that some portion of the high school population may wish to learn the way in which science and people interact. The attempt here is to investigate the hypothesis that a sociohistorical approach to teaching biology is realistic.

THE IMPORTANCE OF UNDERSTANDING THE INTERRELATIONSHIPS OF SCIENCE AND SOCIETY

The belief that science and society are mutually related has been stated explicitly by some philosophers and sociologists of science. Barber (1952), in his book *Science and the Social Order*, quoted the following from an unpublished 1949 manuscript by Parsons:

> Science is intimately integrated with the whole social structure and cultural tradition. They mutually support one another—only in certain types of society can science flourish, and conversely without a continuous and healthy development and application of science such a society cannot function properly.

Lachman (1956) has stated much the same thing:

> Science cannot segregate itself from society. It is, in fact, a product and a part of a society and its morality; and science continues to exist only because social attitudes or institutions support it, or at least, are not generally or violently opposed to it.

Science as an important force in helping shape society has been described in the writings of such men as Bronowski (1965) and Glass (1959).

In the past, education has recognized the relationships that exist between science and society and statements made in the field of education have indicated the importance of understanding that relationship. The Forty-sixth NSSE Yearbook (1947), in a definition of the nature of generalized science courses, carried the following quote from the Harvard Report of 1945:

> Science instruction in general education should be characterized by broad integrative elements—the comparison of scientific with other modes of thought, the comparison and contrast of the individual sciences with one another, the relations of science with its own past history and with general human history, and of problems of science with problems of human society. These are areas in which science can make a lasting contribution to the general education of all students.

In the Fifty-ninth NSSE Yearbook (1960) it was stated that the secondary school curriculum "should carry young people farther along in their understanding of selected generalized concepts, the method of science, and the social implications of science." It was pointed out in this yearbook that "the science teacher must teach so as to demonstrate the function of science in our society and impart the method by which science has made contributions to society."

The problem of transmitting to the students an understanding of the interrelation and interaction of science and society has concerned educators in both science and social studies. From statements made by some of these educators it would seem evident that not all had been done that might have been to aid in transmitting to the student such understanding. Todd (1957) wrote in the NCSS Twenty-seventh Yearbook:

> The problem social studies teachers must come to grips with is not merely the social implications of automobiles or egg-beaters, but the social implications of science itself. But one cannot begin to discuss the social implications of science until he has at least a rudimentary understanding of science, which is to say of the scientist, for without scientists we have no science. It follows that the way the scientist works and the "process of travail" by which he creates scientific knowledge needs to be explored and understood by as many people as possible, for, until the "process of travail" is explored and understood, a lot of otherwise intelligent citizens are going to think of science as modern magic and of the scientist as a twentieth century magician who needs only to pass his hand over his Alladin's lamp to reveal the wonders of heaven and earth.

More recently, Drummond (1964) pointed out the shortcomings of both textual materials and teachers in the process of integrating science into the "cultural matrix":

> Would anyone deny that what is taught in science should be integrated into the cultural matrix, and what is taught about culture should include the role of science? And yet no textbook that I know of, no teacher that I have observed, has yet made more than a passing effort to achieve this goal. No doubt some people have made more strenuous efforts, but that they are in the minority can hardly be doubted.

Later on, Drummond made this statement:

> Upon reflection, we all recognize the impact of society on scientists at work. Why, then, ignore it in the teaching of science? Or in the teaching of history? Or in literature? The other side of the coin, the impact of science on society, can hardly be overlooked in our times. It is a sad commentary that the important interrelationships between science and society receives little more than lip service in most of our schools.

In his discussion of the opinions of C. P. Snow related to the "Two Cultures," Roberts (1961) pointed out that a gap should not and, in fact, does not exist between science and culture or science and the humanities since "science is one of the humanities, a discipline concerned with man and life." Burkhardt (1959) stated that to teach science or the humanities in an absence of their relationship with each other would fail to result in the understanding or unified culture which should be the consequences of teaching science or humanities. These points of view have been translated into responsibility for both science and social studies education by Pella (1965):

> Social studies and humanities teachers know too little about science, and science teachers know too little about what is going on in the social studies and the humanities. How can pupils be helped to see that the social implications of science are the results of the interactions of Science and Society? Is it possible for social studies to ignore the causes of the developments or for science to ignore the consequence of its developments? This problem is one for science and social studies education.

In discussing the historical approach to science teaching, Nash (1951) suggested that perhaps a different method of teaching science than had been used in the past might result in a better understanding of science and scientists.

> The public's understanding of, and occasionally positive antipathy towards, science and scientists is a bitter reflection on the methods by which we have previously attempted to teach science. There is every reason to consider the possibility that some nontraditional approach to this problem may prove superior to the methods that have been our reliance in the past.

On the basis of statements such as these, it seemed important to investigate a method of transmitting to high school students some aspect of science which could serve to illustrate the interrelation and interaction of science and society.

ASSUMPTIONS UNDERLYING THE STUDY

The following assumptions have been made in relation to various aspects of the study:

1. That interrelationships exist in science and society.
2. That some understanding of these interrelationships will be helpful to people in all walks of life as they carry on their daily activities as consumers of knowledge of varying degrees of credibility, as consumers of scientific or technological products, as contributors to making social, economic, and political decisions, and as contributors of financial support needed for such decisions.
3. That some of these interrelationships which are related to the study of biological sciences can be identified and precisely described.
4. That these interrelationships between science and society taught in the unit should be directly related to the scientific concept involved.
5. That a need for more effective means of learning these interrelationships exists.
6. That a group of high school age pupils exists that will benefit from a sociohistorical approach to learning.

STATEMENT OF PROBLEM

To test the feasibility of teaching biology via a sociohistorical approach utilizing the ideas of biogenesis and spontaneous generation with emphasis on the social implications of the two ideas.

CRITERIA FOR ACCEPTANCE OF THE APPROACH

The criteria for acceptance of the approach were:

1. There shall be a significant increase in subject matter knowledge possessed by students of average ability and above as indicated by scores on pretests and posttests related to biological concepts, nature of the scientific enterprise and the work of scientists, and the social implications of the biological concepts involved.

2. There shall be no significant differences between the levels of achievement of students enrolled in a biology course and students enrolled in a social studies course when both receive instruction utilizing this approach.

3. There shall be a high level of student interest as indicated by student responses to an interest questionnaire.

4. There shall be a low level of difficulty encountered by the students as indicated by their responses to items on a questionnaire.

DEFINITION OF TERMS

For the purposes of this study, the sociohistorical approach to science instruction is defined as *teaching the development in a sociohistorical setting of certain selected concepts in science which have exhibited a high level of social significance.*

A societal implication is *a direct or implied relationship between a scientific or technological development and one or more facets of society* (O'Hearn and Pella, 1967).

II

RELATED LITERATURE

THE SOCIOHISTORICAL APPROACH AS A METHOD OF INSTRUCTION

The sociohistorical approach, as defined in this study, has several points in common with other historical approaches to science instruction suggested in the past by such men as Conant (1947), Nash (1952), Cohen (1952), Kilgour (1952), Ihde (1953), and Klopfer and Watson (1957). The primary difference between the sociohistorical approach used in this study and the historical approach generally advocated as a method of science instruction is the considerable stress placed on the interrelation and interaction of science and society in the sociohistorical approach in addition to teaching for understanding of scientific processes and the scientific enterprise.

INTEREST IN THE HISTORICAL APPROACH TO SCIENCE INSTRUCTION IN THE PAST

A consideration of historical approaches previously used in science instruction and their relative value is worthwhile. Ihde (1953) said, "The historical approach to science instruction is merely sound teaching since it enables the student to see knowledge on the subject revealed in the manner in which it unfolded before the eyes of the great investigators in the field." In another statement, Ihde further indicated the basic importance of the use of historical material in science instruction:

> Historical material also helps show that science is part of the human enterprise. This point is often missed when the course becomes solidly loaded with factual and theoretical materials. In the past few decades science teachers have eliminated more and more historical material from their courses. This trend has been particularly marked in colleges but has also taken place in the schools. The excuse has been that science progresses so the old must give way to the new. The fear of not being up-to-date is an awesome one for textbook writers.
>
> This attitude is a dangerous one. It easily leads to the belief that only the new is important. However, the new often represents a development in applied science and leads to the belief that investigations, to be significant, must be practical. There is a failure to recognize that new developments have an earlier and more fundamental background. This recognition is more important than an aura of up-to-dateness.

In the preface to *A History of Physics* (Cajori, 1929), there appears the following statement made by Ostwald more than 70 years ago:

> While by the present method of teaching, a knowledge of science in its present state of achievement is imparted very successfully, eminent and far-sighted men have repeatedly been obliged to point out a defect which too often attaches to the present scientific education of our youth. It is the absence of the historical sense and the lack of knowledge of the great researches upon which the edifice of science rests.

The value of the historical aspect of a scientific subject was described by Dwight (1937) thirty years ago:

> History has an important place in the development of a scientific subject, not only for its cultural value, but for the perspective which it offers to the subject as a whole. It calls to mind the attitudes of the contemporaries of the great scientists towards the latter's discoveries. It indicates the going and coming of "fads" in public interest, and the state of civilization at the time.

Ritchie (1952) wrote that for university students to "hanker after the science" of the current time to the exclusion of the history of science would eventually do away with "genuine men of science" and result in "third-rate technicians obstinately and superstitiously using technique the reason for which they do not understand."

STUDENTS WHO MAY BENEFIT FROM USE OF HISTORICAL MATERIALS

Some scientists and historians of science have been interested in the use of historical materials in science instruction for the "nonscientist" or "layman." Conant (1947) has stated that for "nine people out of ten the historical method will yield more real understanding of a complex matter." According to Stimpson (1947), "The historical method and approach reach many who would otherwise be deterred by their own unfamiliarity with technical terminology." Kilgour (1952) has pointed out that the historical approach is more effective than instruction in the principles and facts of science for the large majority of nonscience students in developing an understanding of science.

Others, including Cohen (1952), have felt that the history of science is of importance to other than just the "nonscientist" or "layman." Cohen wrote,

> From the strict point of view of the practicing scientist, a case may be made that the history of science is not a primary essential; at least, the history of science may be less essential than, say, mathematics. Yet I firmly believe that the history of science is useful to the scientist just as it is to the nonscientist.

Strong (1950) wrote that "men concerned with work in science are, or should be, also concerned with the conditions under which scientific work is furthered or obstructed." While Strong did not question that instruction in science should be the practical requirement in the "immediate foreground" or that instruction in science should be replaced by the history of science, he did question the "notion that the historical study can be omitted without serious consequences." Klopfer (1964) strongly implies that the desired learning outcomes for the case history approach are important for students who will be career scientists as well as nonscientist consumers and science-supporting citizens. Taylor (1952) has stated that from his experience about a third of the science students (university undergraduates) can be interested enough in the history of science to give it serious study while another third thinks it is a waste of time. Taylor delimits what he thinks the historical approach to science instruction should be in the following statement:

> I would suggest that science and the history of science are not as closely akin as the words would imply. The older part of the history of science requires for its study a background that students do not possess, while the newer is too much like the elements of what they are learning. I think that the subject which should be added to the science course should include the whole impact of science upon man, in philosophy, religion, social science, technology and so on and should be treated historically; that in addition to the facts and principles of science, now learnt, the student should be shown what science has done and is doing to us. That is a subject in which the student could scarcely lack interest and it would be of obvious value to his social life.

THE DIFFERENCE BETWEEN "HISTORY OF SCIENCE" AND THE "HISTORICAL METHOD OF INSTRUCTION"

The historical approach to science instruction, in which historical and scientific knowledge are integrated for use in instruction in a science course in the form of case histories, anecdotes, etc., is not to be confused with the *history of science* as a discipline which deals with the history of science as an end in itself. Albrecht-Carrie (1951) wrote that

> it is well to be clear, however, that such an undertaking [Conant's historical approach] is not the same thing as the history of science. Granting that the historical approach to the understanding of science can be a fruitful one, the history of science as such will remain a related but distinct discipline.

Kilgour (1952) stated that "teaching the history of science and teaching the sciences historically are two entirely different things." Kilgour defines the history of science as *the interpretation of the progress of the concepts and conceptual schemes concerning what underlies the appearances of the natural world*. Thomas (1954) wrote that the history of science is "essentially the study of the growth of ideas." Even though the history of science is developed as a discipline in the colleges and universities, many of the ideas which have been expressed concerning the history of science, including the two previous definitions of the history of science, bear some relation to the historical approach to science instruction in the high school. The statement made by Thomas concerning the history of science seems very applicable to socio-historical science courses at the high school level:

> If we can lead students to appreciate the way in which man's concepts of Nature have been built up, telling them of past failures as well as of successes, and revealing the personal characters of some of those who have worked in the search for knowledge, we should make them better scientists and at the same time illustrate the social and human aspects of their studies. All this can be done by the institution of well-planned courses in the history of science.

The history of science has, in fact, been suggested as a part of the secondary curriculum in the past. Sigerest (1944) wrote, "Whether a special course is given or not, the history of science should, in the secondary school, become an integral part of the teaching of history as well as of science." Later, he stated,

> The teaching of science . . . can gain a great deal if the historical approach is used as a didactic method. The teacher will soon find that there is no better way of making complicated matters clear to the student than by presenting the subject genetically.

Klopfer (1964) stated that the case histories used in the historical approach to science instruction with which he was associated were not prepared for use in history of science courses, but might be used profitably in this way if anyone wished to do so. Klopfer wrote,

> In the *History of Science Cases*, we are not attempting to teach history, but we do use the historical approach to illustrate and provoke the development of important ideas concerning science and scientists. It is primarily for this purpose that the *History of Science Cases* have been designed for use as units of instruction within existing science courses in the secondary school.

It would seem logical to assume that the relationship existing between the history of science as a discipline and any historical approach to science instruction in the high school is one in which the factual background for the historical approach in the high school is drawn from the history of science and arranged so as to be compatible with the intended high school science instruction. Certainly there are basic limitations to the use of the history of science in the teaching of science. Bronowski (1963) commented on the limitations as well as the possibilities of the history of science:

> A knowledge of history of course, even the history of science, will not do duty for science. But it gives us the backbone in the growth of science, so that the morning headline suddenly takes its place in the development of our world. It throws a bridge into science from whatever humanist interest we happen to stand on. And it does so because it asserts the unity not merely of science but of knowledge. The layman's key to science is its unity with the arts. He will understand science as a culture when he tries to trace it in his own culture.

Rabinowitch (1958) expressed the following ideas concerning the limitations of "teaching science in historical perspective":

> It has sometimes been suggested that the teaching of science in historical perspective would provide an essential contribution to an understanding of the involvement of science in the general progress of mankind. This is true—but only to some extent; to the same extent to which the teaching of history of science as part of the general history course could assist nonscientists in the realization of the essential role science has played in the progress of human society. In both cases, much more than the knowledge of the historical developments is needed. In high-school teaching, the ethical and moral aspects of science, the relation of scientific truth to the general system of human values, and the responsibility of science and scientists for the future of society, must be impressed on students.

METHODS OF INTRODUCING HISTORICAL MATERIALS

Ihde (1953) has written that, considering the fact that the historical approach to the teaching of science might be desirable, the problem still remains as to how historical materials should be introduced. He listed the following three alternatives:

1. A random use of history: This is possible but not apt to be very successful.

2. The study of the history of science approach: This is an established academic discipline in several universities in the United States. The history of science should not, however, be included in the schools as a subject since the student lacks the background in science necessary for a fruitful study of the history of science. Ihde stated, "We must first teach science, including history, rather than history of science."

3. The case history: This is the most useful approach. The idea of the case history involves the "extensive study of a small number of important scientific developments." Ihde summarized the nature of the case study in the following way:

> The sequence of observations and interpretations in the investigation of a scientific problem is studied in its intellectual and cultural framework. In this way it is possible to see the interplay of ideas, the groping, the false starts, the role of chance, the role of the working hypothesis, the influence of apparatus, the role of mathematics, the friction as well as the cooperation between personalities, and the influence of the social, political, and religious climates.

Of the alternatives listed by Ihde, the case history approach is most similar to the sociohistorical approach used in this study. According to Van Deventer (1960), the case history approach to science instruction developed out of the cultural heritage approach which was one of the three categories of general-education science courses experimented with in the colleges during the late 1930's and the early 1940's. The cultural heritage courses made use of either a chronological historical approach or were case study courses which centered around selected examples chosen from the history of science.

In the sociohistorical approach utilized in this study the histories of the concepts were traced chronologically for two reasons. First of all, this was the way in which the concepts developed, and secondly, this was the most effective way to assure that no important points were overlooked. The chronological historical tracing of the concepts was of no more importance, however, than the relating of the concepts to their social context. The importance of relating historical cases to their social setting has been stated by French (1952).

> Certainly historical cases are simpler and can provide meaningful illustrations of scientific techniques. Nor need they be considered in a social vacuum since they can be closely integrated with social needs of their times.

Later French wrote:

> Far from being "brief excerpts from a variety of sciences," they explore and probe to real depth. Furthermore, these scientific cases are related to the active living events of the day and are placed, so to speak, in their proper social context.

THE CASE HISTORY AS A HISTORICAL APPROACH TO SCIENCE INSTRUCTION

The structure of the unit upon which this study was based closely resembled the case history "pattern" given by Nash (1952). In describing the structure of a case history, Nash listed the following six areas:

1. The technical core of the case. Nash included here such things as "the nature of the data, the difficulties of getting at the 'facts', the ambiguities these 'facts' may contain, and so forth." The emphasis on this factual information was to regard it "as only a by-product of instruction in the patterns of science."

2. The historical core of the case. In this area, Nash included "the gradual development of a conceptual structure, based on experimental observations and on things less tangible . . . considered in particular detail." This area, based on original writings of scientists actually involved, tried to give an accurate picture of the way in which concepts develop by showing "the hesitations, retrogressions, and failures" as well as "the intuitive insights, the inductive brilliancies, and the triumphant apprehension of a major organizing principle of science." Nash mentioned the value of developing two competing theories side by side. An emphasis is placed on the "purely aesthetic appeal of a well-contrived conceptual scheme."

3. The setting of the case in scientific history. By "following the development and assimilation of ideas arising from previous scientific work . . . and examining the influence of preceding and contemporary philosophic attitudes," it can be shown that science develops in a world "full of ideas, scientific and otherwise," and that the attitudes at a time effect "the appraisal of what constitutes a 'rational' explanation."

4. The human aspects of the situation. Nash wrote, "We show the experimental misadventures and human frailties of our protagonists . . . seek to display science as an intensely human venture . . . convey to the students some sense of a 'visit to the laboratory'—a *real* laboratory, where real research is in progress." Nash pointed out that "it is also important to dispel the notion that the operations and conclusions of science have perfect certainty."

5. The setting of the case in general intellectual and social history. In this area are considered such things as "the social and economic atmosphere surrounding the scientific undertaking . . . placing science within the larger framework of human activity . . . the variety of extrascientific factors that have helped to shape the 'scientific' response to both facts and theories." Nash wrote, "Through the integration of science with its social environment, it is possible to overcome the repellent notion that science is a thing apart from the culture of its time."

6. The modern relevance of the facts and ideas involved. The emphasis here was to stimulate the interest and broaden the view of the student by "examination of the continuing significance of the case" without overemphasizing the "technological changes through which science has affected civilization."

It should be pointed out that the historical approach described by Nash was one used in general education, and the course in which it was used had the "relatively limited" objective of presenting "science as a part of our civilization (not simply as the basis of technology), as a rich part of our cultural heritage, and as one of the intensely creative aspects of human endeavor." The six different areas of a case history described by Nash did not all have the same potential for motivation for students with varying interests in science. The technical core of the case, according to Nash, may arouse in some students an interest, but generally for those students who are not going to concentrate on science the "response may be lukewarm." The historical core of the case, with its "aesthetic appeal of a well-contrived conceptual scheme," may be appealing to working scientists, but not a "sufficient source of student motivation" for the student who doesn't concentrate in science. For these reasons, Nash (1952) wrote, "Thus in many instances, the best sources of motivation may lie outside the core of the case."

The setting of the case in scientific history is of interest to "nonmajor students" through the philosophic overtones relevant to the case. The human aspects of the situation allow for student motivation in a way that "more science" might fail to do. According to Nash, "It may be objected that the time expended in these connections might be better spent in teaching 'more science' as such. But there is a strong motivation for our students in the human appeal of the story, and such motivation is probably not present in 'more science.'" Nash felt that "there is a powerful source of motivation here," and also that "considerable stress" can be laid on the integration of science with its social environment. The modern relevance of the facts and ideas involved in the form of an examination of the continuing significance of the case is, said Nash, "a most potent influence in stimulating the students' interest and at the same time broadening their view." If there is not so much emphasis placed upon the "technological fruits" of science that science and the products of science become confused, then Nash believed that the following situation may hold:

> If the importance of the technological impact of science is called to the students' attention, there is good reason to suppose that they can, and will probably want to, continue independently their study of the subject. Surely the preparation of a firm foundation for the students' continued self-education is one of the highest goals of formal education. And, indeed, unless some such foundation is laid down, attempts to acquaint the students with the social implications of science must ultimately fail since, as Professor Le Corbeiller has noted, the social implications of technology are shifting and widening with breath-taking rapidity.

Winthrop (1965) described seven units which make up a proposed liberal arts course in the history of science. Such a course would be introduced at the undergraduate level and, according to Winthrop, "would impart an appreciation of the many ways in which science and social concerns tend to become interlocked in some fashion, and would represent a curricular experiment which would be unique for purposes of general education." The seventh and last of these units was entitled "The social impact of science and technology" and was explained in this way by Winthrop:

> The last and seventh unit in the kind of history of science course which we are proposing here, namely, *the social impact of science and technology*, should be concerned with the extent to which the types of social change which the average citizen experiences, are due to developments in science and technology. In this way the whole subject becomes more directly meaningful for the student. He is then in a position to see why instruction in the history of science is important, by being shown how it may change a country's social psychology and living habits, how it can alter the pattern of living and affect community organization, and why it necessitates the development of new institutions and the revamping of public forms of education.

It seems clearly evident that considerable support has existed for the development of instruction which relates science and society through the study of their interrelationships and is presented through some historical approach. Among the most widely noted approaches to science instruction has been that of Conant's *Harvard Case Histories in Experimental Science* (1948, Conant and Nash, 1957). These cases were prepared especially for use in a general education course for freshmen and sophomores at Harvard University. Conant was not interested in the use of such courses at the secondary level. He wrote, "I suggest courses at the college level, for I do not believe they could be introduced earlier in a student's education." Shirley (1957), however, in discussing the fundamental ideas behind the *Harvard Case Histories*, stated, "Most of our high school and introductory courses in science could be vastly improved by using one or more of these *Case Histories* as Dr. Conant is doing, both to place more emphasis on the methods of science and to mitigate in some measure the necessary dogmatism inherent in such introductory courses."

The objective for such general education courses as mentioned above, according to Conant (1947), "would be to give a greater degree of understanding of science by the close study of a relatively few historical examples of the development of science." Shirley stated that Conant's primary objective was not that of "showing the interrelationships between all sciences, of presenting the salient facts of science, or of presenting a systematic history of science, but of using his case history to render the mode of thinking of the scientist intelligible to the nonscientist."

Conant did express, however, an interest in the interaction of science and society. Even though his treatment of this aspect of the case history may have been limited in comparison to the sociohistorical approach used in this study, Conant set few restrictions on what others may wish to include about the relation of science and society. He wrote, "Obviously there is enormous latitude in the way this aspect of the course might be presented and how much time might be devoted to those phases of the case histories which illustrate the relation of science and society."

Shirley (1950), in discussing Conant's *Case Histories*, made the following statement:

> Yet, though it may be presumptuous to criticize either the Harvard course Natural Science 4 or the ideas behind it on the basis of these printed documents, the social historian is likely to be somewhat disappointed by the restricted view of the development of science which in themselves they present. There is a brief attempt in each volume to place the experiment discussed into the theoretical background of its time, but there is little effort made to show the way in which it grew out of a particular need or a particular situation. As a result, the case histories by themselves at first glance appear to reinforce the nineteenth-century view of science as a series of steps in which the inherent genius of each great scientist advanced men's knowledge by bounds, rather than the twentieth-century view of science as evolutionary with many social and intellectual factors combining to contribute to—if not demand—the new discovery in its time and place. This is probably, however, the result of the academic situation in which the course is taught.

Shirley explained that this course was not for students of science but rather for students mainly trained for and interested in the humanities and social science. Said Shirley:

> To capture their interest, it is necessary to start with social affairs and work

> towards an interest in science and its impact on society, and for this purpose a reading list of philosophical, social, and historical works supplements the *Case Histories*. These form a necessary corrective for the deficiencies inherent in a study of the *Case Histories* taken alone, and if the reader is to obtain a valid picture of the strategy and tactics of science, he must take the two doses together, proceeding from social science to science if he is a social scientist, or from science to social science if he is a scientist.

Shirley questioned that a single course could integrate "the humanities, social science, natural science, and biological sciences." He wrote, "Yet if the attempt is to be made, there should be a balance and a maturity in each segment of what is to be a balanced whole. The case history method alone will not accomplish this, nor will these volumes reflect the balance that is sure to exist with the course at Harvard as Dr. Conant teaches it."

RELATED STUDIES

According to Klopfer and Watson (1957), it is not rare to find material from the history of science being used in secondary schools as well as in college general education courses. They cited the analysis of 35 replies by high school teachers to a survey questionnaire related to the use of historical materials. The replies came from various parts of the country and indicated a wide diversity in the use of historical materials, including such things as anecdotes and stories, historical descriptions in textbooks, biographies of scientists, describing or performing "classical" experiments, and modified use of the *Harvard Case Histories*. The survey also indicated that the value of historical material in science teaching is generally acknowledged by teachers of high school science. A specific reference was made to the successful use of the historically based *Workbooks of Scientific Thinking* developed by Mrs. Brenda Lansdown at the Dalton Schools in New York City, and to the enthusiasm of the children exposed to them.

The counterparts in the secondary high school science instruction of the *Harvard Case Histories in Experimental Science* are the *History of Science Cases for High Schools* developed by Klopfer (1960). These "HOSCs," or adaptations of them, have served as the basis for such experimental studies as have been done in relation to the use of historical materials in secondary school science. Because the case history approach is closely related to the sociohistorical approach used in this study, summaries of these studies are included.

The objectives of instruction which utilizes the HOSC approach generally included understanding by students of the scientific enterprise, of scientists as individuals, of the aims of science, and of the processes of science. Klopfer (1964) has written about the need for reducing the loss of students from the "potential scientist pool," a need which might be considered as a very practical objective of HOSC instruction.

The components of the *History of Science Cases* include a narrative outline, marginal notes and leading questions about which discussions and investigations center, suggestions for experiments and exercises to be carried out by the student, and a short list of related readings for student and teacher.

The primary reason that historical case studies are such a "viable means for conveying understandings about science and scientists to secondary school students," according to Klopfer (1964), is that they "provide an instructional technique which permits the exploration in depth of a multifaceted situation or activity." Klopfer and Watson (1957) have stated that

> in every case, emphasis is placed on specific facets of science, such as the following:
>
> 1. The methods used by scientists.
> 2. The knowledge that science is made by men—not by machines or magicians. It follows that scientists are human beings and have human limitations; that they differ in temperament, outlook, emotions, ambition. We also note that scientists have certain *attitudes*, which we call scientific.
> 3. Science is an international activity; it is not confined to any nation, race or group.
> 4. Science must have money to carry on.
> 5. Science must have free exchange of ideas—in meetings, journals, books, societies.
> 6. Constantly improved instruments and equipment are needed for progress in science.
> 7. Scientific activity is not isolated from, but is, to a large degree, the product of the culture in which it exists.
> 8. Science advances most rapidly when there is controversy.

Klopfer and Watson indicate that not all of these aspects are emphasized in any single case as a matter of effectiveness.

A study based on HOSC instruction was organized in 1960 at Harvard University and carried out at seven Regional Centers in the school year 1960–61. According to Klopfer and Cooley (1963), "The purpose of this study was to evaluate the effectiveness of the HOSC Instruction Method in changing understanding of science and scientists." The study was designed to investigate the following two questions:

1. Do students who study under the HOSC Instruction Method as a part of their regular science class work achieve significantly greater gains in their understanding of science and scientists than students who do not?
2. Do students who study under the HOSC Instruction Method as a part of their regular science class work show as much achievement in the usual content of the science course as students who do not?

Utilizing a relatively large and varied sample of students consisting originally of 2,808 students from 108 schools and who were enrolled in courses in biology, chemistry, and physics, with a variety of schools and classes considered to be representative of schools and classes in the United States, the study showed the following results:

1. There is a highly significant difference in understanding of science and scientists between students who have studied under the HOSC Instruction Method, and those who have not. Only the method of instruction appeared to be a source of variation among the controlled variables. Covariance adjustments were made for scholastic aptitude and initial achievement on the evaluation instrument.
2. The teacher's initial understanding of science and scientists is not a significant source of variation.
3. The type of science course, e.g., biology, physics, or chemistry, is not a significant source of variation.
4. There was no significant interaction between any paired combination of the following effects or among all three effects: the method of instruction, the teacher's initial understanding of science and scientists, and the type of science course being taught.
5. Students taking the courses in biology which utilized HOSC units made significantly greater gains in the understanding of science and scientists, but students not experiencing HOSC instruction scored significantly higher in achievement in the usual course content in biology.
6. Students taking courses in physics and chemistry showed no significant difference in achievement of the usual course content whether they had HOSC instruction or not. Those students having HOSC instruction, however, showed a significantly greater achievement in the understanding of science and scientists.

Klopfer and Cooley (1963) concluded that "the findings of the HOSC Instruction Project clearly demonstrated that the HOSC Method is definitely effective in increasing student understanding of science and scientists when used in biology, chemistry, and physics classes in high schools." It is important to note that relatively short periods of class time [approximately four school weeks] were utilized in the HOSC instruction which produced the results reported by Klopfer and Cooley.

A study utilizing *History of Science Cases* centered about chemical change was done by Carrier (1962). The subjects for this study were students who had just completed the seventh grade. The HOSC instruction was given to three groups of students during a six-week summer session. Two experimental groups of 20 and 31 students received HOSC instruction at different times during the summer course. The control group of 20 students did not receive HOSC instruction. The groups were determined to be equivalent and from the same population.

Difficulties were noted in the teaching situation, including the fact that the teaching was done mostly by interns who were more well versed in the "results of science" than in "the methods of science and scientists," according to Carrier. Difficulties were also noted in establishing vocabulary levels suitable for junior high presentation in both the case history and the modifications of Klopfer and Cooley's test which was designed for high school use. Carrier (1962) stated,

> Despite these objections, the evidence reported here suggests that some of the children were able to grasp certain points which the case history made and which the test could measure. The major findings were:
>
> 1. The results of the study indicated

that the use of history of science material resulted in a significant increase in scores on a "Test of Understanding Science."

2. While the test covered the three themes of Understandings about the Scientific Enterprise, Understandings about Scientists, and Understandings about the Methods and Aims of Science, an analysis of the test responses indicated that a general factor was responsible for the increase in achievement rather than any single specific factor.
3. Students who received HOSC instruction earlier in the course continued to improve in their understanding of science and scientists, perhaps due to orientation of these aspects of the instruction. The students who received HOSC instruction during the latter two-week period did better than the other class during any two-week period. The students in the control group showed no significant change in their understanding of the three themes covered in the test.

A study by Thomas (1967) involved subjects having a low interest or aptitude in science. A case in the area of geology, entitled "The Earth's Crust," was written. In this study, the only teacher assistance offered were the reading guides contained in the recommended reading references.

The number of students involved in the final analysis was 323, of which 148 received HOSC instruction and 175 were taught a "Text-Centered unit." The problem under investigation was the comparison of achievement in the understanding of science, scientists and the methods and aims of science between groups of students instructed by the two methods. The criterion measure was the Test of Understanding Science. Pretest performance was adjusted through analysis of covariance. IQ levels for the two groups of students were "very close." Comparisons were made between levels of performance for HOSC and Text-Centered groups and for subgroups of Males, Females, and IQ levels. All groups and subgroups receiving HOSC instruction were favored at significant levels of at least 5% and more often at 0.5%. It was concluded that, under the conditions of the study, the HOSC unit was effective in increasing understanding of scientists and science.

Thomas (1967) reported that teachers expressed the opinion that students were confused as to what was expected of them and this seemed to present the biggest problem. There was also the expression of a need for more time and additional guide materials, with the most important addition to the unit materials being a discussion guide for the questions found in the historical narrative.

III
PROCEDURE

BASIC CONCEPTS

The concepts of biogenesis and spontaneous generation were chosen as the bases for the selection of the subject matter for the unit for the following reasons:

1. These concepts have been of biological and social importance. Nordenskiold (1928) has called the problem of spontaneous generation "a theoretical problem of greatest significance." The intelligent study of microbes was dependent on the establishment of the fact that microbes come from other microbes of the same kind (Bates, 1960). This study led to preventive medicine. Haggard (1959) stated, "Preventive measures applied to the health of communities have influenced civilization more profoundly than any other advancement."

2. These concepts have had a long "history." The desire was to employ concepts that had a history of sufficient duration so that a number of changes in the concept and changes in the society could be studied.

3. These concepts were generally in opposition to each other at all stages in their development. Nash (1952), in discussing the utilization of case histories in teaching, indicated a positive opinion concerning the use of two competing theories as a means of evaluating the credibility of both at given stages in history.

SELECTION OF SUBCONCEPTS

The history of the concepts of biogenesis and spontaneous generation were studied and those concepts held at any given time in history were listed along with the appropriate information concerning the society of the time. A library search was made using the following topics: general history of science, history of science for specific periods, history of biology and bacteriology, prehistory and medieval science, ideas and experiments in science, health and medicine, and theories of the origin of life.

The subconcepts thought to be of most importance in relation to the historical development of the concepts of biogenesis and spontaneous generation were categorized as being mainly (1) concerned with the biological aspects of the two major concepts, (2) concerned with the work of scientists and the scientific enterprise and its historical development, or (3) sociological in nature.

I. Subconcepts concerned with the biological aspects of the concepts

The idea that living things come from other similar living things is fundamental to the study of life.

Some of the beliefs related to spontaneous generation have been based on direct observations from which incorrect conclusions have been drawn.

Early man's knowledge of the nature of the concept of biogenesis was through his understanding of the life cycles of larger, more familiar animals.

Some life cycles, like that of the wheat rust parasite, are more complex than others and much more difficult to understand.

Belief in the idea of spontaneous generation prevented an understanding of the true nature of infectious diseases.

Early man's attempts at medicine were more successful in treating noninfectious than infectious conditions.

The idea of spontaneous generation received support from other related theories of the time such as the theory of *vital force*.

The idea of *vital force* is closely related to early man's belief that nonliving objects possessed spirits along with some of the characteristics usually attributed to living things.

The effective treatment of disease has been hindered in the past by such vitalistic beliefs as electricity being the cause of certain crop diseases.

Two of the important supporters of the idea of spontaneous generation, Buffon and Needham, agreed that vitality was an indestructible property of living things.

One prominent theory of the cause of disease in the past which was closely related to the idea of spontaneous generation was the miasma theory, or the theory that bad air caused disease.

The miasma theory has been closely associated with malaria, a disease that is often prevalent in or near swampy areas.

Many early treatments for disease involved ill-tasting medicine designed to drive disease-causing demons out of the body.

Recovery by the patient was accepted by early man as definite proof that a medical treatment had affected a cure.

Of the several theories of infectious disease that have existed in the past, the most recent acceptable theory is the germ theory of infectious disease.

Aristotle, whose authoritarian viewpoint on spontaneous generation controlled the thinking on the subject for about 2,000 years, also believed that some organisms reproduced sexually and others asexually.

Aristotle believed that some living things could be produced through the union of an inactive principle called "matter" and an active principle called "form."

The preformation theory, proposed by some scientists to replace the idea of spontaneous generation, was the idea that all future generations are contained in the egg.

Early inaccurate microscopic investigation with crude and poorly illuminated microscopes led to such misconceptions as the *homunculus*, or little man in the head of the sperm, as an example of a belief supporting the idea of preformation.

The phenomenon of parthenogenesis, the development of animals from unfertilized eggs or unmated females, caused some scientists to question the idea of spontaneous generation on the basis that generation was too complex to occur spontaneously.

Important ideas concerned with sterilization procedures, such as hot water sterilization and fractional sterilization, were developed out of the controversy over the idea of spontaneous generation.

Leeuwenhoek's discovery of microscopic organisms did not settle the dispute over spontaneous generation immediately, but rather helped promote new interest in the idea of spontaneous generation for microorganisms.

The simple, controlled, and well designed experiments of Redi in the seventeenth century discredited the idea of spontaneous generation for organisms as large as insects, but had no immediate notable effect on the theory of the cause of infectious disease.

Swammerdam's support of Redi's idea that flies do not arise spontaneously from decaying flesh was based on the belief that flies were too complicated to have arisen spontaneously.

Some scientists such as Redi, who strongly opposed the idea of spontaneous generation, were still influenced by the ideas of Aristotle in instances where they did not understand all the aspects of the problem.

One of the problems in understanding life cycles of organisms was the confusion of the various stages. Harvey and Aristotle were confused by the pupae and eggs of insects.

Some drugs of medicinal value were actually developed from plants which resembled certain organs of the body. These were known as "signature plants."

One reason for the difficulty in controlling wheat rust infections is that new strains of wheat rust capable of infecting previously immune varieties of wheat constantly appear.

The phenomenon known today as "succession of populations" was described by Spallanzani during the course of his experiments.

An example of an important discovery based on a false assumption was Lower's notable discovery that air mixes with the blood in the lungs, based on the erroneous idea that bad air causes disease.

The experimentation of such early scientists as Micheli would have been more effective in discrediting the idea of spontaneous generation if they had been able to observe and report accurately such details as the germination of spores.

In spite of the poor quality of his botanical research which centered about the belief in water as the primary element and his fantastic 21-day recipe for the generation of mice spontaneously, the 17th century scientist van Helmont promoted experimentation and thought diseases should be treated for cause rather than for symptoms.

Schwann and Pasteur, who together were mainly responsible for the germ theory of disease, commonly agreed that it was something in the air which could be destroyed by heat that was responsible as the cause of putrefaction and fermentation.

The most significant result of the debate over spontaneous generation between Pouchet and Pasteur was the discrediting of the idea of spontaneous generation for microscopic organisms.

2. Subconcepts and knowledge items mainly concerned with the work of scientists and the scientific enterprise or its historical development

There is no one scientific method but rather many scientific methods used by scientists.

The major difference between early and present day scientists is not one of intelligence, seriousness, or imagination, but one of the amount of background knowledge available.

Science differs from magic in that science is directed by reason and corrected through observation while magic is taught through mysterious initiations and explained with myths.

Early calendar development was much like true science in that it made predictions based on generalizations drawn from numerous particular instances.

Technology or applied science such as the "science" of the early Egyptians, in contrast to research or pure science, has as its motive the practical application of scientific knowledge for personal gain.

Empirical science is that science based on direct or indirect observation; early science was based upon gross observation while present day science is more precise.

Practices such as the fortune telling practice of haruspicy are not scientific when their experimental results must agree with previously established conclusions or principles.

The findings of research scientists should be available to other research scientists.

Unplanned but fortunate incidents, such as Pasteur's discovery of virus attenuation, often play an important part in many scientific investigations.

Models devised by scientists make concepts or theories, which in themselves may be quite abstract, more understandable in terms familiar to the scientists.

The most crucial test of a scientist's experiments is whether or not they can be repeated under comparable conditions by other scientists.

Science makes its most progress when scientists are free to choose their own topics and procedures.

The idea of fundamental substances in nature was formally stated by the Greek Thales, whose philosophy included the belief that water was the fundamental substance of nature, including living things.

Science at the time of the ancient Greeks was primarily an intellectual activity of the leisure class.

Early Greek science was influenced by Plato's philosophy that ideas should be based on images created in the mind rather than on observations made with the senses.

Science prior to the 17th century was characterized by generalizations developed from mental images for deductive purposes.

The "primary elements" of the early Greeks are known today to be compounds and mixtures.

The Greek concept of the universe and philosophy of nature after 600 B.C. was based on reason and involved abstract ideas which related groups of observations.

During the Middle Ages, the Arabs made a great contribution to science through their translations of the works of Aristotle and other Greek scientists.

The deductive formal logic of Aristotle influenced science greatly for a long period of time, but was more effective for mathematical use than for scientific use.

The belief in final causes, held by Aristotle, supposed that all things in nature existed for a certain purpose.

The science of the Middle Ages in Europe was characterized by little or no incentive to utilize scientific inquiry in order to build a unified theory of the universe.

The academy, the lyceum, the university, and the scientific society were all centers of scientific activity at various times, with the university leading the scientific activity of the late Middle Ages.

The inadequacies of the ideas of Aristotle in answering questions that resulted from the exploration of new lands during the late Middle Ages caused doubt to be cast on the works of Aristotle as the final authority in science.

Hippocrates, the Greek "Father of Medicine," advocated the four humors doctrine of infectious disease but did not believe that diseases had supernatural causes.

By regarding the heart as a pump in a purely mechanical process rather than as the center of animate life and blood as the center of intelligence, Harvey was able to make his great discovery of the circulation of the blood.

The preformation theory was advanced by scientists who believed that plants and animals acted as machines.

Francis Bacon, a 17th century philosopher who believed in the idea of spontaneous generation, advocated experimentation in science and believed that the most important aspects of scientific investigation were observation and tabulation.

The 17th century mathematician, Descartes, who accepted the theory of spontaneous generation, advocated the mathematical development of scientific theories and principles.

3. Subconcepts and knowledge items sociological in nature

There have been historical, social, and scientific consequences attached to the general acceptance of the idea of biogenesis.

The development of preventive medicine has been the greatest benefit man has derived from acceptance of the idea of biogenesis.

The first civilizations were built around water as a vital resource and were mainly restricted to river valleys and the water supplied by them.

Civilizations are characterized by having some metal, a form of writing, and some national organization.

Early farming and hunting populations were not large enough to maintain a reservoir of contagious diseases. The small number of possible hosts did not provide enough contact with the diseases.

The size of early hunting clans was limited by available food supplies and the necessity of always being on the move to locate new supplies of food.

The "unplanned discovery" of the domestication of plants allowed farming clans to settle in one place and increase in size over the hunting clans.

The young and the elderly were more important to the farming clans than they were to the hunting clans.

Underdeveloped countries with limited crop production due to primitive farming methods can least afford crop losses due to infectious plant diseases.

Epidemics of various diseases have been of major importance in the historical development of different countries.

Diseases most readily controlled are those which are insect transmitted.

Malaria is an example of a disease which can be effectively controlled through governmental action.

More money is spent on the control of some diseases than is spent on the research designed to eliminate those diseases.

If all infectious diseases were controlled in the United States, life expectancy at birth would be only slightly increased.

During the Middle Ages, when it was thought that disease organisms were the effects rather than the causes of disease, hospital patients having infectious diseases were not separated from those having noninfectious diseases.

Some successful preventive measures and treatments for diseases have been developed without knowledge of the true cause of the disease.

Modern preventive medicine makes use of the theory that diseases are the effects produced by the attack of one kind of organism upon another.

If the life expectancy is increased for man it means that lower birth rates than in the past can maintain the same population level.

The reduction of death due to infectious diseases among the world population will create new problems which include the provision of food for the increased number of people.

Some regions of the world lag behind others in life expectancy in relation to infectious diseases for reasons other than our lack of knowledge of how to prevent such diseases.

The first application of Pasteur's scientific investigation of spontaneous generation was Lister's development of antisepsis in treatment of wounds and operations.

The development of the canning industry resulted from Appert's application of Spallanzani's experimentation on the production of microorganisms in plant infusions.

Aristotle's ideas, such as his "Ladder of Nature" which arranged living things in order of intelligence, were accepted and protected by the religious powers during the Middle Ages.

Greece was able to give rise to theoretical science because of its simple political structure at the time, its freedom from the superstitious control found in earlier civilizations, and its commercial sea travel which aided in the gathering of ideas.

An example of intolerance for certain scientific ideas by the established authority of the time was the 17th century condemnation of Galileo for his sun-centered concept of the universe.

In the 19th century, the successful work of Semmelweis in the study and control of childbed fever was rejected by the doctors of the time who made use of Semmelweis' past political relationships in the rejection of his ideas.

The effect of the bunt fungus of wheat, which for a long time was thought to be caused by a disease rather than the cause of a disease, was to produce a highly undesirable taste in the bread used by Europeans.

Prevost's recommendations for treating the bunt disease in wheat was accepted by farmers but rejected by scientists because his recommendations did not agree with the traditional ideas of the day concerned with the cause of infectious disease.

The Romans failed to carry on the scientific tradition of the Greeks because their main interest in science was technological, they lacked the freedom of the Greeks, and their language was Latin while the language used in science remained Greek.

The work of Pasteur related to the concepts of biogenesis and spontaneous generation was, except for his research with plant infusions during the controversy over spontaneous generation, mainly directed toward the solution of human problems.

The Irish potato famine in the mid-nineteenth century, which resulted in the starvation of many people and the emigration to the United States of many more, could probably have been controlled except for the prevalence of the belief that the potato blight originated spontaneously.

DEVELOPMENT OF INSTRUCTIONAL MATERIALS

The instructional materials developed for the unit included:

1. A narrative or text with accompanying questions for direct use by pupils and teachers to constitute ten chapters.
2. A collection of selected readings for direct pupil use to supplement the text.
3. A set of illustrative 2 x 2 slides with accompanying narratives for use by the teacher.
4. A small map and sequence of "time" charts for direct use by pupils.
5. An outline and guide to aid the teacher in the instructional sequence.

The organization of the text into ten chapters was determined by the plan to have one chapter serve as the basis for one lesson. The questions included were designed to help the student as he read the material and also to serve as a guide to class discussions. The general topic of each chapter is listed below.

Chapter 1:	Introduction to the ideas of biogenesis and spontaneous generation.
Chapter 2:	Primitive man's concept of nature and continuance of life.
Chapter 3:	The concept of nature and continuance of life held in such early civilizations as Egypt.
Chapter 4:	Early theoretical science in Greece, from Thales to Empedocles, in relation to the ideas of biogenesis and spontaneous generation.
Chapter 5:	Later Greek science from Pythagorus and Hippocrates to Aristotle and its relation to the ideas of biogenesis and spontaneous generation.
Chapter 6:	Science from the Romans through the Middle Ages to the Renaissance in relation to the ideas of biogenesis and spontaneous generation.
Chapter 7:	Seventeenth Century experimentation concerning spontaneous generation and insects.
Chapter 8:	The Eighteenth Century and the first experimentation with microorganisms in infusions concerning spontaneous generation.
Chapter 9:	The Nineteenth Century and the climax of the controversy over spontaneous generation.
Chapter 10:	Social aspects of the acceptance of the idea of biogenesis.

The selected readings included the work of three authors who supported the idea of spontaneous generation and three who supported the idea of biogenesis. Some of these readings were translations of the originals and some were copies of the originals. Each student was expected to complete the readings for each unit as it was studied.

The 200 slides assembled were photographic copies of pictures, sketches, tables, figures, etc. copied from a variety of references. The number of slides per chapter were: Chapter 1, 14; Chapter 2, 17; Chapter 3, 11; Chapters 4 and 5 combined, 20; Chapter 6, 35; Chapter 7, 37; Chapter 8, 23; Chapter 9, 22; and Chapter 10, 22.

Short narratives of 100 words or less accompanied all slides (see Appendix E). Each narrative was a description of the most pertinent observations to be made from the slide in relation to the text content.

The map and the majority of the time-charts prepared for student use were taken from *A Short History of Science and Scientific Thought* (Taylor, 1949).

A teacher's guide to the text and slides, containing suggestions relating to their use, was prepared for each unit.

SELECTION OF EXPERIMENTAL AND CONTROL GROUPS

The experimental and control groups were selected on the basis of such factors as availability and the willingness of teachers and school administrators to cooperate in the study. The experimental and control groups were made up of students enrolled in two high schools located in a south central Wisconsin city having a population estimated to be 173,100 in 1968. This city population was included in an estimated metropolitan population of 203,488. The enrollment of the upper three grades of the high school from which the experimental group was taken totaled 1,774. The upper three grades of the high school from which the control group was selected totaled 1,250 in enrollment. Students attending both schools were considered to come from similar socio-economic backgrounds.

The experimental group made up of four classes included three classes of eleventh and twelfth grade students studying second-year biology and one class of tenth grade students studying social studies. The control group consisted of five classes of tenth, eleventh, and twelfth grade students studying second-year biology. The students in the classes making up the experimental group and those in classes making up the control group were considered to have had similar academic training in first-year biology.

DESCRIPTION OF GROUPS SELECTED

The IQ's as indicated by the Henmon-Nelson test scores of the students participating were collected and the means and standard deviations were computed. It is noted from Table 1 that the three biology classes of the experimental group were similar to each other but different from the social studies class of the experimental group in terms of mean IQ.

The school administrator reported that the pupils in the social studies class were more carefully selected for this class than those in the biology classes and because high mean scores may be caused by some extreme individual score it was decided to seek a more detailed description of the class populations.

The first step was to list the IQ's of the individual pupils enrolled in the separate classes making up the experimental group in ascending numerical order to ascertain the presence of a possible division within each of the classes. It was noted that a division point was possible within all of the experimental classes at 114-115. When each of the experimental classes was accordingly divided into two halves, it was found that the populations of the biology classes in the experimental group were more nearly like each other than like the population of the social studies class. It is noted from Tables 2 and 3 that the proportion of the students with an IQ of 115 and above is greater for the social studies class than for the biology classes in the experimental group. Further examination of Table 3 reveals that the mean IQ for the lower IQ half of the social studies class is higher than the mean IQ of the comparable halves of the biology classes.

The purpose of the control group was to establish whether or not any gains in test scores occurred over the period of time during which the unit was being presented to the experimental group as a consequence of some unknown factor. The subject matter included in the unit used in this study was not included as a part of any of the courses studied by the control group.

When the mean IQ of the classes studying biology are compared, using Tables 1 and 4, it is noted that: (a) three of the control classes (2C, 3C, and 5C) are similar to the three experimental classes, (b) control class 1C has the lowest mean IQ, and (c) control class 4C has the highest mean IQ.

The fact that the classes selected to serve as the control group were of different ability levels (above, equal to, and below the experimental classes) would give added assurance that if an increase in achievement did not occur

Table 1. The Mean IQ and Standard Deviation for Each Experimental Class

	CLASS			
	$BIO_{(1E)}$	$BIO_{(2E)}$	$BIO_{(3E)}$	SOC. $ST._{(4E)}$
Mean IQ	109.44	108.75	110.26	115.50
Standard deviation	11.13	8.68	11.77	8.49
Number of students	25	24	23	25

Table 2. The Mean IQ and Standard Deviation of the IQ's of the Students with an IQ of 115 and Above in Each Class in the Experimental Group

	CLASS			
	$BIO_{(1E)}$	$BIO_{(2E)}$	$BIO_{(3E)}$	$SOC.ST._{(4E)}$
Mean IQ	120.30	121.33	122.53	121.43
Standard deviation	7.44	1.49	5.38	4.98
Number of students	10	6	8	14
Proportion of students	.40	.25	.35	.56

Table 3. The Mean IQ and Standard Deviation of the IQ's of the Students with an IQ of 114 and Below in Each Class in the Experimental Group

	CLASS			
	$BIO_{(1E)}$	$BIO_{(2E)}$	$BIO_{(3E)}$	$SOC.ST._{(4E)}$
Mean IQ	102.20	104.56	103.67	107.73
Standard deviation	6.18	5.42	8.49	5.22
Number of students	15	18	15	11
Proportion of students	.60	.75	.65	.44

Table 4. The Mean IQ and Standard Deviation for Each Control Class

	CLASS				
	$BIO_{(1C)}$	$BIO_{(2C)}$	$BIO_{(3C)}$	$BIO_{(4C)}$	$BIO_{(5C)}$
Mean IQ	104.71	110.68	107.18	114.88	111.05
Standard deviation	9.97	11.06	11.74	16.07	15.69
Number of students	21	23	22	24	18

GPO 811-035-4

among the five uninstructed classes of the control group then ordinary experiences over the period of 16 days would not be an important factor in determining the level of achievement of the experimental group.

The class enrollments indicated in Tables 1 and 4 are the sample of concern in this study.

INSTRUCTION

The technique of instruction utilized was primarily that of presentation-discussion. There were 12 periods of 55 minutes each devoted to instruction and all instructional materials were used in ways believed to be most effective; i.e., although some class discussion was a part of the procedure at all times, the major discussions took place during the second part of the period following the presentation by the teacher. The students always received the printed chapter and accompanying questions on the day preceding its presentation and discussion. All instruction was conducted by the investigator. There was no recitation-drill or review given during the course of instruction. However, constant precautions were taken to assure uniform coverage of the material in all classes.

EVALUATION

A 90-question, five-item multiple choice test based on the text was developed. The development of the test followed accepted techniques for quality test construction. The test questions were drawn from three groups of 30 questions, each related to the three different aspects of the unit. One group of questions was concerned with biological aspects, a second with the work of scientists and the scientific enterprise related to the biological concepts involved, and the third with the sociological aspects of the biological concepts involved. The test instrument was divided into two 45-question parts for administration on two consecutive days. The two parts were administered as a pretest and a posttest to both the experimental and control groups.

A short four-part questionnaire was developed to aid in collecting information concerned with the opinion of students relative to the presentation of the materials. The first part of the questionnaire consisted of six questions, each of which dealt with such items of student opinion as general interest in the unit material as compared to interest in other biology material already experienced, a rating of the content as to learning difficulty, and the average and maximum time spent in reading the text content. A second part of the questionnaire involved ordering chapters of the text in order of their interest to the student. A third part of the questionnaire required the ordering of subject matter areas and general teaching methods in relation to student interest. The fourth part of the questionnaire dealt with determining how thoroughly the text material was read by the students. The questionnaires were identified by classroom number only.

ANALYSIS OF DATA

The data collected during the course of study were analyzed in the following manner:

1. To determine the magnitude and significance of the gains in achievement as indicated by differences between pretest and posttest mean scores, the statistical procedure employed was the paired *t* test as described by Hays (1963) with the pretest and posttest means of a class as a "pair" and the classes as independent subjects with N = 4 for the experimental and N = 5 for the control groups.

H_0: Classes receiving instruction through the study of this unit failed to perform significantly better on the posttest than on the pretest as indicated by an analysis of pretest and posttest mean scores ($\alpha = .001$).

H_0: Classes not receiving instruction through the study of this unit failed to perform significantly better on the posttest than on the pretest as indicated by analysis of pretest and posttest mean scores ($\alpha = .10$).

In order to maximize the likelihood that any achievement gain scores which might occur within the experimental group and not in the control group were not attributable to chance, a conservative criterion of $\alpha = .001$ and $\alpha = .10$ was adopted for the experimental and control groups respectively.

2. The relationships of the individual pupil IQ and individual pupil achievement on (a) the total test, (b) the biological aspects part, (c) the science and scientists part, and (d) the sociological aspects part were accomplished through the calculation of correlation coefficients between individual gain scores and individual IQ's.

3. The relative independence of the three parts of the test instrument were investigated utilizing simple correlation treatments of individual gain scores.

4. The differences between the levels of performance as indicated by mean final scores for students of the experimental groups studying biology and social studies were tested for significance by use of a planned comparison of treatment means (Snedecor and Cochran, 1967) and analyzed using multivariate analysis of variance with a covariate adjustment for IQ (***Multivariance: Fortran Program for Univariate and Multivariate Analysis of Variance and Covariance***, Finn, 1967). The following null hypothesis was tested:

H_0: There is no significant difference in performance as indicated by mean final scores for students enrolled in biology classes and those enrolled in social studies classes when both receive instruction utilizing this unit ($\alpha = .05$).

The mean scores for the classes making up the experimental group enrolled to study biology were weighted one-third and summed to form a single score which was compared to the mean score of the students enrolled in the class to study social studies. In this form, the null hypothesis appears as:

$$H_o: 1/3(\bar{X}_{(1E)} + \bar{X}_{(2E)} + \bar{X}_{(3E)}) - \bar{X}_{(4E)} = 0,$$

$$\alpha = .05.$$

5. The results of the student responses related to the levels of difficulty and interest are given as percentage tabulations wherever possible.

6. Reliabilities for the three parts of the test and for the test as a whole were determined through the use of the ***Generalized Item and Test Analysis Program*** (Baker, 1966). The Hoyt Analysis of Variance procedure is used in this computer program to compute the internal consistency reliability. The reliabilities are listed in Table 5.

Table 5. Reliabilities for All Aspects of Posttest by All Classes of the Experimental Group

	$BIO_{(1E)}$	$BIO_{(2E)}$	$BIO_{(3E)}$	$SOC.ST._{(4E)}$
Biological aspects (30 items)	.67	.69	.76	.65
Science and Scientists (30 items)	.70	.75	.70	.70
Sociological aspects (30 items)	.78	.78	.82	.75
Total Test (90 items)	.89	.89	.90	.88

IV
RESULTS

The results of the analyses of the data are presented in terms of (1) the significance of the mean gain scores earned by classes making up the experimental and control groups and (2) the opinions of students registered on a questionnaire concerned with the materials and method of presentation of the unit herein described.

ANALYSIS OF TEST RESULTS

Experimental Classes

The mean class gain scores were tested for significance by using the *t* test for matched pairs (pretest and posttest class mean scores) given by Hays (1963).

When the *t* test technique is applied to the total pretest and posttest mean scores it is found that the mean gain scores for the classes in the experimental group are positive and significant at the .001 level (Table 6). It is also noted that the mean gain scores were relatively uniform among the biology classes and that the mean gain score for the tenth-grade social studies class was the highest of the four.

The individual scores on the pretest ranged from a low of 23 to a high of 56 and on the posttest from 24 to 81. Only one student performed at a lower level on the posttest than on the pretest (one point) and the gains ranged from 1 to 36 points.

When the results, expressed in terms of separate class mean scores for each of the three parts of the test (Tables 7, 8, and 9) are analyzed using the "paired *t* test" technique, it is found that positive mean gain scores, significant at the .001 level, were made by all experimental classes on all parts of the test.

Control Classes

The statistical procedures followed in treating data collected from the control group also include the *t* test with pretest and posttest class mean scores as matched pairs.

It is noted from Table 10 that each of the five classes used as the control group experienced a mean loss on the total test as indicated by pretest and posttest scores over the period of 16 days. The lowest pretest score was 21 and the highest pretest score was 65. The lowest posttest score was 17 and the highest posttest score was 62.

Table 6. Total Test: Pretest and Posttest Mean Scores and Gain Scores for Experimental Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$\text{Biology}_{(1E)}$	37.84	56.28	+18.44
$\text{Biology}_{(2E)}$	38.79	55.83	+17.04
$\text{Biology}_{(3E)}$	38.69	58.04	+19.35
$\text{Soc. Studies}_{(4E)}$	37.28	58.28	+21.00

Computed value of *t* with 3 d.f.: 23.38

Critical value of *t* with 3 d.f. (α = .001, one-tailed test): 10.21

Table 7. Biological Aspects Part: Pretest and Posttest Mean Scores and Gain Scores for Experimental Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1E)}$	11.36	17.92	+6.56
$Biology_{(2E)}$	11.95	17.71	+5.76
$Biology_{(3E)}$	11.95	19.34	+7.39
Soc. $Studies_{(4E)}$	10.52	19.00	+8.48

Computed value of t with 3 d.f.: 12.11

Critical value of t with 3 d.f. (α = .001, one-tailed test): 10.21

Table 8. Science and Scientists Part: Pretest and Posttest Mean Scores and Gain Scores for Experimental Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1E)}$	13.60	18.52	+4.92
$Biology_{(2E)}$	13.46	17.76	+4.32
$Biology_{(3E)}$	13.52	18.65	+5.13
Soc. $Studies_{(4E)}$	13.04	18.36	+5.32

Computed value of t with 3 d.f.: 22.66

Critical value of t with 3 d.f. (α = .001, one-tailed test): 10.21

Table 9. Sociological Aspects Part: Pretest and Posttest Mean Scores and Gain Scores for Experimental Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1E)}$	12.88	19.84	+6.96
$Biology_{(2E)}$	13.37	20.37	+7.00
$Biology_{(3E)}$	13.28	20.00	+6.78
Soc. $Studies_{(4E)}$	13.72	20.92	+7.20

Computed value of t with 3 d.f.: 81.06

Critical value of t with 3 d.f. (α = .001, one-tailed test): 10.21

Table 10. Total Test: Pretest and Posttest Mean Scores and Gain Scores for Control Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1C)}$	30.95	30.23	-0.72
$Biology_{(2C)}$	36.68	35.21	-1.47
$Biology_{(3C)}$	36.09	34.68	-1.41
$Biology_{(4C)}$	44.30	43.75	-0.55
$Biology_{(5C)}$	36.30	34.50	-2.10

Computed value of t with 4 d.f.: -4.4658

Critical value of t with 4 d.f. (α = .1, one-tailed test): 1.533

Table 11. Biological Aspects Part: Pretest and Posttest Mean Scores and Gain Scores for Control Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1C)}$	9.14	8.95	-0.19
$Biology_{(2C)}$	11.91	11.78	-0.13
$Biology_{(3C)}$	11.54	11.14	-0.40
$Biology_{(4C)}$	13.08	12.95	-0.13
$Biology_{(5C)}$	11.11	12.00	+0.89

Computed value of t with 4 d.f.: 0.03

Critical value of t with 4 d.f. (α = .1, one-tailed test): 1.533

Table 12. Science and Scientists Part: Pretest and Posttest Mean Scores and Gain Scores for Control Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1C)}$	11.76	10.76	-1.00
$Biology_{(2C)}$	13.04	12.30	-0.74
$Biology_{(3C)}$	13.00	12.22	-0.78
$Biology_{(4C)}$	15.45	15.08	-0.37
$Biology_{(5C)}$	12.94	11.38	-1.56

Computed value of t with 4 d.f.: -4.5477

Critical value of t with 4 d.f. (α = .1, one-tailed test): 1.533

Table 13. Sociological Aspects Part: Pretest and Posttest Mean Scores and Gain Scores for Control Classes

Class	Pretest $\bar{X}$	Posttest $\bar{X}$	Gain Scores
$Biology_{(1C)}$	10.04	10.52	+0.48
$Biology_{(2C)}$	11.74	11.13	-0.61
$Biology_{(3C)}$	11.55	11.31	-0.24
$Biology_{(4C)}$	15.79	15.70	-0.09
$Biology_{(5C)}$	12.61	11.16	-1.45

Computed value of t with 4 d.f.: -1.1959

Critical value of t with 4 d.f. (α = .1, one-tailed test): 1.533

Table 14. Correlation of Individual IQ's and Gain Scores for Students in Experimental Classes

	IQ with Total Test	IQ with Biological Aspects	IQ with Science and Scientists	IQ with Sociological Aspects
Correlation coefficients	0.311	0.339	-.006	0.277

Table 15. Intercorrelation Between the Three Parts of the Test

	Biological Aspects	Science and Scientists	Sociological Aspects
Biological aspects	1.000		
Science and scientists	0.193	1.000	
Sociological aspects	0.369	0.132	1.000

When the mean class gain scores are computed for the control classes for each of the three parts of the test, as in Tables 11, 12, and 13, it is found that there are only two positive pretest to posttest gains and these are very small as are the mean losses.

GAIN SCORES AND IQ

The calculation of correlation coefficients between individual student IQ's and individual gain scores for the total test, the biological aspects part of the test, the science and scientists part of the test, and the sociological aspects part of the test indicate little or no relationship between IQ and success in this program (Table 14).

THREE PARTS OF THE TEST

When the gain scores earned by individual students on the three test parts are compared with each other, the lack of overlap of the test parts is apparent (Table 15).

RESULTS OF PLANNED COMPARISON BETWEEN EXPERIMENTAL CLASSES

Table 16. Multivariate Test for Equality of Final Mean Class Scores: Planned Comparison*

d.f.	F Ratio	P Less Than
3,90	1.5938	0.1965

*$1/3(\bar{X}_{(1E)} + \bar{X}_{(2E)} + \bar{X}_{(3E)}) - \bar{X}_{(4E)} = 0$, $\alpha = .05$

The absence of evidence of significant difference (.05 level) between the mean final scores earned by the experimental biology classes and the experimental social studies class was revealed when the data were treated utilizing multivariate analysis techniques on the three posttest subscores with a covariate adjustment for IQ (see Tables 16 and 17).

STUDENT OPINIONS QUESTIONNAIRE

Question 1

It is noted in Table 18 that the majority of the students (61%) spent an average of one-half hour or less in reading each lesson. This indicates that the time spent in studying this material would be in line with the amount of time spent in studying other academic courses.

Table 17. Univariate Test of Equality of Mean Vectors for Each Aspect of the Test with Covariate Adjustment for IQ

Variable	Between Mean Sq.	d.f.	Univariate F	P Less Than
Biological aspects	46.68	1,92	3.90	0.0512
Science and scientists	8.72	1,92	0.97	0.3278
Sociological aspects	0.15	1,92	0.01	0.9117

Table 18. Student Opinion: Question 1
What was the *average* time you spent in reading *each* lesson?

Response	$BIO_{(1E)}$		$BIO_{(2E)}$		$BIO_{(3E)}$		$SOC. ST._{(4E)}$		TOTAL	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
< 1/2 hour	8	(32)	6	(26)	1	(04)	3	(12)	18	(18)
1/2 hour	12	(48)	9	(39)	10	(40)	11	(44)	42	(43)
1 hour	4	(16)	7	(30)	10	(40)	8	(32)	29	(30)
1-1/2 hours	1	(04)	0	(--)	4	(16)	2	(08)	7	(07)
2 hours	0	(--)	1	(04)	0	(--)	1	(04)	2	(02)
> 2 hours	0	(--)	0	(--)	0	(--)	0	(--)	0	(--)
	25	(100)	23	(99)	25	(100)	25	(100)	98	(100)

Question 2

It is found in Table 19 that the majority of the students (56%) spent a maximum reading time of one hour or less on any one lesson. This indicates that some lessons required more reading time than others, and this is probably a reflection of the volume of the reading material rather than the level of difficulty.

Question 3

As shown by Table 20, the majority of the students (57%) expressed the opinion that the reading material had a lower level of difficulty than biology-related materials they had read before, indicating that the reading material for this unit might be readable for a greater number of students than material ordinarily experienced by them.

Question 4

It is noted from Table 21 that a large majority (81%) of the students expressed the opinion that they would have made use of more reading time if available. This may reflect the effect of the rapid pace of the presentation over a period of 12 days.

Question 5

The prevalence of a positive opinion relative to the interest potential of the reading materials provided is evident from Table 22 in which 73% of the respondents expressed the opinion that the material has a higher interest value than other materials they had been reading related to biology.

Table 19. Student Opinion: Question 2
What was the *most* time you spent in reading any *one* lesson?

Response	BIO(1E)		BIO(2E)		BIO(3E)		SOC. ST.(4E)		TOTAL	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
< 1/2 hour	2	(08)	0	(--)	0	(--)	1	(04)	3	(03)
1/2 hour	4	(15)	2	(09)	4	(16)	4	(16)	14	(14)
1 hour	14	(54)	10	(43)	5	(20)	10	(40)	39	(39)
1-1/2 hours	5	(19)	7	(30)	9	(36)	5	(20)	26	(26)
2 hours	1	(04)	4	(17)	5	(20)	3	(12)	13	(13)
> 2 hours	0	(--)	0	(--)	2	(08)	2	(08)	4	(04)
	26	(100)	23	(99)	25	(100)	25	(100)	99	(99)

Table 20. Student Opinion: Question 3
Make the following comparison of this reading material with the *majority* of biology material you have read before.

Response	BIO(1E)		BIO(2E)		BIO(3E)		SOC. ST.(4E)		TOTAL	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Much more difficult	0	(--)	0	(--)	0	(--)	1	(04)	1	(01)
Somewhat more difficult	3	(11)	5	(22)	4	(16)	9	(40)	21	(21)
About the same	6	(22)	5	(22)	4	(16)	6	(24)	21	(21)
Somewhat easier	16	(59)	10	(43)	12	(48)	6	(24)	44	(44)
Much easier	2	(07)	3	(13)	5	(20)	3	(12)	13	(13)
	27	(99)	23	(100)	25	(100)	25	(100)	100	(100)

GPO 811-035-3

Table 21. Student Opinion: Question 4
If you had had more time would you have done more reading?

Response	BIO(1E) No.	(%)	BIO(2E) No.	(%)	BIO(3E) No.	(%)	SOC. ST.(4E) No.	(%)	TOTAL No.	(%)
Yes	19	(70)	17	(74)	23	(92)	22	(88)	81	(81)
No	8	(30)	6	(26)	2	(08)	3	(12)	19	(19)
	27	(100)	23	(100)	25	(100)	25	(100)	100	(100)

Table 22. Student Opinion: Question 5
In comparison with other biology text material generally, this reading is:

Response	BIO(1E) No.	(%)	BIO(2E) No.	(%)	BIO(3E) No.	(%)	SOC. ST.(4E) No.	(%)	TOTAL No.	(%)
Much less interesting	1	(04)	0	(--)	1	(04)	1	(04)	3	(03)
Somewhat less interesting	5	(21)	2	(09)	1	(04)	3	(12)	11	(11)
The same	3	(13)	3	(13)	3	(12)	3	(12)	12	(12)
Somewhat more interesting	13	(54)	13	(56)	8	(32)	12	(48)	46	(47)
Much more interesting	2	(08)	5	(22)	12	(48)	6	(24)	25	(26)
	24	(100)	23	(100)	25	(100)	25	(100)	97	(99)

Table 23. Student Opinion: Question 6
Which of the following things do you think would have helped you most in taking the test?

Response	BIO(1E) No.	(%)	BIO(2E) No.	(%)	BIO(3E) No.	(%)	SOC. ST.(4E) No.	(%)	TOTAL No.	(%)
More class discussion	3	(12)	5	(22)	4	(16)	1	(04)	13	(13)
More lecture-explanation	5	(19)	3	(13)	3	(12)	7	(29)	18	(18)
More review	11	(42)	7	(30)	9	(36)	12	(50)	39	(40)
More recitation-drill	0	(--)	1	(04)	1	(04)	2	(08)	4	(04)
More reading	7	(27)	7	(30)	8	(32)	2	(08)	24	(24)
	26	(100)	23	(99)	25	(100)	24	(99)	98	(99)

Question 6

It is noted in Table 23 that 40% of the students would have liked more review and 24% thought that more reading would have helped them on the test. It is also noted that few students felt the need for recitation-drill and the majority of the students did not feel the need for more class discussion or lecture-explanation as the primary aid to taking the test.

Question 7

When the ratings in terms of the expressed interest of students in the individual lessons were tabulated (Table 24), it is noted that variations existed and that the largest number of students (33) rated Lesson No. 2 (Primitive man's concept of nature and continuance of life) as the most interesting and Lesson No. 1 (Later Greek science from Pythagorus and Hippocrates to Aristotle and its relation to the ideas of biogenesis and spontaneous generation) as least interesting.

Question 8

It is noted from Table 25 that the largest number of students (41) selected the *examples of beliefs* as the most interesting aspect of the unit while only a few (five) students selected *science and scientists* as most interesting.

Question 9

As indicated from Table 26, a majority of the students (51) found the *slides used* to be of most interest in the techniques and instructional materials used in the presentation of the unit. Considerable interest was also expressed for *class discussion* and for the *reading material* in the text. The indication is noted here that interest resulted from the use of several, rather than just one, technique or type of instructional material.

Question 10

From a tabulation of the numbers of the chapters read completely by the students of the experimental classes (Table 27) it is noted that in the majority of instances (28/40) the complete chapter was reported as read by at least 50% of the class, and only slightly less than 50% in most of the other instances. At the end of the first three chapters the level of complete reading became rather stable at about 50% of the students. There is an indication that, in spite of the greater length of the later chapters of the text, student reading of the text material remained rather consistent.

Table 24. Student Opinion: Question 7
List the lessons in order of their interest to you.

	Lesson Number									
	1	2	3	4	5	6	7	8	9	10
Most interesting	9	33	12	1	1	6	6	6	11	11
Least interesting	23	5	5	5	10	11	5	10	8	14

Table 25. Student Opinion: Question 8
List these items in the order of their interest to you.

	Items				
	Biological Aspects	Explanation of Experimentation	Science and Scientists	Examples of Beliefs	Sociological Aspects
Most interesting	19	17	5	41	15
Least interesting	12	19	40	8	18

Table 26. Student Opinion: Question 9
List these items in the order of their interest to you.

	Items				
	Reading Material	Class Discussion	Supplementary Reading	Slides Used	Test
Most interesting	16	22	6	51	2
Least interesting	6	3	30	1	57

Table 27. Student Opinion: Question 10
Which chapters of the text did you read?

Class	Chapter										
	1	2	3	4	5	6	7	8	9	10	
$BIO_{(1E)}$	22	20	16	12	13	12	9	10	10	12	(N = 27)
$BIO_{(2E)}$	19	17	15	12	11	12	14	11	13	11	(N = 22)
$BIO_{(3E)}$	22	21	19	19	13	12	13	13	14	16	(N = 25)
$SOC. ST._{(4E)}$	23	21	18	12	16	11	11	11	11	16	(N = 24)

V
CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS

The conclusions in this chapter were formulated on the basis of the conditions and limitations of the study and the nature of the population with which the study was concerned.

The feasibility of teaching biology via a sociohistorical approach utilizing the ideas of biogenesis and spontaneous generation with emphasis on the social implications of the two ideas is indicated for the following reasons:

1. Analysis of mean pretest and posttest scores indicated that classes in which students of average ability and above were enrolled exhibited a significant increase in subject matter knowledge related to biological concepts, nature of the scientific enterprise and the work of scientists related to the biological concepts involved, and the social implications of the biological concepts involved.
2. There was no significant difference between the levels of performance demonstrated by classes in which eleventh- and twelfth-grade students were enrolled to study second year biology and the class in which tenth-grade students were enrolled to study social studies.
3. Students experiencing instruction utilizing the unit expressed a high level of interest in the reading material utilized as the basic text for the unit.
4. The majority of students expressed the opinion that the reading material which formed the basis for the unit was not as difficult as most of the reading material in biology with which they were familiar.
5. Increase in subject matter knowledge of science-society relationships is not evident in classes of students studying second-year biology or tenth-grade social studies when such interrelationships are not explicitly taught.
6. Students enrolled in some social studies courses are not averse to receiving instruction of a sociohistorical unit of material in science designed to show interrelationships of science and society.
7. Students receiving instruction in science via the sociohistorical approach feel the need for standard teaching procedures not given in the short period of the experimental study, e.g., more review of material prior to testing.

IMPLICATIONS

The following implications seem apparent as a result of the study:

1. Basic concepts such as biogenesis and spontaneous generation serve effectively as central ideas about which sociohistorical units may be developed.
2. The sociohistorical approach to science teaching is different from some approaches to science teaching now experienced by high school students in terms of student interest and level of difficulty for the student.
3. There are some students enrolled in high school courses in biology and social studies who can benefit from the sociohistorical approach to science instruction.
4. The technique of slide presentation with accompanying class discussion is an effective method of presenting the subject matter in a unit such as herein described.
5. Science and society interrelationships can be isolated, can be taught, and are of interest to some portion of the high school population.

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