A Study Of The Effects Of Laboratory Centered Instruction On Student Critical Thinking Skills And Attitudes In Biology.

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A STUDY OF THE EFFECTS OF LABORATORY CENTERED INSTRUCTION ON STUDENT CRITICAL THINKING SKILLS AND ATTITUDES IN BIOLOGY

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by
Irvin T. Edgar

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ABSTRACT

It was the objective of this investigation to analyze the effects of laboratory centered instruction in biology on the improvement of student critical thinking skills and the development of positive student attitudes toward biology.

The sample for the study consisted of six teachers and 148 tenth grade college preparatory biology students from five counties in eastern Pennsylvania. Selection was based on teacher experience and preparation, use of BSCS or conventional biology materials, and consent of the school district personnel.

To investigate the relationship between laboratory based biology instruction and the changes in student critical thinking skills and attitudes toward biology, four existing instruments were used. The Watson-Glaser Critical Thinking Appraisal was employed to obtain data on student critical thinking skills. Remmer's A Scale to Measure Attitude Toward Any School Subject was used to acquire the information on changes in student attitudes. The Minnesota Teacher Attitude Inventory was administered to the teachers to measure any changes in teacher attitudes, and the Otis Quick Scoring Mental Ability Test was utilized to assess the students' scholastic ability.

The resultant analysis revealed that students in the laboratory centered and non laboratory centered instuctional

groups were essentially similar in scholastic ability. An analysis of variance of the IQ's showed no significant difference.

Students in both the laboratory centered (BSCS) and non laboratory centered group showed significant improvement in critical thinking skills after one school year of biology instruction. An analysis of variance of the gain scores revealed that students receiving non laboratory centered biology instruction showed significant improvement in critical thinking over students in the laboratory centered group. There appeared to be little relationship between the teacher's attitude and student gains in critical thinking.

Students in both instructional groups showed a change in their attitude toward biology from their pre- to post-test measurements. The differences were not significant in either instructional group, however; nor was there a significant difference between the instructional groups. A greater degree of agreement seemed to exist between the attitudes of the teachers and students in the laboratory centered group, where both teacher and student attitudes were found to be more negative than the attitudes of the students and teachers in the non laboratory group. Nevertheless, no statistical difference was revealed between the attitudes of the teachers in the laboratory and non laboratory instructional groups. There also was no significant difference in the individual teacher pre- and post-test attitude measures.

CHAPTER I

INTRODUCTION

The development of scientifically literate students is regarded as a major purpose of science education (Grobman, 1967) since the quality of eventual adult participation in determination of public policy will be related to critical thinking skills, attitudes toward science, and understanding of science subject matter. For this reason it is necessary to have research which identifies those instructional emphases that result in the development of favorable attitudes toward science and the development of critical thinking ability of students.

Contemporary science programs emphasize the need for inductive laboratory learning experiences to assist students in their development of the skills necessary to understand science and it processes. Brandwein, Watson, and Blackwood (1958) and Carlson (1967) have suggested that the importance of laboratory work in science lies in the more general aspects of learning which include knowledge of "how a scientist works." However, specific evidence is needed to support the hypothesis that the inductive laboratory is the best way for students to understand science. The extra demands on student-instructor time, space, and facilities warrant empirical evidence that identifies those experiences which result in enhanced student behaviors (Watson, 1963 & Schefler, 1965).

The Biological Sciences Curriculum Study Committee (BSCS) curriculum materials are representative of the use of inductive laboratory procedures or laboratory based instruction in biology. Review of the literature has revealed that most research studies contrast BSCS biology curricular materials with non-BSCS curricular materials to measure the effects of laboratory-centered versus non laboratory centered learning in biology. These studies, frequently concerned with measuring differences in student achievement in biology, do not consider the other facets of learning necessary to understanding science even though both the laboratory and non laboratory curricula recognize overall student growth as more than an accumulation of knowledge. Achievement tests are valid for their intended purpose but explore only a limited portion of the cognitive domain and offer a small basis for any assertion that they bear general relevance to the major objectives in science (Watson, 1963). Instead attention needs to be given not just to what is learned, but how it is learned since the cognitive and affective behavior of students is influenced simultaneously by instructional procedures. Krathwohl, Bloom, and others are persuaded that although relations between cognitive and affective objectives may vary, "The particular relations in any situation are determined by the learning experiences the students have had" (Krathwohl, Bloom, & Masia, 1965, p. 86).

There have been few attempts in recent years to measure the affective behavior of students as represented by their attitudes toward science. Most tests designed to measure scientific attitudes and the impact they have upon daily life are largely outdated in terms of pupil experiences and scientific progress (Baumel & Berger, 1965). Attitude assessment is important to instruction since an attitude has the character of commitment to a policy and leads an individual to choose those facts that are relevant to the individual's beliefs. Furthermore, educators emphasize that growth of attitudes, interests and appreciations in positive directions is essential, and that deliberate and continuing effort toward accomplishing these ends must be a concomitant of instruction (Smith, 1963).

The question of the value of the inductive laboratory approach in developing positive attitudes toward science and improvement of critical thinking skills was worthy of further investigation. The subject of biology was especially appropriate for this research because of its strategic place in the curriculum and highest student enrollment among all high school science courses (Palmer, 1964). An appraisal of the inductive laboratory in biology instruction should have value for education generally because of the present emphasis on inductive learning procedure in education. Other subjects in the school curriculum therefore will need to resolve the same question of whether the extra time required by inductive learning activities is justified by the projected values of such learning procedures (Goodlad, 1966).

Background of Study

As a Science Adviser for the Department of Public Instruction in the state of Pennsylvania, the writer was confronted with many questions related to the use of new curriculum materials and the merits of their increased emphasis on inductive laboratory procedures. Many of the questions raised were not answerable from evidence provided by existing studies. In an attempt to answer these questions, the assistance and consent of six school districts and their personnel was obtained to complete a study of the effects of laboratory centered instruction. The data collected measured critical thinking skills and attitudes of students in tenth grade biology.

Statement of Problem

This study measured the effectiveness of laboratory centered instruction on the development of student critical thinking skills and changes in student attitudes toward the subject of biology. It was assumed that through the use of tests designed to investigate these areas, it was possible to compare changes in critical thinking and attitudes that occur in classes where students were instructed in laboratory based materials. At the same time, measurement of these criteria in classes where non laboratory materials were used allowed a comparison of the effectiveness of the instructional procedures characteristic of both types of biology curricula. Classes using BSCS curriculum materials were considered representative of laboratory centered instruction. No attempt was made to alter the teaching behavior or conditions in either instructional group since it was assumed that the data obtained in this way would be representative of actual classroom practices characteristic of each group.

The influence of teacher differences was minimized by including teachers with similar background and experience in both instructional groups. In addition, the attitudes of the participating teachers were measured and related to changes in critical thinking and attitudes of students to determine this dimension of teacher influence, apart from the use of the curricular materials and their characteristic instructional patterns being investigated.

Origins of the Rationale

The important test of science instruction is how it changes the students who are being taught. Frequently, the procedures used by the science teacher are studied in an attempt to relate them to changes that result in student behavior. The term method is often used in the literature on science teaching to refer to the use of laboratory work in instruction. "While this term does not identify the behaviors of the teacher, at least some teacher behaviors are implicit in it" (Watson, 1963).

Use of laboratory centered instruction, or the inductive laboratory, refers to science teaching that requires students to search for answers in laboratory experiences that have no fixed results, but require careful completion and analysis. Much of the learning in BSCS biology is based on the understanding gained from these experiences and subsequent interaction in meaningful discussion periods (Palmer, 1964). (Hereafter "BSCS" will be used to refer to laboratory centered instruction in biology).

Laboratory work and its value in the science curriculum was the subject of a large number of studies in the 1920's and 1930's. Cunningham (1946) reviewed the literature up to 1945 and listed thirty-seven studies of which eighteen were master's theses, six were doctor's theses, and thirty-three dealt with junior high school instruction. He concluded:

1. Many early studies had inadequate statistical treatment, dubious validity in their design, and undetermined reliability of results.

2. Most studies used paper and pencil tests as a basis for comparing laboratory versus non laboratory instruction.

A number of these early studies of science learning attempted to find relationships between supervisor's ratings of teachers and subsequent pupil behaviors. Later studies by Barr (1948), Mitzel and Gross (1958) reveal that numerous studies have since been completed which make use of pupil descriptions of teacher behavior instead (Watson, 1963).

Studies related to the role of the science laboratory in problem solving have been done in most fields of science teaching. Kruglak (1951) and Balcziak (1953) in physics, Gunkle (1952) and Thelen (1944) in chemistry, Mason (1952), Olson (1957) and Deardon (1959) in biological science are a few of the investigators concerned with the use of individual laboratory work in science. These studies seem to indicate that the use of the inductive-deductive or problem solving method in laboratory work was more effective than "traditional" methods or the approach to verifying facts rather than solving a problem. Frings and Hichar (1958), by contrast, found no significant results in their study of laboratory teaching methods in zoology.

Research in biology has been directed toward: the aspects of instructional procedures, teacher characteristics, grade placement of the subject, student aptitudes, and student achievement. Olstad (1965) measured the difference in effectiveness of biology instruction conducted in two-hour classes compared to instruction in one-hour classes. The effectiveness of the different instructional times was measured in terms of change in pupil's biology achievement, attainment of laboratory and problem solving skills, and student reaction to their biology instruction. Greater variation occurred in student achievement for the two-hour classes and the attitudes of these students were significantly more positive.

Anderson (1950) studied the effects of both increased laboratory time and the teacher's background as they related to pupil scores in biology and chemistry achievement tests. The study, completed in 1945, investigated three kinds of problems: (1) factors in the teaching situation which contributed to achievement of four types of objectives (acquisition of factual information, use of principles of science, use of the scientific method, and acquisition of scientific attitude), (2) relations between the four kinds of objectives, and (3) the practices and attributes of the teachers. Using fifty-six high schools of small enrollment Anderson revealed that gains in student biology scores, after covariance adjustment for I.Q. and pre-test scores, were significantly and positively related to the teacher's background in credits and degrees, and student time spent in the laboratory (60 hours or more vs. 12 hours or less). Chemistry students showed a similar relationship favoring laboratory experiences.

Lahti (1956) explored the effects of various approaches in laboratory work in a collegiate physical science course. While no significant differences were observed in test results, students who had been given problem solving activities in their laboratory experiences scored highest on all of the tests. In an experiment with college freshman, Kaplan (1963) failed to reveal conclusive evidence that college students who have been taught biological science with an emphasis on the scientific method related more positively to their environment than those who were taught biological science by a content-centered method. He asserts that evidence is needed which will show how scientific thinking and attitudes can be made part of a student's everyday judgments and responses through proper educational experiences. His conclusions suggest that science teaching can be effective in promoting positive attitude growth in students provided the teaching procedures and materials are directed toward this goal.

In an attempt to limit non laboratory influences on changes in student behavior, Rainey (1965) contrasted experimental and control groups of high school chemistry students by exposing them to the same class discussion and recitation experiences while varying only the laboratory experiences. The experimental groups were presented with laboratory problems that had no specific directions, while control groups worked through carefully planned and directed experiments involved with the same general problems. Initially, the experimental groups resisted the non-directed experiments, but gradually accepted this procedure. Test scores showed no significant differences between the treatment groups on conventional tests concerned with the facts and principles of chemistry. However, on a performance test, randomly selected experimental students scored significantly higher than a similar control group.

In additional studies on student achievement differences, Pella and Poulos (1963) found no significant differences in student achievement among tenth grade biology students taught by an experimental team teaching approach as opposed to students taught "traditional" or content-centered biology. Further, Walters(1963) found no significant difference in the achievement of ninth grade biology students when compared to tenth grade biology students throughout all the ranges of ability, as measured by standardized tests.

Studies directly contrasting BSCS biology with conventional biology instruction have not illustrated any general differences of achievement between the two groups on standardized test measurements. Lance (1964) analyzed the achievement scores of students studying the Green Version of

BSCS biology and those students using a non-BSCS approach and found no significant difference. Lisonbee and Fullerton (1964) compared tenth grade students using the BSCS Blue version and students studying non-BSCS materials. While holding the student scores on the California Test of Mental Maturity and the Iowa Tests of Educational Development No. 6 constant they found a significant difference only between the scores on the BSCS comprehensive final for the BSCS middle ability subgroup and students in the traditional subgroup of similar ability. Proponents of the inductive laboratory use these findings as evidence to illustrate that students gain as much factual information in BSCS programs as students in non laboratory programs that stress greater accumulation of factual material. The question arises as to the value of changing curricula and teaching methods if no gain can be expected in student achievement. Watson (1963) has suggested that teachers will center their explicit instructional purposes around the limited tasks embodied in narrowly conceived student achievement examinations so long as teacher success is measured this way. Measurement of achievement, however, bears limited importance to the major goals of instruction in science.

Achievement tests measure a relatively narrow range of subject information and are limited by this concern (Watson, 1963). Yet skills of broader application may be gained by students while studying a specific subject, and represent a source of measurement that could aid in determining overall student growth. Specific skills important to science such as critical thinking serve as an example. Some research has been conducted to measure the effects of biology instruc ion on the development of student critical thinking skills. George (1965) analyzed all three versions of BSCS, Blue, Green, and Yellow, as they compared to conventional biology in developing student critical thinking skills. His study illustrated:

1. No significant differences between achievement and critical thinking skills of students studying the Green, Yellow, and conventional biology.

2. Students of the Blue Version scored significantly higher than students of conventional biology.

George used analysis of variance and covariance to adjust for variables, but had only one teacher teaching the Blue Version while two to four teachers taught each of the other versions. Thus, teacher background, philosophy, and ability were uncontrolled variables with effects upon the test scores.

Teacher variables of preparation, philosophy, and years of teaching experiences were investigated by Blankenship (1965) and analysis of the data illustrated that teachers with three years or less experience generally were more favorable to the philosophy of BSCS. Through the use of an Attitude Inventory completed by teachers and a Biology Classroom Activity Checklist designed and validated as part of his study, Kochendorfer (1966) found a significant correlation between the teacher's attitude toward BSCS philosophy (inductive laboratory) and the degree to which the teacher's classroom practices agreed with those advocated by BSCS.

In view of the studies examined, it was reasonable to conclude that achievement tests did not generally illustrate differences among control and experimental groups of students in studies contrasting BSCS with traditional, content-centered methods. It appeared that whatever changes in student behavior resulted from the use of the inductive laboratory, these changes were not measured solely by achievement tests. It is important to note further that few studies illustrated any significant differences of achievement between students who spent less time studying factual content in favor of more time for problem solving, and students who spent most of their time studying content-centered biology.

Research directed toward identifying instructional procedures that improve student critical thinking skills has particular relevance to the production of scientifically literate adults. There is general agreement among investigators that the characteristics of persons with a scientific point of view include: open mindedness toward the work and opinions of others, formation of opinions and conclusions based on adequate evidence, and evaluation of the procedures used for obtaining information (Nelson, 1960). These characteristics are similar to those used in describing critical thinking skills. Mason (1963) described critical thinking as a process characterized by the ability to recognize and define problems, select relevant information in problem solving, and formulation of possible solutions to a problem by recognizing assumptions and testing hypotheses to reach a valid conclusion. He further stated that many present day investigators describe these abilities through synonymous use of the terms critical thinking, problem solving, scientific methods, methods of science, and scientific thinking.

It seemed plausible to expect that certain curriculum materials would lead to more effective development of student critical thinking skills, and that this development would be pronounced in those materials concerned with the overall improvement of student understanding of science and its process, as in the case of BSCS instruction. The Watson-Glaser Critical Thinking Appraisal is designed to test the application of critical thinking abilities in exercises concerned with inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. The test is appropriate for determining the effects of instruction in preparing students to apply these abilities in everyday life situations or the conditions that face an adult (Watson-Glaser, 1954). The data thus obtained was particularly relevant for determining the effects of BSCS instruction on critical thinking skills and the application of these skills in the circumstances that the student will face as an adult.

The attitudes of an individual are usually inferred from observed behavior (Foss, 1960). There are numerous definitions for attitudes and most of them embody the idea that a response of an individual is determined by his mental state and organized experiences which exert a dynamic influence on his choices (Allport, 1954). Attitudes are enduring in that they carry over to new situations (Newcomb, 1964). They do change, however, as a result of acquired experience, and are capable of being developed by experiences that modify the individual's affective structure. Measurement of changes in attitude is possible through the use of certain testing procedures such as scaled devices.

The attitude scale includes questions which result in scores or subscores for an individual on the basis of his responses. The items included in the scale should elicit responses related to the attitude being measured, and should differentiate among people who are at different points along the dimension being measured. Thurstone scales are equal interval scales consisting of statements which represent equal numerical distances along the continuum being measured.

Remmer's test Attitude Toward Any School Subject is based on Thurstone's procedure. While it is doubtful that Thurstone type scales consist of absolutely equal intervals, they provide a reasonable and usable method of determining satisfactory ordinal scales. That is, they provide a basis for saying whether one individual expressed a more favorable attitude than another (Sellitiz et. al., 1954).

The limited amount of research in measuring the effects of inductive laboratory learning on student attitudes suggested that this area might yield profitable data. Boeck (1956) found, for example, that student attitudes were markedly less positive when the students studied an area of physical science through reading experiences only. However, these same students showed no significant difference in achievement scores when compared to students who had read and discussed the same materials, or had read and observed demonstrations of the same materials. While this study does not directly concern inductive laboratory learning, it illustrates the differences that may exist among students with regard to attitude while no differences are illustrated in their achievement test scores.

A favorable attitude toward a science subject was expected to reveal the individual's willingness to accept the ideas, procedures, and basic philosophy of the subject. The relationship of teacher attitude and classroom practices has already been demonstrated (Kochendorfer, 1966) as has the number of years experience and positive teacher attitude toward BSCS philosophy (Blankenship, 1965). Measurement of student critical thinking skills and attitudes as related to the use of inductive laboratory learning procedures measured differences in student behavior of broader application than that measured in subject achievement tests. At the same time this analysis provided data allowing a comparison of the relative effectiveness of inductive laboratory vs. conventional biology instruction upon changes in these student behaviors.

OBJECTIVES

The purposes of this study were:

1. To determine if the use of laboratory based (BSCS) instruction in biology results in greater development of student critical thinking skills than non laboratory based instruction.
2. To determine if the use of laboratory based (BSCS) instruction in biology results in greater development of positive student attitudes toward biology than non laboratory based instruction.
3. To determine whether there is a relationship between the attitude of the teacher and the development of student critical thinking skills through the use of

laboratory based (BSCS) instruction in biology.

4. To determine whether there is a relationship between the attitude of the teacher and the development of positive student attitudes toward biology through the use of laboratory based (BSCS) instruction.

Basic Hypothesis

The hypothesis of this study was that use of laboratory centered instruction in biology will result in greater improvement of student critical thinking skills and the development of a more positive attitude toward biology.

Procedures

The research design compared biology instructional procedures as the independent variable with student critical thinking skills, student attitude, and teacher attitude as the dependent variables. The sample of 148 students and 6 teachers was divided into two instructional groups. The instructional groups consisted of three sections each of tenth grade college preparatory biology students. The experimental group received instruction in BSCS biology, and the control group received instruction in conventional biology. A description of the treatments is as follows:

Treatments 1, 2, 3, and 4:

		Remmer Attitude Scale			Watson-Glaser Critical Thinking	
		Pre-test	Post-test		Pre-test	Post-test
1.	students in experimental group - BSCS instruction	1-74	1-74	3.	1-74	1-74
2.	students in control group - non laboratory based instruction	75-148	75-148	4.	75-148	75-148

Treatments 5 and 6:

		Minnesota Teacher Attitude Inventory (MTAI)	
		Pre-test	Post-test
5.	teachers using BSCS materials	1-3	1-3
6.	teachers using non-BSCS materials	4-6	4-6

Treatment 7:

7. Analysis of student scores on the Otis Quick Scoring Test of Mental Ability for each instructional group.

Treatments 8, 9, 10, and 11:

8. Comparison of teacher attitude scores (MTAI) with student scores on critical thinking (Watson-Glaser) for BSCS instructional group.

9. Comparison of teacher attitude score (MTAI) with student scores on critical thinking (Watson-Glaser) for non-BSCS instructional group.

10. Comparison of teacher attitude score (MTAI) with student attitude scores (Remmer) for BSCS instructional group.

11. Comparison of teacher attitude score (MTAI) with student attitude scores (Remmer) for non BSCS instructional group.

The treatments allowed consideration to be given to differences that occurred in student behavior as a result of the instructional procedures contrasted and changes of teacher attitude. The studies were completed in areas where similarities of training and experience are reflected in teacher salaries. Teachers who participated in the study had salaries ranging from $6000 to $7000, and their training and experience was reasonably distributed among the four treatments.

Population and Sample

The sample for the study included students and teachers from six schools in five counties from eastern Pennsylvania. The schools were selected on the basis of: (1) use of either conventional or BSCS biology with tenth grade college preparatory students, (2) instruction of the biology materials by a teacher responsible solely for teaching biology, who was within the salary range of approximately $6000 - $7000, and (3) consent of the school district personnel who were responsible for the study.

The investigation was limited to tenth grade college preparatory students since the biology materials were designed for this grade level and are used most frequently with this group of students. Because of the difficulty of administration it was impractical to assign students randomly; however, by using the first school from each county in the population that satisfied the above criteria, selected by following the alphabetical listing in the Educational Directory for the State of Pennsylvania, it was possible to obtain a random, intact sample of students and teachers that suited the above criteria.

Perhaps the greatest limitation to this study was that the teachers did not necessarily restrict their patterns of behavior to those characteristic of the material used; thus differences in student behavior were not completely the result of instructional procedures characteristic of the materials used. If there had been a means of providing the participating teachers with training to enact only those patterns typical of the respective biology instructional materials, it is not certain that there might have been greater differences in the outcomes. However, since the curriculum materials used were being studied to determine the effectiveness of laboratory based instruction, then the degree to which BSCS materials evoke teacher instructional patterns appropriate to the the philosophy and design of the curriculum had to be considered an important factor and included as a necessary influence in the study.

The choice of salary range resulted in the participation of BSCS teacher with more than three years experience or teachers beyond the length of experience in which greater willingness to accept the rationale of the different biology materials and their concomitant instructional procedures has been demonstrated by research (Blankenship, 1965).

Data and Instrumentation

1. The data on student critical thinking skills was obtained by using the Watson-Glaser Critical Thinking Appraisal. The test, designed for use in grades nine through twelve, provides problems and situations which require the student to employ the important abilities involved in critical thinking. The test is particularly appropriate for measuring the effect of selected instructional methods on the kind of critical thinking required to interpret the information encountered by a citizen in a democracy, including realistic items, problems, statements, arguments, and interpretation of data representative of newspaper articles, speeches, daily discussions, etc. The sub tests (Inference, Recognition of Assumptions, Deduction, Interpretation, and Evaluation of Arguments) involve critical thinking about two different kinds of subject matter. One kind of subject matter is characteristic of "neutral" subject matter including scientific facts and experiments while the second kind includes items of emotional feelings or prejudices

and provides for affective influence in the student's judgment.

Since the study measured the development of critical thinking skills needed by students to become contributing members of society, the emphasis of the Thinking Appraisal test was appropriate for obtaining data representative of important student behaviors.

Form YM was administered to the students in the fall and again in the spring. Changes in individual student scores were computed for each instructional group. These scores were compared and analyzed for differences that occurred between the groups as a result of their instruction in either BSCS or conventional biology materials.

2. The data for student attitudes toward biology was obtained through use of A Scale to Measure Attitude Toward Any Subject - H. H. Remmers. The test has been validated against Thurstone's specific scales for differentiating attitudes toward a particular subject and shows high correlation. The test measures the degree to which the subject of biology is liked or disliked by students and reveals the effects of the various instructional methods on the growth of positive student attitudes toward biology.

A favorable attitude toward a subject can reasonably be considered to reveal an individual's willingness to accept the ideas, procedures, and basic philosophy of the subject.

A positive attitude toward biology should allow the student to interpret events and information in biology as acceptable, and thus provide him with the ability to relate positively to biological information and to analyze such information freely without interference from a negative bias.

The Remmer's Scale has been shown to be more effective if the number of student responses is limited. Much of the objection to the use of this generalized scale was overcome through the use of this procedure (Howe, 1967) since reducing the number of responses overcomes the tendency to approach the mean, characteristic of numerous responses to the test items. Student responses were restricted to a total number of four for each administration of the test. The procedure of using reduced responses has been employed successfully in research with the Remmer's Scale (Howe, 1967). The Attitude Scale was administered to the students in the fall and again in the spring. Changes in individual student scores were computed and each instructional group was compared and analyzed for differences.

3. Each teacher completed a Minnesota Teacher Attitude Inventory to determine any changes in teacher attitude. The test measures those attitudes that predict how well the teacher gets along with his students and how satisfied he is with teaching. Since attitude is the result of the interaction of a multitude of factors, this attitude measure

reflects the influence of the instructional methods and student reactions to these methods. By measuring changes in teacher attitude it was possible to determine what relationship exists between the teacher's attitude changes and any changes of student attitude and critical thinking skills. Form A of the Minnesota Teacher Attitude Inventory was administered in the fall and again in the spring, at the same time the students completed their attitude test. Teacher attitude changes were compared to changes in student attitudes and critical thinking skills to determine what relationship exists. This measurement was expected to be influenced by the instructional methods employed by the teacher.

4. Each student completed the Otis Quick Scoring Mental Ability Test, Form AM during the spring testing. Data from this test were used to determine whether the respective instructional groups were different in scholastic aptitude and for a covariance analysis if this difference proved significant. The Otis Mental Ability Tests have been widely used as general mental ability tests.

Analysis

1. The gain of pre-test - post-test scores on the Watson-Glaser Critical Thinking Appraisal was examined by an analysis of variance to determine any differences in the

amount of student gain as a result of their use of the respective curriculum materials.

2. The gain of pre-test - post-test scores on A Scale to Measure Attitude Toward Any School Subject was examined by an analysis of variance to determine any differences in the amount of change in student attitudes as a result of their use of the respective curriculum materials.

3. Student scores on the Otis Quick Scoring Mental Ability Test were examined by an analysis of variance to determine whether the students in the respective instructional groups were significantly different in scholastic ability.

4. The change in teacher scores on the Minnesota Teacher Attitude Inventory test was examined by a t test to determine whether a significant difference occurred as a result of the use of the respective curriculum materials.

5. The change in teacher attitude scores was compared to changes in student attitude scores to determine the degree of relationship that existed.

6. The change in teacher attitude scores was compared to changes in student critical thinking scores to determine the degree of relationship that existed.

SUMMARY

The studies made in evaluating laboratory based instruction have provided valuable information regarding student achievement and certain other related factors of learning, but it can be seen that the effectiveness of this instruction in providing for positive student growth in critical thinking and attitudes has not been fully determined. It is important that the contributions made by laboratory based instruction toward realizing significant student growth in these areas be carefully measured with existing instruments rather than postponed until innovative measures are developed to assess science instruction.

Three existing instruments were used to measure the effectiveness of laboratory centered instruction. The Watson-Glaser Critical Thinking Appraisal was used to measure student changes in critical thinking. A Scale to Measure Attitude Toward Any School Subject was administered to assess the changes in student attitudes toward biology, and the Minnesota Teacher Attitude Inventory was employed to measure the changes that took place in the teacher's attitudes toward students and the teaching process. The Otis Quick Scoring Mental Ability Test was used to determine whether students in respective instructional groups differed significantly in scholastic ability.

The research design included six teachers and students from six schools in five counties of eastern Pennsylvania. The laboratory centered and non laboratory centered instructional group pre-test and post-test gain scores were examined by an analysis of variance and _t_ test. Teacher attitude scores were compared with student scores in critical thinking and attitude to investigate their relationship.

CHAPTER II

REVIEW OF RELATED LITERATURE

There have been numerous research studies in education to determine the effects of teaching method on pupil growth. However, in science education generally and biology education in particular, studies of this type have been limited. A review of the literature suggested that the relevant studies be presented in the following manner:

1. Reports and studies concerned with the general aspects of science laboratory instruction.
2. Reports and studies concerned with research on the development of student critical thinking skills.
3. Reports and studies concerned with research on the nature of student attitudes.

Research on Science Laboratory Instruction

Instruction in science has always been influenced by the laboratories of science, either through the research completed there or because instructors believed that learning in the classroom should occur as it does in scientific research. Laboratory centered instruction has been described in various ways but is generally considered to consist of elements of student participation and search for answers to problems through activities with science equipment, and with reduced direction from the teacher.

The value of laboratory work in the science curriculum was considered widely in the 1920's and 1930's. Nevertheless, a review of the literature up to 1945 revealed that many of the investigations were inconclusive and based on written tests (Cunningham, 1946). Frequently the value of laboratory instruction was judged by student performance on achievement tests. As early as 1925 Isenbarger found lecture-demonstration methods in biology superior to laboratory methods of instruction insofar as fact-getting is concerned.

In a study completed to determine the effects of the teacher's background and the length of time students spend in laboratory instruction, Anderson (1950) found a significant and positive relationship between these factors and high school student biology scores. Students showed similar gains in chemistry when covariance analysis of pre-test and post-test scores was repeated and he concluded that teacher background in credits and degrees, together with an increase in student laboratory time, is significantly and positively related to student growth.

Lahti (1956) and Kaplan (1963) experimenting with college students discovered no significant relationship between problem solving and emphasis on scientific method in improvement of student's test scores and positive relationship to their environment. Kirk (1954) asserted that the arguments about laboratory instruction were offered forty to fifty years earlier. He described laboratories as: (1) the best known method for inducing young people to use their minds; (2) the place where orderly habits are established; (3) historical insights are taught; and (4) the source of recruitment for tomorrow's scientists. He maintained that science teachers may have become careless in the use of the laboratory as a teaching tool.

Science educators continued to lay stress on the need for varied experiences in instructional procedures. Richardson (1954) and Hurd (1961) believed that biological science courses must be based on laboratory and field experiences, and in every case must include direct investigation through observation, experimentation, and research.

Bradley (1965) examined freshman at Michigan State University to determine whether there was any difference in achievement as a result of the lecture demonstration, and individual laboratory procedure. Using 162 freshman in the required physical science course, Bradley controlled all the variables except the instructor and methods of teaching variables and found no significant difference at the .05 level in achievement on the final examination in the course. Since no clear superiority of method was demonstrated by the study, he felt that a considerable savings in instructor time, apparatus, and time for using the physical plant might be possible if students did not use the individual laboratory method. He also concluded that many methods have their place in science teaching so that the proper functions of each should be measured.

Additional studies centered on student achievement revealed no significant differences among tenth grade biology students taught by experimental team teaching and traditional methods of instruction (Pella and Poulos, 1963). Similarly Walters (1963) found the achievement of ninth grade biology students equivalent to tenth grade biology students throughout all ability ranges.

Research concerned with the effectiveness of the BSCS curriculum materials also contrasted the inductive laboratory with former biology materials and instruction through the use of achievement test measurements. Lance (1964) found no significant difference between students in conventional biology classes and students in classes studying the Green Version of BSCS biology. Lisonbee and Fullerton (1964) compared tenth grade students in a Blue Version BSCS program with students studying non-BSCS materials and found a significant difference favoring the BSCS classes in the middle ability subgroup only. The researchers based their evidence on the BSCS Comprehensive Examination and utilized procedures to hold student scores constant on a mental maturity and non-BSCS achievement test. Rainey (1965) limited non laboratory influences and found no significant differences between conventional and laboratory treatment groups on chemistry achievement tests. A performance based test did, however, reveal a significant difference among randomly selected students in favor of the laboratory based instruction.

Hurd and Rowe (1964) in reviewing the research on discovery vs. verification procedures found no difference in the effect of either instructional method on student learning and concluded that: "Inductive discovery methods of science instruction failed to produce more effective learning than traditional deductive verification measure." (p. 289) Proponents of the inductive laboratory method of instruction use the demonstrated similarity of learning results as support for discovery procedures, stressing the absence of any adverse effect on student growth in spite of decreased time spent on facts in favor of increased attention to selected principles.

Science educators have repeatedly insisted that education in science must be concerned with student growth in areas that are not merely concerned with acquisition of factual knowledge, and yet as illustrated by the references cited, achievement measurements have served as the focal point of many studies assessing science instruction. Watson (1963) has suggested that teachers will direct their efforts toward imparting subject matter commensurate with the narrow range of information found in achievement tests whenever student growth is measured this way.

In an investigation of teaching methods used by high school biology teachers (Hurd, 1961), demonstration-discussion techniques, lectures, and test-recitation were cited most often as the teaching method used. The investigation disclosed:

> Laboratory work was not considered a primary method for teaching biology; only 3% of the teachers stated the method was frequently used, while 34% classified it as a less commonly used technique. Individualized methods, projects, and research problem approaches were used by 1% of the teachers. Older experienced teachers were more inclined to lecture and teachers rated as <u>conservative</u> by a jury spent two-thirds of their time in a lecture-textbook-recitation routine. Teachers rated as progressive by a jury spent 69% of their teaching time in laboratory work, projects, or demonstrations and also had more students entering science fairs.

Hurd also noted that teachers usually did not use the method they rated as most effective.

In Michigan, Aylesworth (1960) observed the classroom practices of biology, physics and chemistry teachers to determine the attitudes of the teachers toward teaching problem solving skills, and to determine the relationship between those skills the teachers indicate they use and the skills actually employed in their classrooms. Problem solving attitudes and practices in the study were concerned with critical thinking skills and student collection of data as indicated from a standardized checklist used in classroom observations. Although the teachers expressed favorable attitudes toward the teaching of problem solving, and did use the methods they indicated as part of their classes, Aylesworth concluded that the teachers did not use the methods enough. He felt that either the teachers do not understand that problem solving must be taught directly, or else they do not understand the process itself.

It seems clear from research studies that teachers generally employ methods that embody the goals of science as they are defined by testing procedures concerned with student achievement. The apparent contradiction between expressed goals of instruction and the classroom practices of teachers may, of course, be attributed to many causes. Nevertheless, it seems clear from the literature that teachers are inclined to center their instructional patterns on goals that point in the direction of achievement despite expressed belief in the importance of much broader goals of science. Rickert's study (1967) serves to illustrate a growing concern over the importance of instructional procedures that produce student growth of a broader nature.

In a study conducted in 1958-59, Rickert found that students taught by an eclectic physical science course emphasizing problem analysis, examination of assumptions, collection and organization of data, and testing of hypotheses, showed a mean gain in a test of critical thinking (significant at the .05 level) over freshman in the survey course in physical science and freshman in the physics course. Rickert used the A.C.E. Test of Critical Thinking, Form G for his analysis. Participating students in all groups were found to be similar with respect to the measurements of the School and College Ability Test, and STEP Test. The students were all non-science majors. He concluded: "The ability to think is in some degree common to all men; but this ability increases most rapidly when it is intelligently nourished by suitable learning activities." (p. 27) Rickert's experimental data seems to support the hypothesis that the ability to think critically can be improved in the short span of one semester with courses that provide opportunities for problem solving activities.

Following the many attempts to contrast science instruction by comparing student achievement growth, the attention of science educators turned to concern for developing and measuring student skills of a much wider application. Activities related to problem solving and critical thinking began receiving increased emphasis in research.

Research on Critical Thinking Skills

Improvement of student critical thinking skills proved particularly relevant to science instruction and the influences of various instructional methods on critical thinking have been given attention in research studies. In this writer's experience, one result of these efforts has been a proliferation of definitions and terms that describe the nature of critical thinking behavior and attendant student activities.

The characteristics of an individual with a scientific point of view, as agreed upon by many investigators (Nelson, 1960), include intellectual activities similar to those used in describing critical thinking. A scientific point of view is considered to include characteristics of open-mindedness, formation of opinions and conclusions based on adequate evidence, and evaluation of information-gathering procedures. At the same time, critical thinking may be described as the ability to recognize and define problems, select relevant information, suggest solutions that recognize underlying assumptions, and test hypotheses in the act of reaching a valid conclusion (Mason, 1963). The similarities are further heightened by frequent synonymous use of the terms scientific methods, methods of science, scientific thinking, problem solving, and critical thinking.

Waston and Glaser (1952) have defined critical thinking as a composite of attitudes, knowledge, and skills. They include in this composite (1) attitudes of inquiry that involve the ability to recognize the existence of a problem and the acceptance of the general need for evidence in support of what is maintained as true; (2) an understanding of the nature of valid inferences, abstractions, and generalizations in which the weight or accuracy of various kinds of evidence are logically determined; and (3) skills in applying the above attitudes and knowledge.

Dressel and Mayhew (1954) in their definition of the concepts of critical thinking refer to five abilities:

1. The ability to define a problem.
2. The ability to select pertinent information for the solution of a problem.
3. The ability to recognize stated and unstated assumptions.
4. The ability to formulate and select relevant and promising hypotheses.
5. The ability to draw conclusions validly and to judge the validity of inference.

The above definitions serve to illustrate the attention given to critical thinking and underline the basic similarities found in present day research descriptions. The continued stress that investigators place on the need for student practice of the skills of critical thinking is evident (Heiss, 1958). Certain earlier references concerned with the ultimate values of science education discussed this process also.

In the early 1930's, Tyler (1942) stated that the first step in the rebuilding of science education is to recognize the scientific method of critical thinking as a major objective of science instruction. To accomplish this he proposed that students be allowed to work with real problems, seek real data, and entertain generalizations and hypotheses. He felt that in this way students would come to recognize the tentativeness of any scientific formulation.

Using experimental materials, devised to emphasize certain of the critical thinking skills included in the 1942 Yearbook of the National Council for the Social Studies, Anderson and others (1944) analyzed the results of instruction with "doing" and "telling" methods. After administering objective tests, prepared by the investigators and tested for adequate reliability and validity, the experimenters noted almost identical final averages for the 1800 Iowa and New York seventh and tenth grade students in both the "doing" and "telling" groups. Data obtained from control classes, that did not receive the instruction in critical thinking, showed similar results on the "Abstracting and Organizing Information" portion of the test, but decidedly lower gains on the section of the test "Drawing Conclusions". The experimenters suggested that the results seemed to indicate that instruction in critical thinking problems developed skills associated with making of inferences and drawing conclusions.

Edwards (1950) stated that critical thinking is regarded as one of the most important aims of education at all levels and it is given a high place by authoritative committees such as the Educational Policies Commission, The Harvard Faculty, and the American Council on Education. While considering the status of research in critical thinking, Dressel and Mayhew (1954) observed that the major need of research in connection with critical thinking is that it be basically oriented toward and integrally related to classroom practices.

The relationship of problem solving and laboratory instruction was considered in many fields of science with results generally favoring the inductive-deductive or problem solving laboratory: Kruglak (1951), Balcziak (1953), Gunkle (1952), Thelen (1944), Mason (1952), Olson (1957), and Deardon (1959). Other studies showed no significant results (Frings and Hichar, 1958). Dawson (1956) found the problem solving method of instruction to have significant advantages over the lecture-recitation method in terms of achievement on tests covering certain abilities in problem solving. The two instructional methods produced no important differences in achievement on tests requiring specific recall of information however.

In 1956, Bloom wrote emphasizing the importance of critical thinking and noted that educators were looking toward a broad application of such skills:

> Improvement in critical thinking is an urgent necessity. This is apparent in all disciplines by the growing emphasis placed upon training in critical thinking. The

> need is focused by educators who emphasize that more assistance be given to students to develop problem-solving methods which will yield more complete and adequate solutions in a wide range of problem situations. (p. 10)

The daily classroom activities were examined by Oburn (1960) to determine the extent to which teachers employed practices important to critical thinking growth. He pointed out that while problem solving or scientific thinking was an accepted outcome of science teaching, little reliable evidence was available to indicate the extent to which this objective is provided for in everyday classroom activities. As an outcome of this he cited the billions of dollars spent annually for medicines and unfounded cures as sound evidence of the scientific illiteracy persistent in our nation.

Research directed specifically toward the influence of three BSCS Versions of biology on critical thinking skills and student achievement was completed by George (1965). He found that only students using the Blue Version of biology showed a significant difference in their scores as compared to the Yellow, Green, and conventional biology courses. However, one teacher was responsible for instructing the Blue Version biology while two to four teachers provided instruction in the other classes so that the teacher variable was a factor in the study.

Sorensen (1966) in his review of the literature on the development of critical thinking in biology instruction concluded that:

1. Although critical thinking was recognized as a goal of science teaching in the early twentieth century, those teachers who attempted to employ critical thinking in their classrooms were unable to recognize much success.

2. Later reports and research suggested that critical thinking could be taught if the teacher understood the behavior involved.

3. Scientific thinking that deals with applying principles and interpreting data is closely related to a knowledge of scientific facts and principles.

4. Meaningful learning appeared to be closely related to critical thinking.

5. There appeared to be an urgent need for broader research in critical thinking at the high school level since many of the studies made in this area were done with college students, using only slightly different methods of teaching.

Sorensen further stated that in recent years progress in critical thinking has been made in at least three directions: (1) a recognition of the need for improvement; (2) a clarification of what is meant by the term critical thinking; and (3) analysis of the deterrents to better performance.

In the process of assessing instructional and learning acts as they relate to critical thinking, science educators have attempted to define the values of critical thinking in terms of the adult or post-school importance of such skills. They have applied the term scientific literacy to this goal and have come to recognize that likes and dislikes - the affective or attitudinal component of students - are integrally related to the realization of this goal. Although thinking seems dependent on knowledge, additional factors are believed to influence thought processes. Thinking is not an automatic outgrowth of knowledge and the dimension of attitudes is recognized as important. Reiner (1959), for example, describes the aim of science instruction as follows:

> The pupil is expected to think critically, and to solve problems, to develop interests, attitudes and appreciation, to make wise functional and consumer application of information he has learned; to develop an understanding of science as a force in molding society . . . (p. 30)

After completing a study of the critical thinking abilities and recognition of science intangibles with sixty eleventh and twelfth grade students attending a National Science Foundation sponsored summer institute, Smith (1963) felt that the science intangibles (i.e. the attitudes and mood of science and scientists) are not getting through to students by indirect teaching. He suggests that they be taught directly through courses or units of experience.

The attention to attitudes and appreciations, evident in Smith's conclusion, was found in much of the research literature of this decade. Frequently, however, this research related to instruction in science courses other than biology.

<u>Research on Attitudes</u>

Attitudes have been defined in many ways, and in most cases the individual's attitude is inferred from his overt behavior (Foss, 1960). These observed responses of an individual are explained as choices resulting from the dynamic influence of his mental state and organized experience (Allport, 1954). In addition, the attitude of an individual, while capable of modification and change, frequently endures from one situation to another (Newcomb, 1964).

Sells and Trites (1960) define an attitude as ". . . a psychological construct, or latent variable, inferred from observable responses to stimuli, which is assumed to mediate consistency and covariation among these responses" (p. 103). From the nature of response it can be inferred that attitudes follow either an approach or avoidance direction with regard to stimuli, illustrate an affective content, or are of a certain intensity. The degree of generality of an attitude is inferred from the class of stimuli to which common responses are made.

Research concerned with the effect of inductive laboratory instruction on student attitudes is somewhat limited. However, studies concerned with the measurement of achievement and critical thinking have revealed information on attitudes which suggests that measurement in this domain may yield dividends for learning research. Boeck (1956) illustrated differences in attitude among students according to the type of instruction they received even though their achievement scores did not differ significantly. Smith (1963) urged that direct teaching be employed to develop the intangibles of science as a result of his research. The attitude of students is recognized as exerting more than minor influence on their learning activities.

The influence of science instruction on student attitudes was examined by Oliver (1961). He used the Otis Mental Ability Test, the Nelson Biology Test, and the Indiana High School Biology Test to evaluate outcomes of over-all achievement, acquisition of factual information, application of principles, and attitudes toward science and scientists in his study of three methods of teaching high school biology, 1957-59. Results of the evaluations showed significant differences in outcomes of classes taught by each of the three methods. However, students with over 100 IQ on the Otis Mental Ability Test had more desirable attitudes toward science and scientists than did lower IQ students.

Lowrey (1967) studied 335 fifth grade students in an attempt to measure their changes in attitude toward the field of science as a result of instruction with new curriculum material (Elementary School Science Project) that stresses inductive learning to introduce the scientific method. The classes were selected from three socioeconomic areas in Oakland, California, and paired within each area on the basis of mean IQ scores. Teachers were randomly assigned to either the newer curriculum group, or the control classes using the

California state textbook series. After 7 - 8 weeks instruction, Lowrey concluded that the fifth grade students using the newer curriculum material stressing inquiry changed their attitudes toward science in a positive way as measured by the investigator's Projective Test of Attitudes. The gain of the students in the experimental group over the control group was significant at the .01 level. Moreover, children's attitudes were similarly affected throughout all socioeconomic groups, with attitude changes independent of gains in general science knowledge. Lowrey further asserted that although his study could not determine causes of attitudes and their changes, it was found that attitudes and their changes over a short period of time can be detected.

In a five year study of student attitudes as they are influenced by science instruction, relationships of attitudes to the classroom teacher, grades received, different science courses, and the time elapsed in a given course were examined. Wick and Yager (1966) used the test A Scale to Measure Attitude Toward Any School Subject to study the attitudes of students at the University of Iowa Laboratory School, grades seven to twelve, over a five year period. The study suggested the following conclusions:

1. In any group of students it appears that a certain portion will show a severe decrease in course attitude and they are not balanced by a comparable group of students showing a gain.

2. Student's attitudes toward the course appear to be highly dependent on the teacher in the classroom.

3. Grades do not seem to be of particular importance in determining the student's attitude toward a course.

4. Student's attitudes toward different science courses are not stable. There does not appear to be a group of students who are consistently pro or con in their attitudes toward science in the secondary school.

Recent studies of learning as it is related to retention of information and selected affective tone variables has produced a reassessment of the structure of attitudes. Attitudes are presently considered by some researchers to have both an affective and cognitive component with the cognitive component chiefly responsible for the contribution of proper attitudes to learning efficiency. In this theory a person with a positive attitude toward a subject learns more readily because he possesses a more stable and elaborated cognitive structure composed of prior knowledge, and is better able to "fit in" new material (Jackson and Strattner, 1967). Thus studies that hold cognitive variables constant seem to indicate little relationship between attitude and subject matter retention, or attitude and end of course achievement in biology.

Gaverick (1964) conducted a study to investigate whether in non-anxiety producing situations selective retention of meaningful learning can be attributed to cognitive rather than to affective dimensions of attitudes. Using A Scale To Measure Attitude Toward Any School Subject developed by Silance and Remmers, Gaverick tested 303 high school biology students to determine whether students who score high on such a scale tend to retain more school subject matter. Using data obtained approximately five months after the end of the biology course, post-test scores in the Nelson Biology Test were compared with end of the semester pre-test scores in the Nelson Test, and attitude scale scores. Holding intelligence statistically constant, partial correlations between end-of-course achievement scores and attitude toward biology scores was .23 which was significant at the .05 level. Gaverick concluded that any overall differences in retention had to be interpreted as being influenced primarily by factors related to differential end-of-course achievement, with significant correlations between attitude scores and retention obtained only before some controls were used to reduce the influence of cognitive aspects.

Vitrogan (1967) used a sample of sophomores enrolled in an academic program at the senior high school level to develop a generalized attitude scale that would measure positive or non-positive student attitudes toward science. Using an original eight-item summary of ideas taken from writings of scientists, philosophers, science educators, and researchers in science education, Vitrogan was able to construct an attitude scale which reflected four of the original hypothetical components of a positive generalized attitude toward science:

> 1. controlled observation will be distinguished from causal observation;
>
> 2. constant change will be stressed over non-change; a basic notion that reality is to be regarded as a process implying continuous change; no two things are exacting alike, no one thing stays the same;
>
> 3. structure in the form of relations and equations will be stressed over function; structure, the nature of the phenomenon, the broad unifying principle is stressed rather than the application (detail) or function;
>
> 4. the form of the question will be considered more important than the answer. (p. 170)

Subjects in the experiment who showed a high motivational involvement and high achievement in science as shown by the Iowa Test of Educational Development Numbers 2 and 6, Kuder Preference Form-Vocational, school grades, and a Science Teacher's Rating Scale, were found to have a high degree of acceptance and conviction concerning the components of the scale. Students of low motivational involvement and achievement on the external measures showed a high degree of acceptance and conviction with regard to the non-positive components of the scale which were stated positively to avoid response bias. The differences of the scores of the 205 subjects was found to be significant at the .01 level.

As a result of his findings, Vitrogan suggests further study in the same direction regarding attitudes and educational objectives:

> Research studies which would attempt to relate current practices in the teaching of science at the secondary level and the development of the components of a positive generalized attitude toward science is recommended . . . Further studies that relate the components of a generalized attitude toward science with critical thinking might shed light on the relationship of these attitudes and scientific methods. (p. 174)

Research in attitudes has not been limited to students only. The teacher's attitude toward students and subject matter has also received some consideration in research related to instruction. Nelson (1964) completed a study to determine if there was any difference between teachers and pupils with regard to affective and cognitive attitudes toward each other in the classroom. Using the Preferred Instructor Scale (PICS) and a modification of it for use in measuring students, Nelson found that 692 eighth grade pupils and 61 junior high school teachers deviated significantly in their attitudes toward one another. Teachers were found to be cognitively oriented toward pupils and pupils were found to be affectively oriented toward teachers. Furthermore, the findings suggested that teachers tended to reject those students not cognitively disposed in the classroom, and to accept those who are, resulting in a lack of emotional support in the classroom and withholding of needs satisfaction from the teacher by the majority of students who show preference for an affective teacher orientation.

The relationship of a teacher's attitude toward BSCS materials and the degree to which his classroom practices agreed with those advocated by the materials was examined by

Kochendorfer (1966) and found to have a significant positive correlation. Blankenship (1965) found a more favorable teacher attitude toward the BSCS program among teachers with three or less years of teaching and teachers who ranked higher on measures of capacity for independent thought and action.

The studies examined show that the influence of the teacher's attitude on his instructional procedures has been deemed important in biology instruction.

Summary

This chapter discussed certain of the studies that were concerned with laboratory instruction, critical thinking, and attitudes as they relate to science education. The studies were described in this order because of the nature of the information they offered and their logical contribution to the writer's research study. The controversy over laboratory and non laboratory instruction is of a long standing nature and has not been resolved. It appears that while educators aspire to broad goals of science, teaching patterns in biology seem concerned largely with the factual achievement of students.

A major concern is that evidence is needed which will demonstrate the superiority of laboratory based science instruction in developing student skills that are considered necessary to produce adults who are scientifically literate.

Furthermore, evaluation procedures have to be directed toward this goal since instructional patterns are greatly affected by the devices used to measure student growth.

The review of literature concerned with the facets of this study suggested the following summary:

1. Research studies do not demonstrate a clear superiority of either laboratory or non laboratory instruction in science but instead suggest that teaching for certain goals can effectively determine the nature and results of classroom practices.
2. Proponents of both the laboratory based and non laboratory based instruction use the lack of significant differences in research findings contrasting these methods of instruction to justify their instructional practices.
3. Science educators have voiced agreement on the broad goals of science but classroom practices are of a nature that seems directed toward producing student growth as determined by achievement tests.
4. Studies of the effectiveness of laboratory or non laboratory instruction are frequently measured by achievement tests, but the more recent research appears directed toward broader goals of science.
5. Critical thinking, problem solving instruction, and understanding of the scientific method are considered

valuable to science instruction because of their future contributions to a student's adult life.

6. Students can be taught to think critically if the teacher understands the behavior involved and provides appropriate learning and instructional opportunities for practice of these behaviors.
7. Attitudes determine the nature and intensity of a learner's response to stimuli. They are linked to student perception of the teacher, teacher perception of the student, and the cognitive and affective relationship of both parties to the instructional material.
8. Student attitudes toward science and science instructional procedures can change over the course of one semester, but frequently become more negative.

On the basis of the research described, the value and need for measurement of the effectiveness of laboratory centered biology instruction on student critical thinking skills and attitudes seems to be clearly demonstrated.

CHAPTER III

INSTRUMENTATION AND PROCEDURE

Brief Statement of the Problem

Research is needed which will reveal the effect of the new laboratory centered biology materials on the development of student critical thinking skills and student attitudes in biology.

To test the hypothesis that laboratory centered instruction in biology will produce greater improvement of student critical thinking skills and the development of a more positive attitude toward biology, relationships between methods of instruction and student critical thinking skills and student attitudes were determined for laboratory centered (BSCS) and non laboratory centered instructional groups. Teacher attitude changes were compared to student changes in critical thinking and attitude toward biology for both BSCS and non laboratory instructional groups. Teacher preparation, subjects taught, and salary and classification were also obtained and analyzed.

Selection of the Sample

Students and teachers from six schools in five counties from eastern Pennsylvania were included in the sample of this study. The selection of schools was based on:

(1) use of either conventional or BSCS biololgy instruction with tenth grade college preparatory students, (2) instruction of the biology materials by a teacher responsible solely for teaching biology whose salary was approximately within the range of $6000 to $7000, and (3) consent of the school district personnel responsible for the study. The individual classes were chosen by the teachers and principals.

The participating schools were Boyertown High School, Easton Area High School, Freedom High School, Hazleton High School, Pennridge Senior High School, and Souderton Area High School. Table I lists the schools, counties, and school enrollments.

TABLE I

SCHOOLS, COUNTIES, AND NUMBER OF STUDENTS ENROLLED

School	County	Enrollment
Boyertown Area High School	Berks	1611
Easton Area High School	Northampton	1995
Pennridge Senior High School	Bucks	2190
Freedom Senior High School	Northampton	1453
Hazleton City High School	Luzerne	1713
Souderton Area High School	Montgomery	918

The characteristics of the participating teachers and their classes are presented in Tables II and III.

TABLE II

TEACHER AGE, TYPE OF CLASS, TOTAL YEARS EXPERIENCE, YEARS EXPERIENCE IN PRESENT POSITION, AND SALARY

Teacher	Age	Type of Class	Total Years Experience	Years Experience at Present School	Salary
1	26	Laboratory Based	4	4	$6700
2	29	Laboratory Based	4	4	6750
3	26	Laboratory Based	5	5	6800
4	24	Non laboratory	3	3	5900
5	35	Non laboratory	5	½	7100
6	27	Non laboratory	6	6	6300
Average	28		4.5	3.8	$6592

NOTE: Teachers #1 and #2 used the Green Version of BSCS biology, and teacher #3 used the Yellow Version.

TABLE III

TEACHER, TYPE OF CLASS, CLASS SIZE, TEACHER PREPARATION IN BIOLOGY, CHEMISTRY, AND MATHEMATICS, AND THE YEAR LAST SCIENCE COURSE WAS TAKEN

Teacher	Type of Class	Class Size	Hours in Biology	Hours in Chemistry	Hours in Mathematics	Year of Last Course
1	Laboratory Based	26	23	24	6	1966
2	Laboratory Based	26	38	8	3	presently enrolled
3	Laboratory Based	33	43	8	9	1967
4	Non laboratory	30	43	4	3	presently enrolled
5	Non laboratory	27	32	16	0	1954
6	Non laboratory	28	60	4	0	presently enrolled
Average		28	39.8	10.7	3.5	

Collection of Data on Student Critical Thinking Skills

The latter portion of the testing period was used by the writer to administer the Watson-Glaser Critical Thinking Appraisal to the students. Form YM was used as a pre-test and post-test. The test contains five subtests which were designed to reveal how well the student is able to reason logically and analytically. The names of the five subtests are (1) Inference, 20 items; (2) Recognition of Assumptions, 16 items; (3) Deductions, 25 items; (4) Interpretations, 24 items; and (5) Evaluation of Arguments, 15 items. Separate answer sheets were provided for the pre-test and post-test with reusable test booklets. The one hundred items were multiple choice and true-false. All students were allowed to finish the test as recommended in the manual of instructions for administering the test.

The students were told that they were to be part of a research study but that there would be no change in their daily activities as a result of the study. It was further explained that their test results would be known only to the writer, and that any answers or opinions they recorded would in no way affect their grade in the course. The students were not told the nature of the research study so that they were unaware of any outcomes that might be considered desirable by the teacher or writer, and could be considered therefore as not having been given any specific response set as a result of the above information provided.

The test administration was completed exactly as directed in the manual of directions with the time allotments preserved as instructed. The teacher completed a teacher attitude test during this time and did not participate in the testing procedures involving the students. In most cases, the teacher was not present during the major portion of the testing period.

The results of the pupil scores were used as one of the measures of the effectiveness of laboratory centered instruction. The raw scores from fall and spring were used to compare the laboratory and non laboratory centered instructional groups with regard to critical thinking skills.

The Manual of Directions states (1964, p. 1): "The Watson-Glaser Critical Thinking Appraisal consists of a series of test exercises which require application of some of the important abilities involved in critical thinking." The test authors' concept of critical thinking involves three areas:

1. An attitude of inquiry involving the need to have supporting evidence for what is asserted as true and an ability to perceive the existence of problems.
2. Knowledge of the procedures of inquiry that allow for determining the weight or accuracy of different

kinds of evidence in making valid inferences, abstractions, and generalizations.

3. Skill in applying the above attitudes and knowledge.

Ennis (1958) observed that the Watson-Glaser test gave too high a score to the chronic or pathological doubter. The CTA has since been revised (1963) and presented in different forms. The reliability of Form YM has been computed for 180 ninth grade students and two hundred senior college women using corrected split-half reliability coefficients. With standard errors of 3.8 and 3.7 the coefficients of .82 for the ninth grade and college senior women respectively represent satisfactory test reliabilities. Correlations of the CTA with mental maturity tests and non-language mental maturity tests indicate the CTA measures convergent thinking skills and is different from scholastic aptitude tests.

Collection of Data on Student Attitudes Toward Biology

The other method used to measure the effectiveness of BSCS biology instruction was to compare changes in attitude scores of students on Remmer's *A Scale to Measure Attitude Toward Any School Subject*. Form A was used for both the pre-test and post-test. The reliability coefficients for this test range from .71 to .92 from grade six pupils to graduate students and are considered adequate for group measurements.

The test to measure student attitudes was administered at the beginning of the testing period to avoid the possible effects that weariness from any previous testing in that subject might have had upon the student's attitude toward the subject. Students were told that their answers would be helpful only if they were completely truthful. Particular attention was taken to explain as clearly as possible that the research study and the answers they provided on the tests would not affect their program of instruction in biology or their grades in biology, and that the writer would be the only person to see their answers.

The attitude scale, which consists of one page containing the statements students are to consider and a place for responses to the statements, was given to each student in the pre-testing period, and a second copy again in the post-testing period. Students were asked to write a plus sign before only those statements which, in their opinion, described the way they felt about the subject of biology. The students were further instructed to limit their total choices to no more than four answers on each test as advised by the associate director of the Educational Research Information Center (ERIC) for science education, Ohio (Howe, 1967). This procedure is used to reduce the tendency for student answers to ineffectively approach the mean because students, to avoid leaving statements unanswered on their paper, tend to provide more answers than may be necessary.

The test A Scale to Measure Attitude Toward Any Subject, validated against Thurstone's specific scales for differentiating attitudes toward a particular subject, consists of seventeen statements with scale values ranging from 1.0 which is considered to represent an extremely negative attitude toward the subject, to 10.3 which is considered to represent an extremely positive attitude toward the subject. The median scale value of the statements endorsed is the attitude score. If an odd number of answers is endorsed, the score is the scale value of the middle answer. The value halfway between the middle two scores of an even number of answers is the student's score when an even number of statements is selected. Wick and Yager (1966), in their five year study of students in grades seven to twelve, found the median of the test's scale units to be a more stable measure than the mean over a testing period between fall and spring, and from one grade to another.

The Thurstone technique of attitude measurement has been compared to self rating methods. Riker (1944) compared the results obtained using a logical technique of attitude measurement with the results obtained by the use of an empirical technique. Substantially similar results were obtained with the Thurstone technique (empirical) and by simple self-rating methods (logical) technique) employing a line sectioned into eleven steps placed below questions matched to Thurstone's scale. No scale values were defined for the subjects except the extremes at both ends: "Extremely in favor," and "Extremely opposed." The results were concluded to be essentially the same based on the correlations between the two measures and the demonstration of the similarity of the distributions of responses on both types of scales.

Pre-test post-test attitude designs have proven to be valid. Rayder and Neidt (1964) in their study of the effects of multiple exposure to attitude tests commented that they found no evidence to substantiate the proposition that pre-test sensitization acted to depress subsequent attitude scores, as revealed by their use of the Solomon design. Using Thurstone's "Equal Appearing Intervals" technique, the investigators constructed and validated a twenty-six item scale to measure attitude. They found no evidence indicating that attitudes involving method of instruction and expectation fulfillment evoke sufficient involvement on the part of the subject to be an issue in attitude change designs of a longitudinal nature, thus lending support to a pre-test post-test scale administration to control and experimental groups. The investigators did observe a consistent decline in attitude for all areas measured in the courses however.

Bartlett and others (1960) describe bias in attitude measurement as: ". . . any response to a statement that is a result of something other than agreement or disagreement with the statement itself . . ." They cite deliberate faking, response set, or simple inaccurate estimation of one's own opinions as possible sources of bias and warn that pre-test post-test gains may result as a function of response set, i.e., the subject's desire to please the experimenter rather than positive attitude change. Inasmuch as no clue was provided that could allow for students to detect and employ a desired response set, bias due to deliberate faking was minimized. It would appear that there is little that can be done to compensate for a subject's inaccurate appraisal of his own opinions so that this factor would be expected to operate throughout most all appraisals concerned with this type of subject reaction, and therefore, most tests would remain comparable to one another in this respect.

Collection of Data on Student Mental Abilities

The *Otis Quick Scoring Mental Ability Test, Gamma: Form AM* was selected to provide a measure of the mental ability of the students and to allow this factor to be statistically controlled. The test consists of eighty multiple choice items and an answer sheet attached to the test booklet. Separate answer sheets were supplied to the students to allow for ease of correction and re-use of the test booklets.

Standardization norms (52) for the Form AM Test were based on a comparison of scores on Form EM with Form AM as a result of an experiment in which 1176 pupils in grades 10-12 were tested. The reliability coefficient for Form EM, determined by the odd versus even method and corrected by the Spearman-Brown formula, was .92 for tenth grade students. The standard error of measurement was 3.0 points.

The Otis Mental Ability Tests are accepted as general mental ability tests and have been used widely.

Collection of Data on Teacher's Attitude Toward Students

The attitude of the teachers in the study was measured in the fall and again in the spring during the student's testing period. The test administered to the teachers was the Minnesota Teacher Attitude Inventory (MTAI) which consists of one hundred fifty statements related to teacher-pupil relations that are answered by choices ranging from "Strongly agree" to "Strongly disagree." Teachers were given the reusable test booklet and separate answer forms used for each testing period, and were instructed to work rapidly, basing their answers on their first interpretation and their personal understanding of the statements. No information concerning the ultimate use of the scores was provided for the teacher. They were told that the test was part of the research study but were given no indication of the relationship of the testing results to the study of laboratory and non laboratory based instruction. All participating personnel were advised instead that they would be given a summary of the results of the research study.

The MTAI was hand scored using keys that discriminated between the teacher's agreement or disagreement with the statements and the test author's interpretation of the statements. Scores are determined by subtracting the number of "wrong" statements of the teacher (those that do not conform to the test author's interpretation of the statements) from the number of statements "right." Scores may range from plus 150 to minus 150.

The MTAI has consistently revealed differences between the attitudes of teachers at various grade levels, and between teachers of various special subject fields, among education students, education graduates, and experienced teachers (Manual, p. 6). As a result of earlier study, Form A was constructed and items significantly influenced by experience were removed. From a sample return of 1714 inventories, the test authors found (1) no significant relationship between teacher attitude and length of experience; but (2) significant relationship between attitudes of high school teachers and subject taught, with teachers of academic subjects scoring higher than teachers of special fields such as music, art, business, and physical education.

A later study by Rabinowitz and Rosenbaum (1960) found a decrease in 343 elementary teachers' attitude scores using the MTAI. Scores of the teachers after three years experience were significantly lower than the responses to the Inventory during their senior year in college.

Rossi, Yengo, and Boyd (1966) conducted a study to determine whether the MTAI can be faked to provide a "good" score, that is a score consistent with the image of the teacher desired - permissive, authoritarian, and so on. Their results confirmed the findings of Callis and Rabinowitz, that the test could be faked "good" if subjects are provided with a responding set. Using 272 subjects including freshman, juniors, and experienced teachers, the investigators supplied positive and negative responding sets in the experiment to discover whether scores could be faked in either direction from an original score. Their findings suggested that faking of scores was possible if provided with a response set, but not as likely to occur without the set. The limited subjects' success in faking "good", they inferred from their study, seemed to be related to the inability or inflexibility on the part of the subject to predetermine the teacher - type desired by those giving the test. It seems reasonable to conclude therefore that subjects taking the MTAI will not be likely to alter their scores without knowing what is a desired response set.

A recent study of the MTAI by Yee (1967) questioned its effectiveness as a predictor of future teacher-pupil relationships which the authors of the Inventory maintain the test is intended to measure. In his study of the homogeneity and validity of the MTAI, Yee concluded that it is especially useful for research purposes as an indicant of teacher's attitudes toward pupils, the use to which MTAI was put in this study.

Instructional Procedures

The BSCS instructional materials were completed with the intention that the materials would be taught by methods de-emphasizing lecture and rote learning, but emphasizing instead a laboratory orientation. BSCS materials place greater stress on the use of laboratory work of an investigative nature to introduce the student to science as a process of inquiry. Some investigations in the laboratory treat problems for which the text provides no answer. Generally, the materials replace the conventional laboratory exercises of an illustrative nature with exercises requiring students to search for answers under less direct external guidance.

Although it was the intention of the BSCS writing committees to create materials that provide an opportunity for instruction to be laboratory oriented, it is, nevertheless, possible for the materials to be used for lecture demonstration instruction. Teachers could demonstrate many of the exercises and make observations that could be imparted to students. However, because the majority of biology teachers choose curriculum materials and begin using them without benefit of specialized training in those materials, this study makes no attempt to influence the instructional patterns and philosophy of the teachers in either the laboratory based or non laboratory instructional groups. The representation and instruction of curriculum materials depends on the teacher's interpretation and acceptance of the procedures and philosophy. This study attempts to appraise this influence by accepting the real classroom activities of one school year's instruction in biology devoid of specialized influences that may structure activities uncommon to everyday biology instruction.

Laboratory Centered Patterns of Instruction

The BSCS biology patterns of instruction were designed to guide students to make their own discoveries. Questions and problems are posed but answers are not given in advance. Procedures for laboratory study guide the student and provide an opportunity to learn facts and techniques in much the same way as a scientist. Students are expected to gain much of the background information needed to investigate problems at hand with some information provided through reading the instructional materials, other books and journals, and through discussion with the teacher at appropriate times.

By studying a given series of problems, students are required to make observations and obtain data relative to the problems. Students are then expected to interpret their observations and data and arrive at conclusions which would not only answer specific questions related to the problem under investigation, but which would also increase the understanding of fundamental biological principles.

Lecture Demonstration Patterns of Instruction

Students are not expected to follow investigatory procedures in lecture demonstration patterns of instruction. The main sources of information for students are their textbook and teacher. Students are usually assigned questions to answer in the classroom and at home, but they include few problem solving activities carried on for any length of time.

The teacher demonstrates certain problems and their solution, usually gathering the data and placing it on the chalkboard for students to copy. Discussion of the data is teacher directed and the meanings, implications, and conclusions regarding the data collected are usually drawn by the teacher. Students do not do investigatory work by themselves.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

Introduction

The analysis and interpretation of the data are presented in this chapter. The objectives of the study and their accompanying statistical analysis are examined separately in order to interpret the findings as they apply to each individual objective. The research design compared biology instructional procedures as the independent variable with student critical thinking skills, student attitude, and teacher attitude as the dependent variables. The four principal objectives were:

1. To determine if the use of laboratory based (BSCS) instruction in biology results in greater development of student critical thinking skills than non-laboratory based instruction.
2. To determine if the use of laboratory based (BSCS) instruction in biology results in greater development of positive student attitudes toward biology than non laboratory based instruction.
3. To determine whether there is a relationship between the attitude of the teacher and the development of student critical thinking skills through the use of laboratory based (BSCS) instruction in biology.

4. To determine whether there is a relationship between the attitude of the teacher and the development of positive student attitudes toward biology through the use of laboratory based (BSCS) instruction.

The .05 level of confidence was chosen to determine whether the differences observed in the statistical analyses were the result of experimental treatment rather than chance.

To ascertain whether the respective instructional groups were different in scholastic aptitude, an analysis of variance of the student scores on the Otis Quick Scoring Mental Ability Test, Gamma: Form AM was completed. Table IV shows the results of that analysis. As a result of the F ratio of .0377, it was assumed that the instructional groups were essentially similar in scholastic ability as demonstrated by the Otis Test of Mental Ability.

TABLE IV

ANALYSIS OF VARIANCE OF SCORES ON THE OTIS QUICK SCORING MENTAL ABILITY TEST, GAMMA: FORM AM FOR LABORATORY AND NON LABORATORY INSTRUCTIONAL GROUPS

Source	df	Sum of Squares	Variance Estimate	F Ratio
Between	1	3.57	3.57	.0377 N.S.
Within	146	13,838.50	94.78	-
Total	147	13,842.07	-	-

N.S. An F ratio of 3.91 is required for significance at the .05 level of confidence.

Laboratory Based Instruction and Development of Student Critical Thinking Skills

The *Watson-Glaser Critical Thinking Appraisal* was used as a pre-test and post-test to measure the development of student critical thinking skills in each instructional group. The pre-test and post-test means, mean differences, and *t* test analysis of the change in means for each instructional group are presented in Table V.

TABLE V

PRE- AND POST-TEST MEANS, MEAN DIFFERENCES, AND t RATIO OF CRITICAL THINKING TEST FOR BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS

Groups	N	Pre-Test Mean	Post-Test Mean	Difference	t	
BSCS	74	66.68	68.00	1.32	2.14	Significant
Non laboratory	74	62.74	67.51	4.77	5.27	Significant

The .05 level of confidence is 1.99.

Both the BSCS and non laboratory instructional groups showed a significant increase in their mean scores from pre-test to post-test on critical thinking. A subsequent analysis of variance examination of the gain scores of each instructional group revealed a significant difference between the BSCS and non laboratory instructional groups. Students in the non laboratory centered group improved significantly in critical thinking skills over students in the BSCS group. Table VI shows the analysis of variance of the gain scores for each instructional group. The F ratio of 10.10 was significant at the .01 level of confidence.

TABLE VI

ANALYSIS OF VARIANCE OF PRE-TEST POST-TEST GAIN SCORES OF STUDENTS IN THE BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS ON THE TEST OF CRITICAL THINKING

Source	df	Sum of Squares	Variance Estimate	F Ratio
Between	1	446.29	446.29	10.10 Significant
Within	146	6,448.55	44.17	------
Total	147	6,894.84	------	------

An F ratio of 3.91 is required for significance at the .05 level of confidence.

The significant gain in critical thinking skills of the non laboratory centered group over the BSCS group is reflected in the gain of 4.77 points from their pre-to post-test mean as compared to the corresponding gain of 1.32 points for the BSCS group. It should be noted, however, that the BSCS group mean of 66.68 in the pre-test was considerably higher than the non laboratory group pre-test mean of 62.74. The post-test mean of the BSCS group was again higher (68.00) than the non laboratory group post-test mean (67.51) but represented a much smaller net gain.

The results of this analysis indicate that the students in this study who received non laboratory centered instruction in biology showed a significant improvement in critical thinking skills over students of similar scholastic ability who received BSCS instruction.

Laboratory Based Instruction and Development of Student Attitudes

A Scale to Measure Attitude Toward Any School Subject was used to measure the attitude of the students toward biology in each instructional group. Scores may range from 1.0 to 10.3. Scores above 6.0 indicate a favorable attitude, scores below 6.0 an unfavorable attitude. The pre-test and post-test means, mean differences, and *t* test analysis of the change in means for each instructional group are presented in Table VII. The results showed no significant change in student attitude toward biology in either instructional group.

The lack of any significant change in student attitudes toward the subject of biology does not support a conclusion of Wick and Yager (1966) cited in the review of related literature since this study did not reveal a severe decrease in attitude toward the science of biology among the students examined.

TABLE VII

PRE- AND POST-TEST MEANS, MEAN DIFFERENCES, AND t RATIO FOR BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS ON THE TEST OF ATTITUDE TOWARD BIOLOGY

Groups	N	Pre-Test Mean	Post-Test Mean	Difference	t
BSCS	74	7.32	6.96	-0.36	1.97 N.S.
Non laboratory	74	7.57	7.76	0.19	1.28 N.S.

N.S. A t of 1.99 is required for significance at the .05 level of confidence.

The analysis of variance of the gain scores of students for each instructional group is shown in Table VIII.

TABLE VIII

ANALYSIS OF VARIANCE OF PRE- AND POST-TEST GAIN SCORES OF STUDENTS IN THE BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS ON THE TEST OF ATTITUDE TOWARD BIOLOGY

Source	df	Sum of Squares	Variance Estimate	F Ratio
Between	1	2.68	2.68	1.298 N.S.
Within	146	301.48	2.06	---
Total	147	304.16	----	---

N.S. An F ratio of 3.91 is required for significance at the .05 level of confidence.

The foregoing data which illustrate no significant difference in the gain scores between the instructional groups, and no significant difference in gain scores within each instructional group suggest that the subject of biology may influence students to maintain a more positive attitude toward science than characteristically occurred in the other science subjects as described by Wick and Yager (1966).

Teacher Attitude and Student Critical Thinking Skills in Laboratory Based Instruction

The teacher's attitude toward pupils was measured through the use of the Minnesota Teacher Attitude Inventory, as a pre- and post-test. Table IX lists the pre- and post-test scores, score differences, and mean scores for the teachers of the BSCS instructional group.

TABLE IX

PRE- AND POST-TEST SCORES, SCORE DIFFERENCES, AND MEAN SCORES FOR TEACHERS OF THE BSCS INSTRUCTIONAL GROUP ON THE TEST OF ATTITUDE TOWARD PUPILS

Teachers	Pre-Test Score	Post-Test Score	Score Difference	Mean Score
1	45	46	1	45.50
2	-11	-5	6	-8.00
3	-1	-41	-40	-21.00

The BSCS instructional group teacher scores were examined by a *t* test for related-sample means and produced a *t* ratio of .76 which was not significant. However, a comparison of the mean scores of each teacher with the percentile rank equivalents for raw scores in the Minnesota Teacher Attitude Inventory Manual, ("Table 2, Experienced Teachers," p. 9), illustrated that the teachers' attitudes in the BSCS group ranged from average to below average.

Table X presents the pre- and post-test scores, score differences, and mean scores for the teachers of the non laboratory instructional group.

TABLE X

PRE- AND POST-TEST SCORES, SCORE DIFFERENCES, AND MEAN SCORES FOR TEACHERS OF THE NON LABORATORY INSTRUCTIONAL GROUP ON THE TEST OF ATTITUDE TOWARD PUPILS

Teachers	Pre-Test Score	Post-Test Score	Score Difference	Mean Score
4	7	-21	-28	-7.00
5	53	56	3	54.50
6	63	61	-2	62.00

The above non laboratory teacher scores were examined by a t test for related-sample means and yielded a t of .937 which was not significant.

A similar comparison of non laboratory instructional group teacher scores with the percentile rank equivalents of Table 2 in the Minnesota Manual (p. 9) showed that the attitudes of these teachers ranged from below average to above average.

From the above data it seems safe to conclude that the attitudes of the teachers of the BSCS instructional group, on the whole, tended to be somewhat more negative than the attitudes of the teachers in the non laboratory group throughout the period of the study, although not significantly so. A t ratio of 1.03 was obtained in a comparison of the means of the teachers of each instructional group which proved non significant.

Since the mean attitude score of each teacher was used as an indication of that teacher's attitude toward his students during the study, the teacher's mean attitude score was compared to the pre- and post-test mean scores of his class, and the total gain of his class on the test of critical thinking. Examination of this relationship by inspection reveals little evidence that the teacher's attitude exerted any substantial influence on the change in student critical thinking skills in either instructional group. The nature of the sample size and selection do not warrant a product moment coefficient of correlation analysis of this relationship since any conclusions from such a procedure would prove tenuous.

Table XI lists the mean attitude score for the teachers in each instructional group, the teacher's score difference, the mean pre- and post-test score of his class on the critical thinking test, and the mean gain of his class.

TABLE XI

MEAN ATTITUDE SCORE OF TEACHER, TEACHER SCORE DIFFERENCE, PRE- AND POST-TEST STUDENT SCORES ON CRITICAL THINKING TEST, AND MEAN STUDENT GAIN ON CRITICAL THINKING TEST FOR BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS

Teacher	Mean Teacher Attitude Score	Teacher Score Differ-ence	Mean Student Pre-Test Score	Mean Student Post-Test Score	Mean Student Gain
BSCS	45.50	1	63.83	64.83	1.00
BSCS	-21.00	-40	58.14	61.68	3.54
BSCS	-8.00	6	75.41	75.31	-0.10
Non laboratory	-7.00	-28	59.04	62.83	3.79
Non laboratory	54.50	3	65.13	68.29	3.16
Non laboratory	62.00	-2	63.96	71.16	7.20

Teacher Attitude and Student Attitudes in BSCS Instruction

The Minnesota Teacher Attitude Inventory measures described in the previous section were utilized in the comparison of the teacher's attitude with the attitude of his students toward biology. Although no significant change occurred in teacher attitudes throughout the study, the previous conclusion that the attitudes of the teachers of the BSCS instructional group were, on the whole, somewhat more negative than those of the teachers of the non laboratory instructional group, seems to have particular importance in this instance.

Comparison of the mean attitude score of each teacher with the pre- and post-test attitude scores of his class, and the total gain in the attitude score of his class, suggests evidence of some relationship between the teacher's attitude and the attitude of the class in each instructional group. Inspection of the relationship between BSCS teacher and class attitude scores appears to reveal a common directional response. In practically every instance where the teacher's attitude is more positive, the class attitude is also more positive on a comparable basis.

Table XII illustrates the mean attitude score for teachers in the BSCS and non laboratory instructional groups, the teacher's score difference, the mean pre- and post-test attitude score of his class, and the mean attitude gain of his class. The relationship between the attitude of the teacher in biology and the attitude of his students toward the subject appears to warrant further investigation.

Summary

Examination of the differences between the pre-test and post-test means for each instructional group on the test of critical thinking showed that each instructional group made significant gains in critical thinking. An analysis of variance revealed that the students in the non laboratory centered instructional group showed significant improvement in critical thinking skills over the students in the BSCS group. No significant change in student attitudes was noted within either instructional group, nor between the instructional groups. The change in attitudes for the BSCS students approached significance however, and the teachers in that instructional group also appeared to have a more negative attitude in general.

TABLE XII

MEAN ATTITUDE SCORE OF TEACHER, TEACHER SCORE DIFFERENCE, PRE- AND POST-TEST STUDENT SCORES ON ATTITUDE TEST, AND MEAN STUDENT GAIN ON ATTITUDE TEST FOR BSCS AND NON LABORATORY INSTRUCTIONAL GROUPS

Teacher	Mean Teacher Attitude Score	Teacher Score Difference	Mean Student Pre-Test Score	Mean Student Post-Test Score	Mean Student Gain
BSCS	45.50	1	7.76	7.73	-.03
BSCS	-21.00	-40	7.38	6.76	-.62
BSCS	-8.00	6	6.93	6.52	-.41
Non laboratory	-7.00	-28	7.52	7.60	.08
Non laboratory	54.50	3	7.56	7.74	.18
Non laboratory	62.00	-2	7.62	7.92	.30

No significant attitude change was observed for the teachers in the BSCS and non laboratory instructional group. In addition, the attitude of the teacher appeared to exert little influence on the development of student critical thinking skills. The attitude of the teachers in the non laboratory group did not show much relationship to their student's attitude toward biology. However, the attitude of the BSCS teachers and students seemed to be related.

CHAPTER V

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

Teachers, administrators, and educators at all levels must be able to determine the effects of various instructional procedures on the development of critical thinking skills and attitudes of students. The demands of a rapidly changing society make it imperative that education produce an informed citizenry which is capable of adapting to rapid change. Inasmuch as science is largely responsible for today's changing conditions, students must be led particularly to an understanding and awareness of the operations of science in order that they may, subsequently, participate wisely in the determination of public policy. When relationships between specific instructional acts and ultimate changes in student behavior are identified it will be possible to design curricula and prepare teachers more wisely than is possible in the absence of such information.

Studies of science instructional procedures can provide a basis for modifying present learning theories. Evidence of desirable relationships between existing classroom practices and student intellectual behavior can form the basis for preservice and inservice science teacher instruction. In addition, reliable research of this type contributes heavily to the development of future research rationale.

The study presented here was concerned primarily with determining the effect of BSCS instructional procedures on the development of student critical thinking skills and positive student attitudes toward biology since these characteristics were considered essential to the development of an informed, scientifically literate citizenry. Because of an absence of evidence concerned with the effectiveness of specific instructional activities, frequently the choice of instructional methods is determined by past learning experiences or favorable personal reaction to certain classroom procedures. In many cases, evaluation is also based on intuition. Research which links classroom activities to changes in student behavior offers a rational basis for choosing instructional methods and can serve to generate teacher interest and enthusiasm toward applying effective procedures.

A great deal of research concerned with evaluating the effectiveness of science instruction has been directed toward measuring the effectiveness of laboratory centered versus non laboratory centered instruction on the achievement gains of students. Student achievement test measures represent a limited area of cognitive development however, and achievement generally assumes a supportive role in the process of attaining broader goals of science instruction.

Laboratory centered instruction is capable of providing opportunities for students to participate in the use of equipment, the formation of conclusions from science activities, and the dialogue of refinement that often takes place between teacher and learner in this setting. These procedures appear to provide a sound basis for developing student reasoning skills. In addition, it might be expected that students actively participating in the instructional setting would develop a more positive attitude toward the subject than when a student assumes a passive role. By comparison, lecture demonstration, or non laboratory centered patterns of instruction, it is expected, would tend to result in less individual participation in problem solving activities of any reasonable duration, and would produce instead a teacher centered classroom atmosphere.

The problem of determining whether laboratory or non laboratory centered instructional procedures contributed more fully to student cognitive and affective growth was attacked by measuring the effects of the various instructional procedures on student critical thinking skills and student attitudes toward biology. BSCS procedures and their potential for student participation appeared to offer the possibilities for greater student change. The question of what student changes did take place in the classrooms of the teachers using the respective materials, and by assumption teachers employing the respective instructional methods, was examined statistically. Differences in teacher experience and preparation were held to a minimum in the study.

A total of six teachers and their classes were selected from five counties on the basis of teacher experience and preparation, use of laboratory centered (BSCS) or non laboratory centered instructional materials, and consent of the school district personnel. The classes were visited in the fall and again in the spring. Pre- and post-test student scores were obtained on the Watson-Glaser Critical Thinking Appraisal and A Scale to Measure Attitude Toward Any School Subject. The students also completed the Otis Quick Scoring Mental Ability Test to provide a control over any differences of scholastic ability between the respective instructional groups.

In addition, pre- and post-test scores were obtained for each teacher on the Minnesota Teacher Attitude Inventory during the classroom visitations. The degree to which teacher instructional practices reflected the philosophy of the materials they were using was not measured in the study but was expected to contribute toward the results of the test. The extent to which BSCS materials resulted in teacher use of laboratory centered teaching procedures was included as a necessary influence in the study.

The results of the observations in each instructional group were examined by an analysis of variance of gain scores and IQ's, and the t test for mean differences. Teacher attitudes were compared to changes in student attitudes to examine the influence of this dimension in the classroom settings.

Discussion

The frequent difficulties encountered in attempts to relate learning theory to the processes of teacher behavior and finally, student outcomes, attests to the need for additional empirical evidence of relationships between known teacher practices and ultimate student changes. The applicability of theory to teaching circumstances is often limited to special instances of narrow activities that offer little support to the development of an overall rationale as it is needed to guide the teacher in his daily activities.

This study was concerned with examining the representative activities of one school year of biology instruction and was not restricted to segments of specialized activities that are seldom characteristic of the total instructional program of biology classes. It seemed important to measure the influence of existing school practices which are not subjected to experimenter direction and control. It is reasonable to expect that teacher acceptance and use of biology instructional materials and their respective procedures are therefore accurately portrayed in these research findings.

However, the study does not distinguish the degree to which laboratory centered (BSCS) or non laboratory centered teaching procedures were used. It is not possible therefore to assert conclusively that the results represent the superiority of one method of instruction over another. The findings instead represent the differences of student growth as they resulted from the practices of the teachers in the study, and are typical of the instructional methods only to the degree that the teacher's practices reflected the recommended instructional methods of their group.

One factor that may have exerted an influence on the findings of this study therefore, is the increased use of laboratory based procedures and concepts in non laboratory curricula. The original laboratory-non laboratory instructional differences that existed when BSCS curricula were first introduced have steadily decreased so that today one is not as likely to find sharp distinctions between the instructional materials and procedures. While a merging of instructional procedures may prove beneficial to students, it does not allow researchers the benefit of drawing clearer contrasts between the two teaching methods.

The changes in the critical thinking skills of the students measured in this study indicate that the non laboratory centered instruction was superior in this regard since the students of that group showed significant improvement over the students in the BSCS group (see Tables V and VI). The similarity of IQ's in each instructional group reduces any doubts concerning differences in scholastic ability that could have accounted for the superior improvement of the students receiving non laboratory centered instruction (Table IV).

The original difference in means between the BSCS and non laboratory groups on the critical thinking test deserves consideration, however. Any attempt to account for the original difference would be speculatory. Nevertheless it is safe to assume that if the groups had been more similar at the outset, findings of the study may have been different. In any case, the difference of pre-test means between these groups which appeared to be essentially similar in scholastic ability, diminished greatly over the period of one year's instruction. To the extent that this study measures the influence of biology instruction only, as originally intended, the improvement of student critical thinking skills can be attributed to this influence. It is not possible to isolate with certainty, the influence of biology from the influence of the other subjects to which the students were exposed. Other subjects may have influenced the results of the study so as to favor one group or the other. However, biology instruction was the criterion for sample selection, teacher selection, and all procedures of analysis, and should therefore be looked upon as an essential influence in the results.

It is interesting to hypothesize what might occur if the present biology instructional groups were to continue their study of biology using the same instructional procedures. If the non laboratory group continued to improve their critical thinking skills at the same rate as revealed in the data, they would be expected to surpass the BSCS students by a considerable margin as shown in Figure 1. The net result would be a mean score for the non laboratory group students well beyond the mean score for the BSCS students whose rate of growth would remain slower. This possibility does not seem plausible, even though it can be projected from the data.

It is more reasonable to expect that the difference between the instructional groups is not likely to ever become this large, even though the difference may be significant (Figure 2). The similarity of the scholastic ability of the students in each group precludes the likelihood of such a development. The outstandingly significant growth of the non laboratory students in critical thinking skills over the BSCS students is more likely to have been the result of their lower pre-test mean and, correspondingly, their increased opportunity to show a gain as this mean became similar to the mean of the BSCS students. One would not expect to find so

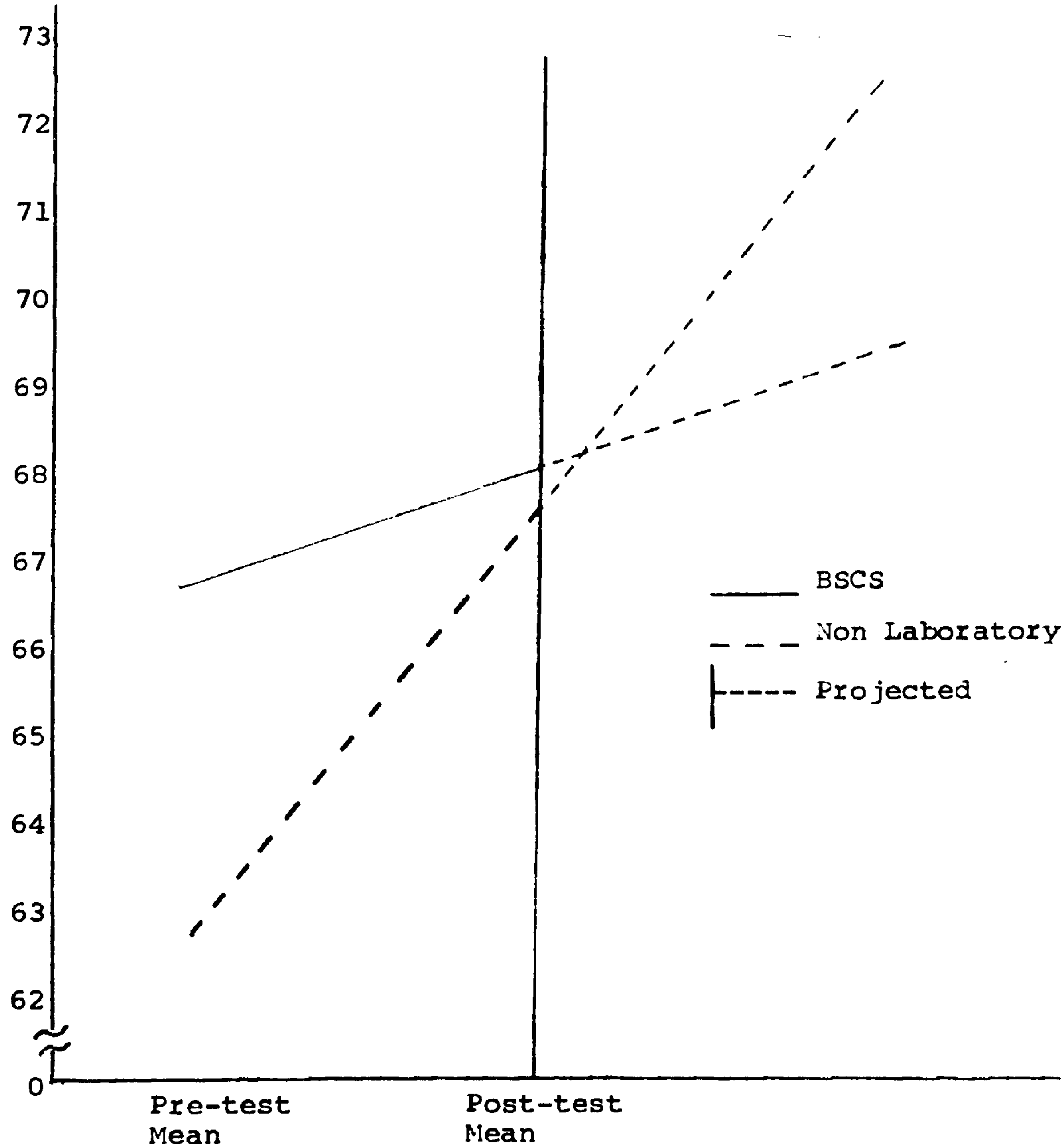

Figure 1. Measured and Projected Student Rates of Growth in Critical Thinking Established by the Data.

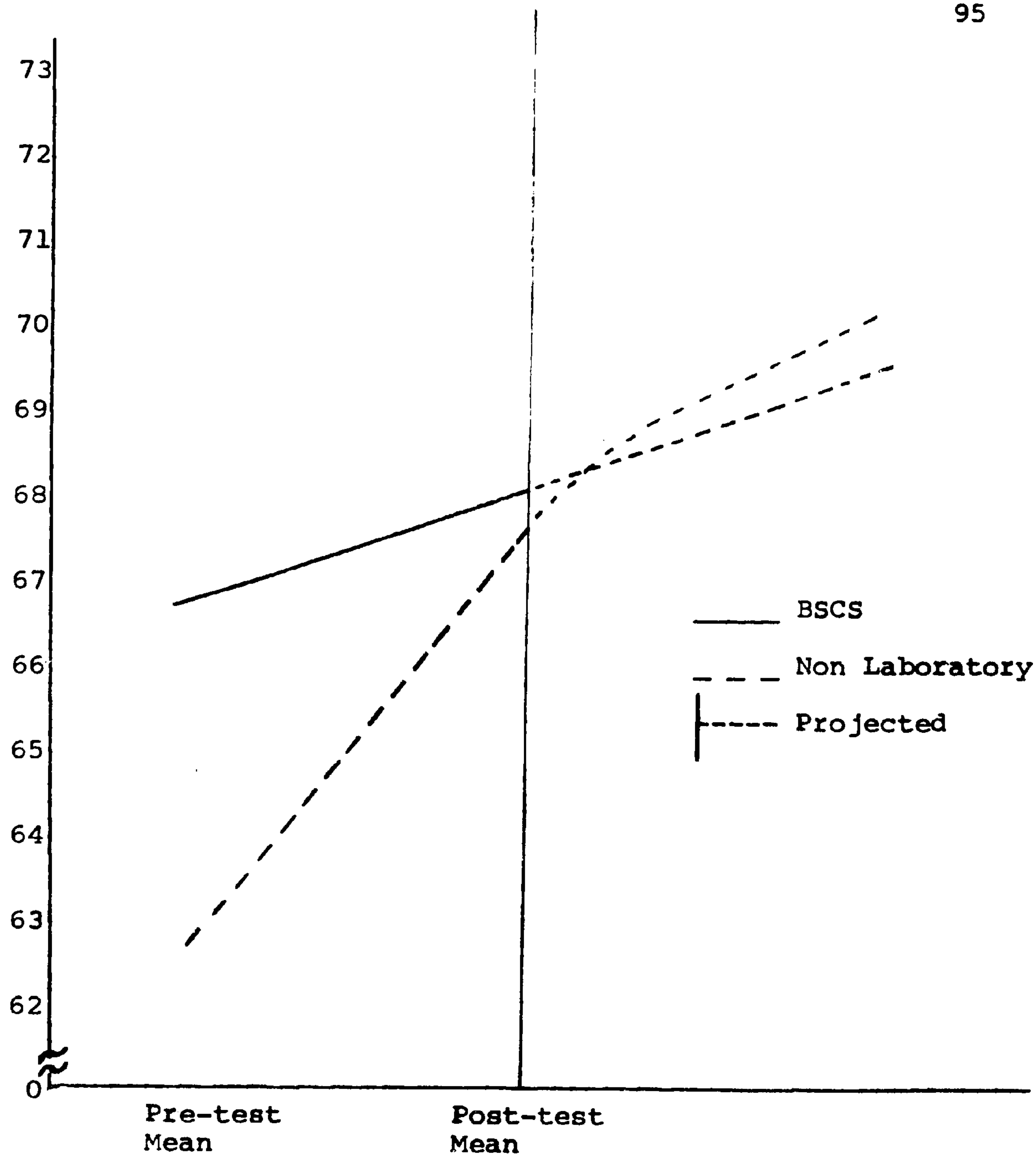

Figure 2. Measured and Projected Student Rates of Growth in Critical Thinking as Expected for Students of Similar Scholastic Ability.

large a difference in critical thinking skills of students who were very similar in scholastic ability as was observed in the pre-testing. The sample in this study may, therefore, have been a deciding influence on the results in the critical thinking test.

Another factor that may have influenced the results of the critical thinking test is the length of teaching experience of the BSCS teachers in the study. Blankenship (1965) demonstrated that teachers with three years or less experience were generally more favorable to the philosophy of BSCS biology. Since the BSCS teachers in this study all had more than three years of biology teaching experience, it can reasonably be assumed that they were less likely to have used the instructional methods characteristic of the BSCS philosophy. Consequently, the potential impact of laboratory centered instruction on student critical thinking skills may not have been adequately represented in the findings.

It is also possible that the BSCS teachers may have had less understanding of the behavior and experiences involved in critical thinking. There is evidence to suggest that teaching students to think critically requires that the teacher be informed about the concepts and methods used to foster critical thinking among students. The smaller gain of the BSCS students may be interpreted on this basis as evidence of a lack of awareness on the part of the BSCS teachers concerning the procedures essential to student critical thinking growth, irrespective of the curriculum materials used.

Nevertheless this study demonstrated significant improvement of students in the non laboratory instructional group in regard to critical thinking skills. The degree to which the students in the instructional groups were exposed to activities truly reflective of the respective instructional materials can not be ascertained from this study, and therefore it is not possible to use these findings as demonstration of the superiority of one type of instruction over another *per se*.

In spite of differences between the instructional groups with regard to changes in pupil attitude, and changes in teacher attitude, the differences proved to be nonsignificant (Tables VII, VIII, IX, and X). On the basis of the findings of this study it is necessary to conclude that the instructional procedures exerted a limited influence on this dimension of student and teacher behavior.

It is interesting to note that the difference in pre- and post-test student means for the BSCS instructional group on the test of attitude approached significance. By itself this fact suggests a need for further investigation into the relationship of the use of BSCS instructional materials and the development of student attitudes. When the mean differences of attitude scores of the students in the BSCS group are examined for evidence of a possible relationship to attitude means for the teachers of that group, a general tendency seems to emerge. The similarity between the somewhat more negative attitudes of these teachers and the correspondingly more negative attitudes of their students illustrates both a common direction and extent of attitude change (Table XII). While it is not possible to draw any exact conclusions from the data, it appears likely that the direction and extent of the relationship may be representative of an increased sensitivity between teacher and student. It is possible that BSCS instructional materials provide opportunities that lend themselves to increased reaction between the teacher and student so that teacher attitudes would assume a role of greater influence. It is impossible to confirm or disprove this hypothesis on the basis of this study. However, implications for future research seem to be present in the relationship.

There is no way to establish whether the more negative attitude of the teachers using BSCS materials was a result of of use of these instructional materials. It is possible that the sample included laboratory teachers with an attitude that was somewhat more negative because of the influence of other factors associated with instruction such as class size, general student behavior patterns, socio-economic status of students, parental expectations for students, and so on. It might be advisable for future studies to seek out teachers that have essentially similar attitudes toward students in the beginning of the study in order to measure changes of teacher attitude in biology instruction.

Certain limitations should be recognized as part of the study. Classes labelled BSCS or non BSCS were accepted as representative of laboratory centered and non laboratory centered instruction respectively. There was no direct observation or measurement of the classroom procedures to verify the instructional practices. The results of one school year of biology instruction using either BSCS or non BSCS curricula were measured for 148 tenth grade college preparatory students and six teachers. The participating sections were selected as intact samples by the teacher and principal of each school. Teachers with three to six years of teaching experience and salaries ranging from $6000 to $7000 were included in the study. Differences of teacher background and experience were reduced in the selection process, however, no similar attempt was made to reduce differences in the teacher's attitudes. The sample was drawn from a five county area. Finally, the socioeconomic status of students, sex of students, and the enrollment of the participating schools were not controlled.

Conclusions

The data from this study suggests the following conclusions:

1. Laboratory based (BSCS) instruction in biology did not result in greater development of student critical thinking skills. Instead, non laboratory centered biology instruction resulted in greater development of student critical thinking skills.
2. Laboratory based (BSCS) instruction in biology did not result in greater development of positive student attitudes toward biology. No significant change in student attitudes toward biology was observed in either instructional group.
3. No relationship was observed between the attitude of the teacher and the development of student critical thinking skills through the use of laboratory based (BSCS) or non laboratory instruction in biology.
4. No relationship was demonstrated between the attitude of the teacher and the development of positive student attitudes toward biology. The degree of agreement between the attitude of the teacher and the attitude of his students in the laboratory based (BSCS) instructional group warrants further investigation, however.

Recommendations

As a result of this study it is recommended that:

1. Future research into the effects of laboratory centered (BSCS) and non laboratory centered instructional procedures on student critical thinking skills should provide a means of identifying and measuring the amount of agreement between teacher choice of instructional materials and actual teacher practice of the suggested instructional procedures.
2. Efforts should be made to develop and standardize tests for measuring student growth in critical thinking skills. These tests should be sensitive to science instruction mainly, and select against the influence of other subjects as much as possible within contemporary means of research.
3. Investigations should be completed which determine the extent to which teacher training in the philosophy and activities of laboratory centered (BSCS) biology instruction results in actual classroom practice of the instructional methods by the teacher; and, the degree to which the current methods of accepting and using materials through traditional textbook selection and adoption procedures results in the use of the appropriate instructional methods by the teacher.
4. Research be conducted that would determine whether the use of laboratory centered (BSCS) instructional procedures results in the development of negative teacher attitudes.

5. Research be conducted that would determine whether an actual relationship exists between laboratory centered (BSCS) and non laboratory centered instructional procedures and changes in student attitude, or whether such student attitudes change more as a result of teacher influence.
6. Investigation be conducted that determines the degree of relationship which may exist between student attitude change, and the degree to which laboratory centered (BSCS) instructional methods are used by the teacher.

Implications

It is seldom possible to determine whether the adoption of curriculum materials will produce any changes in teacher behavior, or whether in fact a teacher will be able to practice effectively what are considered to be the necessary procedures of the curriculum materials selected. In such matters consideration must be given to the teacher's willingness to experiment with the materials, his capability, and his understanding of the instructional processes.

Educators need to know whether the increases in time for science schedules and money for science facilities are justified by laboratory based instruction. The gains made by students must be evident and the values that are inherent in all inquiry centered instruction should be capable of being demonstrated to the public and to business, both of whom show an increasing interest in education. Perhaps education's faith in the heuristic values of inquiry learning requires greater scrutiny and objective appraisal. On the basis of this study it would seem advisable that such matters be given careful consideration as the findings here do not offer any support to laboratory centered (BSCS) instruction. Neither do they firmly deny that there are other important dividends obtainable from laboratory centered instruction. The findings represent changes that took place in the sample examined by the study and are generalizable only to the degree that the sample is representative of other school districts.

In recognition of the importance of developing student critical thinking skills it is recommended that, irrespective of curriculum materials, science educators acquaint prospective teachers with the concepts of critical thinking and provide experiences in the methodology of teaching critical thinking so that these teachers will be able to adapt this instruction to all classrooms. Science educators should also impress prospective teachers with the influence of a teacher's attitude toward students on the development of student attitudes toward the teacher and the subject.

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