AN EVALUATION OF THE ACHIEVEMENT OF GENERAL COURSE OBJECTIVES FOR A SECONDARY BIOLOGY PROGRAM

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ABSTRACT

AN EVALUATION OF THE ACHIEVEMENT OF GENERAL COURSE OBJECTIVES FOR A SECONDARY BIOLOGY PROGRAM

By

Thomas John Grgurich

Problem investigated. The purpose of this study was to evaluate the achievement in biology of selected pre-determined general course objectives by A, B, and C ability grouped tenth grade students of the Cherry Hill School System in Cherry Hill, New Jersey. The students were exposed to the Blue Version BSCS Biology course, the Yellow Version BSCS Biology course, and a general survey Biology course respectively. Pretest to posttest mean gains and sex relationship to objective achievement were also evaluated.

Design and descriptive features of the study. A non-equivalent control group design was used to evaluate achievement of the general course objectives of increased scientific literacy, increased understanding of and ability to use the processes of science, and increased interest in science in general and biology in particular. The evaluation instruments chosen as indicative of achievement of the general course objectives included the Nelson Biology Test, the Comprehensive Final Examination, the Test on Understanding Science, the

Processes of Science Test, the Watson-Glaser Critical Thinking Appraisal, the Kuder Preference Record Vocational, and A Scale to Measure Attitude Toward Any School Subject. Each ability group was evaluated separately for the dependent variables chosen as indicative of objective achievement. The ability group samples included 27 A experimental students, 25 A control students, 37 B experimental students, 37 B control students, 40 C experimental students, and 40 C control students. A covariant t test was used to evaluate the significance of the data for the sixteen dependent variables indicative of achievement of the three general objectives under study.

Findings. The following conclusions were supported by the data:

1. A ability grouped tenth graders in the Blue Version course partially achieved increased scientific literacy, but did not achieve increased ability to understand and use the processes of science or increased interest in science and biology.

2. Sex was a significant factor on some measures of ability to understand and use the processes of science and of interest in science and biology, but was not a significant factor on measures of scientific literacy for A ability grouped tenth graders in the Blue Version course or no science course. Males achieved greater means on interest measures while females achieved greater means on measures of the processes of science.

3. Experimental A ability grouped tenth graders in the Blue Version course achieved significant mean gains from pretest to posttest on most measures of scientific literacy and ability to understand and use the processes of science, but not on measures of interest in science and biology.

4. Control non-science A ability grouped tenth graders achieved significant mean gains from pretest to posttest on some measures of scientific literacy and ability to understand and use the processes of science, but not on measures of interest in science and biology.

5. B ability grouped tenth graders in the Yellow Version course achieved increased scientific literacy and ability to understand and use the processes of science on several measures, but did not achieve increased interest in science and biology.

6. Sex was a significant factor on one measure of interest in science, but was not a significant factor on measures of scientific literacy or ability to understand and use the processes of science for B ability grouped tenth graders in the Yellow Version course or no science course. Males achieved a greater mean in interest in science.

7. Experimental B ability grouped tenth graders in the Yellow Version course achieved significant mean gains from pretest to posttest on most measures of scientific literacy and ability to understand and use the processes of science, but not on measures of interest in science and biology.

8. Control non-science B ability grouped tenth graders achieved significant mean gains from pretest to posttest on some measures of scientific literacy and ability to understand and use the processes of science, but not on measures of interest in science and biology.

9. C ability grouped tenth graders in the general Biology course achieved increased scientific literacy on one measure and increased interest in science and biology on two measures, but did not achieve increased ability to understand and use the processes of science.

10. Sex was a significant factor on one measure of scientific literacy and on two measures of interest in science and biology, but was not a significant factor on measures of ability to understand and use the processes of science for C ability grouped tenth graders in the general Biology course or no science course. Males achieved the greater means on all significant results.

11. Experimental C ability grouped tenth graders in the general Biology course achieved significant mean gains from pretest to posttest on one measure of scientific literacy, but not on measures of ability to understand and use the processes of science or interest in science and biology.

12. Control non-science C ability grouped tenth graders did not achieve significant mean gains from pretest to posttest on measures of scientific literacy or interest in science and biology, but did achieve significant mean gains on two measures of ability to understand and use the processes of science.

It is apparent from these findings that pre-determined general course objectives for given ability groups of secondary students exposed to selected biology courses can be taught for and achieved with varying degrees of success.

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Thomas John Grgurich

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CHAPTER I

INTRODUCTION

This study was concerned with an evaluation of the achievement of objectives for a secondary biology program by students enrolled in the program during the 1968-69 school year. The study was conducted in the Cherry Hill Public High Schools Cherry Hill, New Jersey. The study should be of interest to science teachers who are contemplating curriculum revisions or adoptions in biology at the secondary level.

The need to evaluate educational objectives has been recognized for many years. Credit for the first systematic comparison of school attainment is generally given to J. M. Rice. Rice completed his study in 1897.[1] Since that time educators have given increasing attention to the significance of evaluation and the means by which objectives may be measured.

As early as 1918, Ayres wrote:

> The importance of the [educational measurement] movement lies not only in its past and present achievements, but in the hope of the future. Knowledge is replacing opinion, and evidence is supplanting guess-work

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[1]Lee J. Cronbach, Essentials of Psychological Testing (New York: Harper and Row, 1960), p. 396.

> in education as in every other field of human activity. This is the supreme fact to which this Yearbook bears witness. The future depends on the skill, the wisdom, and the sagacity of the school men and women of America. It is well that they should set about the task of enlarging, perfecting, and carrying forward the scientific movement in education, for the great war has marked the end of the age of haphazard, and the developments of coming years will show that this [is] true in education as in every other organized field of human endeavor.[2]

In the same Yearbook, Judd stated the following:

> The time is rapidly passing when the reformer can praise his new devices and offer as the reason for his satisfaction, his personal observation of what was accomplished. The superintendent who reports to his board on the basis of mere opinion is rapidly becoming a relic of an earlier and unscientific age. There are indications that even the principals of elementary schools are beginning to study their schools by exact methods and are basing their supervision on the results of their measurements of what teachers accomplish.[3]

Tyler identified the time of Ayres and Judd as the beginning of the behavioral concepts of the objectives of education, which were to have a tremendous effect on the concept of evaluation in terms of objectives.[4] The trend toward more formalized evaluation methods continued in the 1930's. The view of the time and the foundation of future development were stated by Frutchey in 1938.

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[2]Jack C. Merwin, "Historical Review of Changing Concepts of Evaluation." In: National Society for the Study of Education. Educational Evaluation: New Roles, New Means, Chapter II, Sixty-eighth Yearbook, Part II (Chicago: University of Chicago Press, 1969), p. 7.

[3]*Ibid.*, p. 8.

[4]*Ibid.*

> The most important use of evidence concerning the mental, social, emotional, and physical behavior of boys and girls is to aid in developing an understanding of them. Teaching may be based upon valid evidence, carefully collected and wisely interpreted, or it may rest upon a series of untested assumptions, poor guesses, and wishful thinking--or some degree between the two.[5]

The efforts of Ralph Tyler in the nineteen thirties gave direction and impetus to the evaluation movement with an emphasis on objectives as a basis for instruction and evaluation. Tyler's principles and procedures of evaluation have served as the basis for many of the major efforts in educational evaluation.[6]

With the development of new learning theories, teaching approaches, and techniques changes have continued to take place in educational evaluation. In the past decade a new trend began to develop in science education evaluation. This trend was a movement away from comparative method studies with a shift to criterion or objective centered studies. In this study, a formative, criterion centered evaluation was used rather than the comparative method approach of evaluation.

Need for the study. There were several considerations which indicated the need for this study. These considerations included theoretical constructs concerning the need for non-comparative method studies with emphasis on evaluation in terms of objective achievement, the need for evaluation of national curriculum projects, and the need for local research

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[5]Ibid., pp. 11-12.

[6]Ibid., pp. 12-13.

as a basis for decision making concerning curriculum choice and development.

The attempt to evaluate curricula using a comparative method approach has come under serious question by some educators and emphasis on evaluation in terms of objective achievement has gained support in recent times. Smith and Anderson, in reviewing studies made in evaluation in science education in 1960, expressed the need for objective achievement studies as follows:

> These studies attempted to relate accepted objectives of science instruction to actual classroom practices and, in addition, employed some of the newer testing techniques to obtain valid and reliable measures of the abilities desired as the outcome of good science instruction. More research of this quality is needed in the area of science education, to determine factors contributing to student achievement of the objectives of science instruction, and to make possible their effective use in the teaching situation. . . .[7]

Watson and Cooley[8] expressed support for the need for research concerning evaluation of objective achievement in science education in the Fifty-ninth Yearbook of the National Society for the Study of Education. Marshall and Herron[9]

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[7] LaVar Leonard Sorensen, "Change in Critical Thinking Between Students in Laboratory-Centered and Lecture-Demonstration-Centered Patterns of Instruction in High School Biology" (unpublished Doctor's dissertation, Corvallis: Oregon State University, 1966), p. 25.

[8] Fletcher G. Watson and William W. Cooley, "Needed Research in Science Education." In: National Society for the Study of Education. Rethinking Science Education. Chapter XVI, Fifty-ninth Yearbook, Part I (Chicago: University of Chicago Press, 1960), pp. 297-312.

[9] J. Stanley Marshall and James Dudley Herron, "Trends in Science Education Research," Education 87 (December, 1966), 207.

specifically pinpointed the need for science education research to determine the degree of attainment of objectives concerned with the processes of science, scientific attitudes, and interest in science.

Mayor stated a view concerning the major problems of comparative method studies when considering objective achievement when he wrote:

> During the past decade of major effort devoted to the improvement of education, and science education in particular, there has been an increasing interest in and concern about evaluation of the effectiveness of new courses, new curricular sequences, and modified teaching procedures. School people ask for comparisons of the "new" with the "more traditional," but there has been little to give them. Comparisons are exceedingly difficult to come by unless they can be made in terms of measures of achievement of common and specified objectives of the programs subject to comparison.[10]

Tyler also found evaluation of objective achievement in terms of comparative approaches a serious problem. His view was stated as follows:

> . . . Since Sputnik, massive financial support has been given to projects concerned with the development of new courses in science and mathematics. Those supporting the construction of the new courses and teachers and administrators who are considering the use of them in their schools are asking for an evaluation of the effectiveness of the courses in comparison with other courses in the same fields. Most tests on the market were not constructed to furnish relative appraisals of different courses, and they have been found inadequate for the task. This need for evaluation of courses and curriculums is stimulating the development of new

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[10]John R. Mayor, "Objectives and Evaluation," Science Education News, No. 67-7 (Washington, D. C.: American Association for the Advancement of Science, 1967), p. 1.

procedures, instruments, and theories that are designed to meet the need.[11]

Heath summarized the argument concerning the value of comparative method studies when he wrote:

> It seems most unlikely that any single experiment will provide the answer to the omnibus question "which is better?" This is not because the experiment may be poorly designed, but because the question is unanswerable in the general case. The fault in this question is not that it calls for a value judgment and not that it calls for data. Its defect is that it calls for both, at the same time, inextricably mixed.
>
> More useful information would likely come from a number of studies, performed under a variety of conditions. One might look for data bearing upon questions such as these:
>
> 1. What cognitive abilities are emphasized in these curricula?
> 2. What is the distinctive nature of achievement resulting from different curricula?
> 3. What is the effect of different courses on student enthusiasm for the subject matter?
> 4. How are aptitude and achievement related in various courses?
>
> Obviously, this list is not complete. However, it is probably investigation of this sort that will provide a realistic basis for the assessment of the new curricula.[12]

Smith, Anderson, Watson, Cooley, Mayor, Tyler, Marshall, Herron, and Heath have identified the need for evaluation of objective achievement in science curriculum evaluation. These educators, in general, also indicated that the comparative method approach is theoretically not fruitful unless the goals are common and the testing techniques are valid for the materials and method employed in the comparison.

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[11]Ralph W. Tyler, "Introduction," In: National Society for the Study of Education, Educational Evaluation: New Roles, New Means, Chapter I, Sixty-eighth Yearbook, Part II (Chicago: University of Chicago Press, 1969), p. 1.

[12]Robert W. Heath, "Pitfalls in the Evaluation of New Curricula," Science Education 46 (April, 1962), 216.

The need for evaluation of national science curriculum projects such as BSCS[13] Biology has been expressed by prominent science educators. Walbesser stated the following concerning evaluation of national curriculum projects:

> . . . What is important, however, is the recognition and acceptance of the principle that every curriculum project has the honest and inescapable obligation to supply objective evidence of accomplishment. Furthermore, the evidence presented by the project must be able to satisfy the criterion that it was obtained by defensible research procedures and that these procedures can be replicated if someone should desire to do so.[14]

Welch concerned himself with the impact, rights and independence of evaluation of national curriculum projects. His ideas were expressed as follows:

> One way to assess the impact of the new programs is to determine whether the stated goals of the project have been achieved. . . .
>
> . . . School personnel, foundations, and the public have the right to information useful in sorting fact from speculation, innovation from repetition, and improvement from mere change. . . .
>
> Whatever the group, an independent evaluation of the impact of national curriculum projects is required. Both the foundations that support these projects and the schools that use them require a spectrum of unbiased information for guidance in making judicious use of resources. Thus far this guidance has not been forthcoming.[15]

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[13]The abbreviation BSCS refers to the Biological Sciences Curriculum Study and is used throughout the thesis to designate this project and/or its products.

[14]Henry H. Walbesser, "Science Curriculum Evaluation: Observations on a Position," The Science Teacher 33 (February, 1966), 34.

[15]Wayne W. Welch, "The Need for Evaluating National Curriculum Projects," Phi Delta Kappan 49 (May, 1968), 530-532.

Hastings stated the following concerning the need for evaluation of BSCS programs:

> BSCS has conducted, and will continue to conduct, a range of studies which fits the needs of evaluation; but the real evaluation jobs will never be accomplished without use and extension of studies by the schools--with or without help from Science Education Centers.[16]

The expressed views of Walbesser, Welch, and Hastings identify an obligation both national and local for evaluation of objective achievement for national science curriculum projects.

Another consideration which emphasized the need for this study was the position held by the administration of the Cherry Hill School District through support for and advocation of research oriented toward curriculum developmemt and choice. The school district had developed a new research department and a District Instructional Council for the purpose of curriculum evaluation and development. This study constituted one facet of this developmental effort.

Purpose of the study. The main purpose of this study was to evaluate the achievement of selected pre-determined general course objectives by A, B, and C ability grouped tenth grade students exposed to one of three biology courses of the Cherry Hill School System as taught during the academic year September 1968 to June 1969. This study was also designed to determine the relationship of sex to objective achievement

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[16]J. Thomas Hastings, "A Note on Evaluation," BSCS Newsletter 30 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1967), p. 2.

and to determine the significance of pretest to posttest gains for experimental and control ability groups for the general objectives under study.

General design of the study. This was a three part study with independent evaluation of achievement of objectives by three ability levels of tenth grade pupils exposed to three different biology courses. The study was based on a non-equivalent control group design.[17]

Three ability groups, each of which was composed of one-hundred tenth grade biology pupils from two Cherry Hill High Schools, Cherry Hill, New Jersey, were randomly selected for consideration. Of the three-hundred pupils selected, 206 volunteered to take part in the experiment.

The three ability groups were identified as A, B, and C by the school system. The A or advanced college preparation biology study group was composed of two samples. There were twenty-seven pupils in the experimental group and twenty-five pupils in the control group. The B or college preparation biology study group was made up of forty pupils in an experimental group and forty pupils in a control group. The C or general biology study group included thirty-seven pupils in an experimental group and thirty-seven pupils in a control group.

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[17]Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally and Company, 1963), p. 47.

The A experimental group was exposed to a year of the BSCS Blue Version Biology course. These students were taught in any one of 10 classes. The B experimental group was exposed to a year of the BSCS Yellow Version Biology course. These students were taught in any one of 26 classes. The C experimental group was exposed to a year of a general survey locally developed Biology course. These students were taught in any one of 8 classes. The students in the control groups did not have a science course during the academic year in which the study was done. Most control pupils substituted a history course or an additional study period for the biology course.

The pretesting for the study began in June 1968. A set of seven pretests with sixteen scores in the areas of biological knowledge and concepts, scientific method, critical thinking, scientific processes, and scientific interests were administered over a two day period. The treatments implemented in the study began with the opening of school in September 1968 and were concluded with posttests given on the same variables in April 1969.

Hypotheses of the study. This study was designed to evaluate achievement of objectives by ability grouped students exposed to selected biology courses. The study was also designed to determine the significance of gains on selected variables and to determine the relationship of sex to objective achievement.

Twelve basic research hypotheses were proposed for the study. Each proposed hypothesis was evaluated separately for each of the three ability groups. The basic research hypotheses were based on the pre-determined objectives for the first year biology program of the two Cherry Hill High Schools. Each objective selected for evaluation was evaluated using more than one testing instrument. In all seven evaluation instruments with sixteen scores were used.

The twelve basic research hypotheses were as follows:

1. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater scientific literacy than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

2. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater understanding of and ability to use the processes of science than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

3. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater interest in science in general and biology in particular than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

4. There is a difference in achievement of scientific literacy between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

5. There is a difference in achievement of understanding of and ability to use the processes of science between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

6. There is a difference in achievement of interest in science in general and biology in particular between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

7. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater scientific literacy on posttest evaluation than on pretest evaluation using the same evaluation instrument.

8. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater understanding of and ability to use the processes of science on posttest evaluation than on pretest evaluation using the same evaluation instrument.

9. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater interest in science in general and biology in particular on posttest evaluation than on pretest evaluation using the same evaluation instrument.

10. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater scientific literacy on posttest evaluation than on pretest evaluation using the same evaluation instrument.

11. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater understanding of and ability to use the processes of science on posttest evaluation than on pretest evaluation using the same evaluation instrument.

12. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater interest in science in general and biology in particular on posttest evaluation than on pretest evaluation using the same evaluation instrument.

Definition of terms. For the purpose of this study the listed terms were used in accordance with the following explanations and/or definitions:

1. Objective achievement was for the purpose of this study synonymous with the phrase achievement of objectives.

2. General objectives were those objectives established as the aims of the biology programs of the Cherry Hill School System.[18]

3. Biology IA was a college preparation program for students with superior ability in which the BSCS Blue Version text was used.

4. Biology IB was a college preparation program for the middle group of students in which the BSCS Yellow Version text was used.

5. Biology IC was a general survey biology program for

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[18]Biology Department, "General Objectives" (Cherry Hill: Cherry Hill School System, n.d.), 2pp. (Mimeographed.) Copy found in Appendix A.

terminal students in which the text Living Things[19] was used with a locally developed course of study.

6. Scientific literacy was:

   a. . . . knowledge, comprehension and ability to apply basic biological principles.

   b. . . . understanding of the biological basis of problems in medicine, public health, agriculture, and conservation.

   c. . . . understanding and appreciation of scientists, their work, and the interrelationship of historical developments and contemporary technology in biology.[20]

7. Understandings about the scientific enterprise was:

   1. Human element in science.
   2. Communication among scientists.
   3. Scientific societies.
   4. Instruments.
   5. Money.
   6. International character of science.
   7. Interaction of science and society.[21]

8. Understandings about scientists was:

   1. Generalizations about scientists as people.
   2. Institutional pressures on scientists.
   3. Abilities needed by scientists.[22]

9. Understandings about the methods and aims of science was:

   1. Generalities about scientific methods.

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[19]Frederick L. Fitzpatrick and Thomas D. Bain, Living Things (New York: Holt, Rinehart and Winston, Inc., 1958).

[20]Biology Department, op. cit., p. 1.

[21]William W. Cooley and Leo E. Klopfer, TOUS Test on Understanding Science Form W Manual for Administering, Scoring, and Interpreting Scores (Princeton: Educational Testing Service, 1961), p. 2.

2. Tactics and strategy of sciencing.
3. Theories and models.
4. Aims of science.
5. Accumulation and falsification.
6. Controversies in science.
7. Science and technology.
8. Unity and interdependence of the sciences.[23]

10. Processes of science was

a. . . . basic skills necessary in the study of science in general and biology in particular.

observation, classification, communication, inferrence, measurement, prediction, space time relations and number relations

b. . . . critical thinking or problem solving ability.[24]

11. Critical thinking was:

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 inferences.[25]

12. Inference was:

. . . ability to discriminate among degrees of truth or falsity of inferences drawn from given data.[26]

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[22] Ibid.

[23] Ibid., p. 3.

[24] Biology Department, loc. cit.

[25] Goodwin Watson and Edward M. Glaser, Manual for Forms YM and ZM Watson-Glaser Critical Thinking Appraisal (New York: Harcourt, Brace and World, Inc., 1964), p. 10.

[26] Ibid., p. 2.

13. Assumption was:

. . . ability to recognize unstated assumptions or presuppositions which are taken for granted in given statements or assertions.[27]

14. Deduction was:

. . . ability to reason deductively from given statements or premises; to recognize the relation of implication between propositions; to determine whether what may seem to be an implication or a necessary inference from given premises is indeed such.[28]

15. Interpretation was:

. . . ability to weigh evidence and to distinguish between (a) generalizations from given data that are not warranted beyond a reasonable doubt, and (b) generalizations which, although not absolutely certain or necessary, do seem to be warranted beyond a reasonable doubt.[29]

16. Argument was:

. . . ability to distinguish between arguments which are strong and relevant and those which are weak or irrelevant to a particular question at issue.[30]

17. Interest in science in general and biology in particular was:

a. . . . student awareness of and interest in biological careers.

b. . . . student interest in biologically oriented leisure time activities.

c. . . . student enjoyment of learning in the biology classroom.[31]

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[27] *Ibid.*

[28] *Ibid.*

[29] *Ibid.*

[30] *Ibid.*

[31] Biology Department, *op. cit.*, p. 2.

<u>Assumptions and limitations of the study</u>. The following were recognized assumptions in the design of this study.

1. The accepted general objectives were achievable and were valid objectives of a first year high school biology program.
2. The accepted ability groups could achieve the same general objectives.
3. The accepted ability groups were valid groupings for the programs offered.
4. The samples were representative of the populations under study.
5. The individuals constituting each group were drawn from a normally distributed population of scores for the variables as measured.
6. The pretests had no significant learning value.
7. The evaluation instruments were valid measures of the selected objectives under study.
8. The evaluation instruments were reliable under the conditions used in this study.
9. Data lost due to mortality was random and the remaining samples were representative.

The following were recognized limitations of the study.

1. The unique nature of the rapidly growing suburban community and school system under study.
2. The specific method of ability grouping used in the school system under study.

3. The interaction of selection and treatment.

4. The combination of teachers, facilities, and materials unique to the school system under study.

Overview of the dissertation. Chapter I contains the needs, purposes, general design, definition of terms, assumptions and limitations of the study. The literature review of studies involving evaluation of objective achievement for secondary biology curricula, national BSCS project evaluations, evaluation of achievement as related to comparative method in secondary biology, evaluation of critical thinking as an objective of secondary biology curricula, and evaluation of interest as an objective of secondary science curricula is presented in Chapter II. Chapter III contains a description of the design, populations, samples, and evaluation instruments. Hypotheses are also stated as well as methods of treatment and statistical analyses of the data. The results and analyses of data are summarized in Chapter IV. Conclusions and implications for further research are reported in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

This chapter contains a review of selected literature relative to curriculum evaluation. One of the basic questions to consider in selecting any new curriculum is "Does it accomplish the goals for which it was designed?" Curriculum evaluation in science--and particularly biology--has been of great concern recently due to the large investment and great profusion of projects both national and local. For example, in the past ten years, the National Science Foundation of the federal government has spent more than one hundred million dollars in an effort to develop new science and mathematics curricula at all levels of education.[1] One of the most-used materials has been those developed by the work of the individuals associated with the Biological Sciences Curriculum Study. BSCS had its inception in 1959 and came into full publication by 1961. Since then over 50 percent of the public secondary schools, 1,500,000 high school pupils, and 15,000 to 20,000 secondary teachers have

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[1]Wayne W. Welch, "The Need for Evaluating National Curriculum Projects," Phi Delta Kappan 49 (May, 1968), 530.

been involved in the implementation of the several versions of BSCS biology.[2]

Past evaluation studies have taken one of two distinct approaches; a comparative method orientation or an objective orientation. Most research studies in the evaluation of biology curricula including BSCS have been of a comparative method nature. That is, comparisons were made between pupils using BSCS and pupils using so-called "traditional" approaches. Those studies oriented toward objectives have been centered on a single objective, often not pre-determined in the curriculum, or toward the so-called "ideal" objectives as isolated by "experts." In the following review of pertinent literature both types of evaluation of biology curricula at the secondary level of education are reported and analyzed.

A review of the literature from 1930 to 1968 revealed many studies dealing with one or more aspects of the problem under consideration. However, no one study was similar to this present study. In the review, particular attention was given to studies involving evaluation of BSCS programs. Only representative studies were reviewed for those areas related to the problem partially or indirectly. The studies presented here are divided into categories based on their orientation

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[2]J. David Lockard (ed.), Sixth Report of the International Clearinghouse of Science and Mathematics Curriculum Developments 1968. (College Park, Maryland: American Association for the Advancement of Science and the Science Teaching Center, University of Maryland, 1968), p. 167.

and emphasis and are as follows.

1. Evaluation of achievement of objectives for secondary biology curricula.
2. National BSCS project evaluation.
3. Evaluation of achievement as related to comparative method in secondary biology.
4. Evaluation of critical thinking as an objective of secondary biology curricula.
5. Evaluation of interest as an objective of secondary science curricula.

Evaluation of achievement of objectives for secondary biology curricula. Few reported studies were found involving evaluation of achievement of objectives for specific biology curricula. No studies were found in the literature reviewed oriented toward evaluation of a curriculum in terms of achievement of pre-determined objectives using a non-comparative method approach. Of the studies concerned with evaluation of objectives in secondary biology curricula, two were found which emphasized comparative method in relation to achievement of objectives in secondary biology, and two were concerned with the identification of factors related to achievement of objectives in secondary biology curricula.

Baumel,[3] at New York University, studied the comparative effects of method on achievement of selected science

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[3]Howard B. Baumel, "The Effects of a Method of Teaching Secondary School Biology which Involves the Critical Analysis of Research Papers of Scientists on Selected Science Education Objectives," Dissertation Abstracts 24:1090; No. 3, 1963.

education objectives using first-year biology students in a New York City academic high school. Comparative analyses were made of the effect on achievement, critical thinking, and interest when selected research papers of scientists were used as a supplement to the regular biology curriculum. The Cooperative Biology Test, Watson-Glaser Critical Thinking Appraisal, and the Kuder Preference Record were used to test two experimental classes using research papers and two control classes in which research papers were not used. Baumel found no significant difference in mastery of biology content, critical thinking ability, or science interest between the two groups. Students in the experimental group did express positive opinions concerning the use of such materials as an influence on their concepts of science and scientists. Baumel concluded that, since no significant difference existed in the groups in achievement, teachers need not fear loss in content achievement due to supplemental research materials. He further concluded that student reaction indicated that this method has the potential of motivating interest in science and has potential for developing student attitudes, appreciations and understandings in the way science works.

In 1937 Burnett,[4] using high school students in Concordia, Kansas, did a rotational design study of the comparative

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[4]R. Will Burnett, "An Experiment in the Problem Approach in the Teaching of Biology," Science Education 22 (March, 1938), 115-120.

effects of the problem approach and the "traditional" approach on the achievement of three objectives of biology teaching. Unit tests, the Hoff Scientific Attitude Test, a final exam, and the Ruch-Coosman Biology Test were given. Burnett compared unit quiz average with combined final average, attitude scores for biology students with non-biology students and Ruch-Coosman scores with national norms. Results were analyzed using percent differences in relation to the following objectives: (1) recall of facts, (2) ability to think scientifically, and (3) maintain scientific attitudes. Burnett found the following: (1) Concordia students were superior in factual knowledge, (2) Biology students' scientific attitudes were better than non-biology students, (3) problem approach students were better in scientific attitude than recitation students, (4) problem approach students were better in factual recall and thinking ability than recitation approach students. Based on these findings Burnett concluded that the problem approach was superior in fulfilling the objectives of ability to think scientifically, recall facts and maintain scientific attitudes. However, several weaknesses in this study are to be noted. The weaknesses include inadequate statistical treatment of data, poor sample selection, failure to consider rotational effects, failure to control treatment, and use of combined test scores.

At Oregon State University, Howe[5] studied the relationship of learning outcomes to teacher factors and methods in tenth grade biology. Using a stratified random sample of one class from each of fifty-one high schools, Howe analyzed the relationship of teacher factors and teaching methods to five basic objectives of science education. The basic outcomes compared were as follows: (1) gain in knowledge and understanding of biological facts, concepts, and principles, (2) gain in skill in applying the methods of science, (3) improvement in critical thinking skills, (4) development of an understanding of the nature of science and (5) development of more favorable attitudes toward science and scientific careers.[6] The tests used were the Otis Mental Ability Test, The Nelson Biology Test, the Watson-Glaser Critical Thinking Appraisal, The Reaction Inventory, Attitudes Toward Science and Scientific Careers and the Student Inventory. Howe found certain teacher factors significantly related to each of the five objectives at the .10 level of confidence. He also found the pupil centered method characteristic of a majority of classes with high composite scores. The data indicated that teaching which was planned to achieve a specific objective was more efficient than incidental learning. This

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[5]Robert Wilson Howe. "The Relationship of Learning Outcomes to Selected Teacher Factors and Teaching Methods in Tenth Grade Biology Classes in Oregon" (unpublished Doctor's dissertation, Corvallis: Oregon State University, 1964).

[6]<u>Ibid</u>., p. 24.

conclusion was particularly evident in attitude changes. Positive attitude changes toward science and gains in interest were significant at the .10 level, but no significant gains were found in relation to the effects of methods upon the critical thinking ability of the student.

Anderson,[7] at the University of Minnesota, studied the relative achievement of the objectives of secondary school science in fifty-six Minnesota schools. From the literature Anderson isolated the following objectives: (1) acquisition of factual information in science, (2) the understanding of principles of science, (3) the understanding of and use of the scientific method, and (4) the acquisition of scientific attitudes. He analyzed these objectives in relation to the scientific method and pupil and teacher factors contributing to their achievement in biology and chemistry classes. Scores on the State Board Examination, developed by Anderson, the Otis Quick Scoring Mental Ability Test, and questionnaire information were used in the analyses. Part scores on the Board Examination were developed for each of the isolated objectives. Anderson used intercorrelations and found that intellectual ability contributed most to understanding and use of the scientific method in chemistry and biology. He also found that understanding principles in biology contributed

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[7] Kenneth E. Anderson, "Summary of the Relative Achievement of the Objectives of Secondary-School Science in a Representative Sampling of Fifty-six Minnesota Schools," Science Education 33 (December, 1949), 323-329.

most to understanding and application of the scientific method in biology. The total score for achievement of all four objectives on the Board Examination was used in a co-variance analysis holding intelligence and pre-test knowledge constant. The following factors were not found to be significant in biology: (1) sex, (2) school size, (3) number of teacher preparations, (4) hours of college biology for teacher, (5) use of laboratory manual, (6) time of laboratory classes, (7) teacher knowledge of scientific method, (8) years experience teaching biology. The following factors were found to be significant in biology teaching: (1) teacher in upper fourth in hours of college science, (2) teacher graduated from a private college, (3) teacher had a masters degree, (4) number of hours in the laboratory for students, and (5) class size. Considering this data, Anderson concluded that this study isolated significant factors in pupil achievement in science which could be utilized in part or total in considering the problems in science education.

<u>Summary</u>. Studies emphasizing achievement of objectives appear to support the following conclusions. In comparative method studies, Baumel (3),* Burnett (4), and Howe (5) reported respectively positive effects in favor of the problem approach, the supplemental materials approach, and the pupil centered approach to the teaching of biology in the

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*Numbers in parentheses refer to previous reference and will be used throughout the dissertation.

development of achievement, thinking ability, and interest or attitude changes. In two cases, however, inferential statistics were either not significant or not used.

Howe (5), and Anderson (7) isolated factors related to the achievement of objectives in the teaching of secondary biology. Among the factors which were significant were the number of hours of college science which the teacher had taken, type of college attended by the teacher, number of laboratory hours for pupils, size of class, and teacher personality adjustment. Important areas which did not achieve a significant relationship with objectives included number of years teaching experience in biology, pupil sex, and school size. Conflicting evidence was found for the number of hours of college biology earned by the teacher. Although the four studies cited above touch upon the study of objective achievement in the teaching of biology, they are only partially related to the present study. They differ from the present study in that they are comparative method studies, or they emphasize factors related to achievement, or they fail to evaluate a specific curriculum such as BSCS, or they use objectives not pre-determined for the curriculum, or they do not answer the question, "Does the curriculum achieve its intended objectives?"

National BSCS project evaluation. Since the experimental implementation in 1960 of the BSCS Versions four major BSCS directed assessments have been made. These evaluations have varied in breadth, purpose, and depth of statistical treatment.

The first assessment attempt by the BSCS evaluation committee took place in 1960-61.[8] Evaluation instruments were devised in an attempt to ascertain the feasibility of BSCS objectives and the usability of the materials. The three questions evaluated were:

> 1. Is the biology presented to students in each of the versions of the BSCS course sound with respect to substantive content and compatible with the needs of secondary schools in the mid-twentieth century?
>
> 2. Is there evidence that the new courses developed by the BSCS have been tried out on groups of students reasonably representative of those who take biology in high schools throughout the United States?
>
> 3. To what extent can it be objectively demonstrated that the new course materials are indeed appropriate for the "typical" high school biology student?[9]

The answer to the first of these questions could not be determined in terms of quantifiable data. The answer was determined by collective opinion of those working in the development of the project. The conclusion concerning this question was stated in the report by Ferris in 1961.

> . . . While there was difference of opinion among professional biologists and outstanding secondary school teachers on the matter of topics to be included in a satisfactory secondary school biology course, there was

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[8]Hulda Grobman (ed.), "Centers Chosen for 1961-62 Evaluation Program," BSCS Newsletter 8 (Boulder, Colorado: Biological Sciences Curriculum Study, May 1961).

[9]Frederick L. Ferris, "Report on the 1960-61 BSCS Testing Program," BSCS Newsletter 10 (Boulder, Colorado: Biological Sciences Curriculum Study, November 1961), p. 3.

> unanimity of all involved with respect to certain themes and over-all objectives. . . .[10]

Question two was evaluated using objective data. The School and College Ability Test was given to samples of pupils who used either the BSCS Blue, Green or Yellow text versions. The scores of these pupils were compared with the scores of pupils taken from a national sample of tenth grade students who had taken biology. All BSCS samples combined and separated by version achieved a higher median score than the national sample of tenth graders. A hierarchy of median scores existed among the pupils having used the various BSCS Versions. The students using Blue Version achieved the highest ranking. Those using Yellow Version were second, and those using Green Version were lowest.

Question three was evaluated using specially constructed sequential batteries of achievement tests for each version and a comprehensive final examination constructed for all versions. Tests were designed with the expectation that the average student would get half of the questions right. The conclusion drawn from the data collected was stated as follows:

> Summarizing these achievement test results, it is clear that each version of the course is indeed teachable to the "typical" high school biology student. None of the three versions, even in their preliminary form, can be labeled a course appropriate only for the gifted student. The interpretations of the data obtained as a

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[10] *Ibid.*

> result of the achievement test program can certainly be made as gross generalizations. . . .[11]

The 1960-61 testing program evaluation was concluded as follows:

> In any event, the results of the 1960-61 testing program of the BSCS are highly suggestive that these course materials are teachable to the average high school biology student. With revised and improved versions both of the curriculum material and of the tests available for tryout during 1961-62, there is every reason to believe that the Biological Sciences Curriculum Study will achieve its desired goals.[12]

Based on the limited data and statistical treatment, the answer to each of the three questions was reported by the Biological Sciences Curriculum Study Committee as affirmative.

The second major BSCS assessment project was carried out in 1961-62 on the revised experimental edition of the BSCS Versions.[13] Five basic evaluation studies were included in this program. They were summarized as follows:

> Plan A. Plan A includes 67 Blue Version teachers, 30 Yellow Version teachers, and 30 Green Version teachers--a total of 127 teachers and 8200 pupils. These schools have purchased the student books; the teachers involved have received training for teaching BSCS High School Biology under a preparation program approved by the BSCS (e.g., in-service institute or summer institute at which BSCS materials were taught) or a BSCS Briefing Session. Teachers furnish quarterly feedback on BSCS materials and all students take the battery of BSCS-ETS tests.

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[11] Ibid., p. 4.

[12] Ibid., p. 5.

[13] Hulda Grobman (ed.), "B. Evaluation of BSCS Biology," BSCS Newsletter 12 (Boulder, Colorado: Biological Sciences Curriculum Study, February 1962), pp. 9-11.

Plan B. Plan B includes teachers organized into the 37 BSCS Evaluation Centers throughout the country; there are 361 teachers, and their 39,000 students in this plan, with approximately one-third of the teachers and students in each of the three versions. There are 12 Centers for the Green and Yellow Versions and 13 Centers for the Blue Version of BSCS High School Biology, for the most part, Centers are at the 10th grade level. However, at the 9th grade level there are: one Blue Version Center, two Yellow Version Centers, and two Green Version Centers.

Weekly meetings of all teachers in the Center are required and weekly feedback reports are made by each teacher, and an additional report is prepared for the Center as a whole. Classes of each teacher are visited by a BSCS Consultant during the academic year; the Consultant also visits a Center meeting. All Plan B teachers have received special preparation for BSCS Biology, either through the BSCS Briefing Session or at an in-service institute or summer institute. For Plan B, the BSCS supplies books for teachers and students. All students involved in this program take BSCS-ETS tests.

Plan C. Plan C includes teachers who participated in either the 1960 or 1961 Summer Writing Conference and who wish to use BSCS materials in their classes, but who, for some reason, could not be included as part of an Evaluation Center. This category also includes a few teachers who participated in the 1960-61 Testing Program who could not be accommodated in the 37 BSCS Evaluation Centers this year. Books for teachers and students are supplied by the BSCS. Quarterly feedback is expected from each teacher and all students take all BSCS-ETS tests.

Plan D. The teachers in Plan D are participants in local in-service institutes in Tampa, Florida, or Grossmont or San Diego, California. These institutes, under the sponsorship of a local university and/or school system, meet periodically (usually weekly) with a college instructor teaching BSCS materials; at the same time, the teachers are instructing their own students in BSCS Biology. The BSCS supplies student and teacher books. All students take BSCS-ETS tests. Feedback is received only from the institute instructor. The only teacher contact with BSCS involves shipment of books and tests, and information and instructions concerning such shipments.

The purpose of this category is to permit the BSCS to learn as much as it can about the effectiveness of BSCS materials in a teaching situation closely approximating usual school operation where there would be no direct contact with the BSCS.

Plan F. One college is using BSCS High School Biology, Green Version, experimentally at the college level in a first-year class. The BSCS is providing student books to this class and feedback is expected from the college instructor. All students are expected to take BSCS-ETS exams.[14]

Some feedback data of a non-statistical nature was reported in the literature, but no statistical data were provided on Programs A, C, D, and F.

Plan B was the major one in the 1961-62 BSCS evaluation program. The sample of 39,000 BSCS pupils in this study was compared to a control group of tenth graders selected by the Educational Testing Service from high schools not using any BSCS materials. According to Wallace's report, the control group was reasonably well matched in terms of teacher, school, and community characteristics.[15] Covariance adjustment for ability differences was used to eliminate biases due to lack of equivalence in groups compared. Students were tested using the School and College Ability Test, BSCS Comprehensive Final, Impact Test (POST), Cooperative Biology Test, and an attitude battery which included items from the Test on Understanding Science, Purdue Opinion Poll and a constructed semantic differential instrument.

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[14]Ibid., p. 9.

[15]Wimburn Wallace, "The BSCS 1961-62 Evaluation Program--A Statistical Report," BSCS Newsletter 19 (Boulder, Colorado: Biological Sciences Curriculum Study, September 1963), p. 22.

The following is a summary of major findings based on the 1961-62 testing:

1. As indicated by student achievement on the BSCS version tests and common, end-of-year final exams, BSCS students were able to master the BSCS Biology materials and to achieve the desired skills. Average and above-average students did well in all versions.

2. On the average, boys consistently outscored girls for both experimental and control groups on BSCS tests and on the conventional test (Cooperative Biology Test).

3. Tenth-grade BSCS students achieved significantly higher on the BSCS Comprehensive Exam than did tenth grade control students. Control group students achieved higher on the conventional Cooperative Biology Test than did BSCS students. These differences appear to be sufficiently great to be of educational significance. On the BSCS Impact Test, results were not definitive.

4. An analysis of variables in BSCS student performance as measured by the BSCS Comprehensive Final Exam indicated significant positive relationships with teacher salary, adequacy of laboratory, small class size and proportion of school's graduates going to college.

5. This analysis of variables in BSCS student performance as measured by the BSCS Comprehensive Final indicated no significant difference in terms of rural-urban-suburban schools, size of schools, length of class period, number of periods per week, per pupil expenditure and teacher age, years of experience and number of undergraduate and graduate hours in biology.

6. Above-average ninth-grade students in situations with relatively good teacher preparation and good biology laboratories were able to handle BSCS Biology materials. Test data tend to substantiate feedback reports that BSCS Biology would probably not be suitable for the average ninth grader.

7. Compared with non-block students, block students tended to score slightly lower on the BSCS Comprehensive Final; this difference in achievement was surprisingly small in view of the fact that the

laboratory block takes the student out of six weeks of regular class work.

8. For nonblock BSCS students, the version used by the students was of less significance than were such other variables as sex of student, teacher salary, proportion of the school's graduates going to college, class size and adequacy of laboratory.

9. Students who achieved high scores on the BSCS Comprehensive Final Exam also tended to achieve high scores on the BSCS Impact Test and the conventional Cooperative Biology Test.[16]

No statements were made concerning attitudes and opinions in the summary of conclusions. In the statistical report, the following was stated:

> In an attempt to assess the effect of the BSCS instruction on the attitudes and opinions of the students toward science and scientists, three measures were administered to the BSCS classes and the control group classes at the end of the school year. One of these measures was a selected set of 26 multiple-choice items from the Test of [sic] Understanding Science. The second was composed of 10 items selected from attitude scales developed at Purdue University. The third measure was an adaptation of the semantic differential method using concepts such as "Biology" which the students rated in terms of 15 polar adjectives, such as exciting-dull. On the first two measures, preliminary analyses revealed negligible differences between the BSCS groups and the control group, and no intensive analyses were performed. The results from the third measure have not yet become available.[17]

In a personal communication, Dr. Hulda Grobman stated the following concerning the analysis of data from the semantic differential test:

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[16]Hulda Grobman (ed.), "Summary of 1961-62 Evaluation Program Test Results," BSCS Newsletter 18 (Boulder, Colorado: Biological Sciences Curriculum Study, June 1963), p. 24.

[17]Wallace, BSCS Newsletter 19, op. cit., p. 24.

> This is in further reference to your inquiry to the BSCS concerning the word association test that was administered to BSCS students some years ago. A copy of the test is enclosed; you will note it was part of a larger, omnibus instrument on attitudes. The word-association section was developed in consultation with Dr. Osgood, of the University of Illinois.
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> A number of difficulties arose in data treatment, including the departure from the University of Illinois of the expert who was to help us in data treatment. As a result, data were turned over to Dr. Klopfer of the University of Chicago and Dr. Thomas Hastings of the University of Illinois who agreed to see that it was processed and interpreted. As far as I know, no report was submitted to the BSCS. Thus, I cannot give you any data on it.[18]

Considering these results the following conclusion was drawn in the BSCS evaluation report:

> Thus, although major goals have been achieved, it is recognized that some of the BSCS objectives are not susceptible to quantitative measurement at the present time. Others can be investigated in follow-up studies only after a number of years have passed. The BSCS realizes many of the limitations of its evaluation studies to date and plans to continue its investigations of the use of BSCS Biology; it is also hoped that other investigators will contribute to the knowledge concerning the BSCS Biology materials and their use.[19]

The third major phase of BSCS evaluation was centered on the BSCS Second Course and the Special Materials Course.[20] From 1961-63, the Second Course materials were evaluated to determine feasibility in a non-quantitative manner. The

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[18]Personal correspondence, February 23, 1968.

[19]Hulda Grobman, "Some Comments on the Evaluation Program Findings and Their Implications," BSCS Newsletter 19 (Boulder, Colorado: Biological Sciences Curriculum Study, September, 1963), p. 29.

[20]Hulda Grobman (ed.), "Evaluation Issue," BSCS Newsletter 24 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1965).

evaluation was based on review by experts and feedback by teachers. During 1963-64 the evaluation included quantitative instruments. No statistical comparisons were made with a control group since no comparable courses existed. The evaluation focused on feasibility and competences gained. The analysis was based on a sample of 1,117 tenth, eleventh, and twelfth grade students. Data were analyzed using correlations for the Differential Aptitude Tests and Second Course Final Examination. Based on the data analyzed the following conclusions were made:

1. The course represents good biology. (Whether or not this is the biology that should be included in a second high school course in biology is a value judgment that cannot be tested in an evaluation program.)

2. Above-average high school students are able to master the materials and concepts to the satisfaction of the authors.

3. Ability to master the course is highly correlated with student general ability as measured by a standard ability test, that is, DAT (VR ÷ NA).

4. Ability to master the course is related to grade level of student. The variable here may be maturation level of the student or it may reflect the increased academic background in math and other sciences of students in the higher grades. Further investigation of this relationship is in progress.[21]

The Special Materials evaluation was carried out during 1963-64. The major purpose of this evaluation was not to collect detailed statistical data, but rather to determine

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[21]Hulda Grobman, "Comments on the Second Course Evaluation," BSCS Newsletter 24 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1965), p. 15.

whether the approach was feasible. A non-random sample of 609 students was taught by 39 teachers. No control group was chosen since no comparably oriented group was available for the purpose. To give some means of comparative description and analysis of data, comparisons were made with a matched sample of students in regular version classes. Students were tested using the Differential Aptitude Tests, Impact Test, a three-unit Final Exam and three unit tests. The data were analyzed using inspection, correlation, and a t test. Grobman summarized the evaluation report with the following statement of intent and conclusions:

> Since test data on the regular versions over a four-year period indicate that average and above-average students can use the BSCS versions, in testing the Special Materials it is not necessary to use a "shotgun" approach--that is, to try them with a wide variety of students to see who can use them. The BSCS SM materials are intended only for those students whose ability level does not permit them to use the regular version materials, since, obviously, the regular materials would be more enriching and beneficial to the student able to use them. The problem then arises as to identifying students not able to use the regular materials, so that the SM materials may be tried out with them. This was the aim of the pilot SM study in 1963-64. The experimental sample was not intended to be representative of all high schools in the United States, but rather diverse enough to give some idea of the feasibility of the SM materials. It was hoped that SM classes would be relatively homogeneous in terms of general ability, as measured by Differential Aptitude Tests (DAT), and that there would be more uniformity in supplementary materials used; in practice, this was not the case. However, despite limitations in the sample and in the evaluation instruments used, the following conclusions appear warranted:
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> 1. The basic principles of biology embodied in the versions of BSCS Biology can be taught successfully to the lower-ability student.

2. The use of SM materials as a supplement to regular version materials is not feasible with low-ability students.

3. Successful use of the SM materials apparently depends on the teacher and his interest in the lower-ability student and desire to work with him.

4. Assignment by schools of students to the SM classes was often based on factors other than general ability.

5. It is possible to use multiple-choice tests with the lower-ability student to measure student achievement.

6. Students in SM classes do gain knowledge of some biological concepts as measured by the BSCS Impact Test and by the SM tests.

7. The DAT Verbal Reasoning + Numerical Ability is a good predictor for achievement on the BSCS SM tests.

8. Students assigned to SM classes differ from students of similar ability who are assigned to regular biology sections.

9. Attainment of the objectives of the SM class appears more possible when the class includes a relatively small range of ability levels.[22]

The most recent evaluation study reported by BSCS took place during 1964-65.[23] The earlier evaluations emphasized feasibility and comparison of achievement and scientific reasoning with conventional curricula. The 1964-65 study emphasized analyses of BSCS tests and their relationship to other tests. Investigations included comparisons between

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[22]Hulda Grobman, "Some Comments on the SM Evaluation," BSCS Newsletter 24 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1965), pp. 36-38.

[23]George M. Clark (ed.), "Evaluation Issue," BSCS Newsletter 30 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1967).

test forms and between different tests. Another phase of the study involved the use of the Davis Reading Test and the Illinois Natural Science Reading Comprehension Test to determine the relationship of reading skills to BSCS achievement. Inter-group comparisons for versions were tested using a t test for differences. The evaluation report was concluded with the following summary:

> The 1964-65 evaluation study was conducted in conjunction with the standardization of the BSCS tests. The evaluation study included comparisons of the student achievement between sexes, between forms (R & S) of the BSCS achievement and final examinations, and among the three curricula Versions. Also included was a study of BSCS student performance on two reading tests.
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> The major results of the study were:
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> 1. The academic ability and BSCS achievement tests were appropriate in difficulty for the groups.
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> 2. Males generally had higher test means than females on both ability and achievement tests.
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> 3. Differences in mean raw scores between the Form R and Form S groups were very small, and they are of no importance when the independently derived percentile equivalents are used.
>
> 4. Consistent differences appeared in both ability and achievement among the groups in the three curricula Versions. The Blue Version groups had the highest means, the Yellow Version groups were next, and the Green Version groups had the lowest means.
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> 5. Both reading tests were highly related to the academic ability tests and to the BSCS achievement tests.[24]

In addition to efforts to evaluate its own materials, BSCS has been interested in supporting studies by schools and

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[24] *Ibid.*, p. 3.

independent researchers. One such study is that of Dr. Richard C. Anderson of the Training Research Laboratory at the University of Illinois.[25] This project consists of preparing a programmed lesson in population genetics and studying the learning activity in great detail on a relatively small number of students. Another study is being done in cooperation with the U. S. Office of Education's Mid-Continent Regional Education Laboratory at Kansas City.[26] This project focused on behavioral objectives which were related to teaching science as inquiry. The project was completed in 1970 and is presently being evaluated. Independent studies have proliferated. Some of these studies are summarized under different categories of this review. An abstract of other significant studies of BSCS materials was compiled by Lehman.[27]

Summary. BSCS evaluation projects have established, to the satisfaction of the BSCS staff, the feasibility and appropriateness of the basic versions for average and above-average high school students. Test materials have produced a series of consistent results. A consistent difference in

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[25]J. Thomas Hastings, "A Note on Evaluation," BSCS Newsletter 30 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1967), p. 2.

[26]Personal correspondence with Manert H. Kennedy, BSCS Consultant, January 25, 1968.

[27]David L. Lehman, "Abstracts of Recent Research and Development: A New Dimension in the Evaluation of BSCS," BSCS Newsletter 30 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1967), pp. 21-25.

performance was found between males and females on BSCS testing materials. Males consistently achieving greater means than females. Tests specifically designed for BSCS tended to produce significant differences in favor of BSCS, while those not so designed showed no significant differences or favored the control group. One exception to this was found on the Impact Test (POST) which produced no significant difference although designed for the BSCS program. Form differences on BSCS tests were not significant. Since reading tests were found to have a high relationship with BSCS tests, reading has been identified as a factor related to success in BSCS as measured by BSCS tests.

In the affective domain little was done in these studies by the BSCS evaluators. When compared to traditional programs, no significant change was found in attitude or opinion of students for any of the BSCS Versions.

Although the BSCS materials were initially designed and tested for tenth grade students, the various versions have been found to be appropriate for above-average ninth grade students as well. To fill the gaps when BSCS Versions were found inappropriate, special BSCS Versions were developed. Two such programs were developed. One, known as the Special Materials program, was designed for the slow learner, and the other, known as the Second Year Program, was developed for the advanced student. Both programs were found to be appropriate for the designed level. In both cases, academic

ability was a determining factor as to success and appropriateness. A major factor in the use of the Special Materials for slow learners was the homogeneity of the academic ability of the group.

Most of the conclusions of the national BSCS studies have been based on opinions of experts or data of a comparative method nature. Little has been done in terms of evaluation of objectives achieved without considering comparative methods. The affective domain received little consideration and data collected were not fully analyzed.

Evaluation of achievement as related to comparative method in secondary biology. Many studies in biology curriculum evaluation have emphasized achievement of a single objective. Achievement, in terms of factual understanding, principles application and the understanding of science, has been studied and reported by a number of researchers. All of these studies have taken a comparative method approach to evaluation.

One such study was done by Newman[28] at the University of Oklahoma. Newman studied the comparative effectiveness of three teaching methods in high school biology. The Nelson Biology Test was used to determine acquisition of biological knowledge. Six high school classes was divided into three groups using the lecture-discussion with outside reading,

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[28]Earl Nelson Newman, "A Comparison of the Effectiveness of Three Teaching Methods in High School Biology," Dissertation Abstracts 17:2940; No. 12. 1957.

lecture-discussion with in-class textbook reading assignments, and lecture-discussion with no text or reading assignments in or out of class. Each method resulted in significant gains in biology information from pretest to posttest, but no method was statistically superior to any other method.

Oliver,[29] at Purdue University, studied the comparative effects of three methods of teaching high school biology on achievement, factual and applied, and attitude changes. Three classes were chosen in a high school in Indiana. One class was exposed to the lecture-discussion method, a second to the lecture-discussion and demonstration method, and a third to the lecture-discussion and demonstration with laboratory exercises method. The classes were sub-grouped on IQ into high, medium, and low ability categories. Oliver found no significant difference in over-all acquisition of factual information or achievement on the Nelson Biology Test and Cooperative Biology Test. There was a difference in the acquisition of facts at the .05 level between high and low IQ ability groups. No significance was found in the application of principles on a constructed principles test. There was no change in attitude toward science and scientists, although average students exhibited a more favorable attitude than the high or low ability groups. Oliver concluded that

[29]Montague Montgomery Oliver, "An Experimental Study to Compare the Relative Efficiency of Three Methods of Teaching Biology in High School" (unpublished Doctor's dissertation. Lafayette: Purdue University, 1961).

students achieved factual information, ability to apply scientific principles, and have equally favorable attitudes toward science regardless of the method of instruction. He further concluded that regardless of method the higher the intellectual ability the greater the achievement.

At Arizona State University, Lisonbee[30] studied the comparative effects of BSCS Blue Version and "Traditional" Biology on student achievement. An experimental group of 120 and a control group of 132 tenth grade biology students from six Phoenix Union high schools were randomly selected and grouped by ability. They were tested using the Nelson Biology Test, BSCS Achievement Test--Comprehensive Final, California Test of Mental Maturity (CTTM) and Iowa Tests of Educational Development (ITED). Using covariance analysis and holding the CTTM and ITED scores constant, no significant difference was found on the Nelson Biology Test between the experimental and control groups. However, a significant difference for the middle and high ability IQ experimental and control groups was found on the BSCS Comprehensive Final, the experimental BSCS group excelling. No significant difference appeared between schools on the Nelson Biology Test, but did on the BSCS Test. Lisonbee suggests that the results may indicate that students using BSCS materials learned the important core of information of the traditional plus the

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[30]Lorenzo Kenneth Lisonbee, "The Comparative Effect of BSCS and Traditional Biology Upon Student Achievement" (unpublished Doctor's dissertation. Tempe: Arizona State University, 1963).

new up-dated biology knowledge of the BSCS course. He also suggests that the BSCS test is inappropriate for testing the low ability group since no significant differences were found between experimental and control slow learner groups.

Lance,[31] at the University of Georgia, used ninth and tenth grade biology pupils from Athens' Georgia high schools in a comparative method study of the effects of "conventional" and BSCS Green Version Biology courses on achievement. A control group of 126 pupils used a conventional biology program and an experimental group of 134 pupils used the revised Green Version, 1962-63. An analysis of covariance using adjustment for differences in initial scores, mental age, academic average, and age was used. Although measures made by both the Nelson Biology Test and What Do You Think? Test showed greater gains for the experimental group, no significant differences were found. On the Nelson Biology Test boys out-performed girls at the .01 level of significance. Interaction of course and school was rejected.

At Arizona State University, Moore[32] studied the effects on achievement and interest of a BSCS approach as compared

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[31] Mary Louise Lance, "A Comparison of Gains in Achievement Made by Students of BSCS High School Biology and Students of a Conventional Course in Biology" (unpublished Doctor's dissertation. Athens: University of Georgia, 1964).

[32] C. Olan Moore, "An Evaluation of the Effectiveness of the Biological Sciences Curriculum Study Approach to Teaching Biology to High Ability Students in the Ninth Grade" (unpublished Doctor's dissertation. Tempe: Arizona State University, 1965).

to a "traditional" approach using high-ability ninth grade pupils. The Nelson Biology Test, BSCS Comprehensive Final and two self-designed interest instruments were given. Forty-nine experimental students were matched with forty-nine other high ability ninth grade students of equal IQ from Scottsdale, Arizona high schools. Using the analysis of covariance, Moore found significant differences in favor of the experimental BSCS students on the BSCS Comprehensive Final, but not on the Nelson Biology Test. Males achieved greater means than females in all sub-groups. No significant changes occurred in interest in science in any group. Based on the evidence of achievement, Moore concluded that ninth grade high ability students should be taught by one of the three versions of BSCS biology.

At the University of Wisconsin, Gennaro[33] studied the comparative effects of two methods of teaching high school biology on achievement. Forty-eight ninth grade pupils of the Wisconsin High School were randomly assigned to two classes in biology. One used the Yellow Version program and the other three Laboratory Blocks incorporated into the Yellow Version course of study. BSCS Achievement Tests and Comprehensive Final were used to test for subject matter achievement. The BSCS Impact Test and tests consisting of

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[33]Eugene Daniel Gennaro, "A Comparative Study of Two Methods of Teaching High School Biology: BSCS Yellow Version and Laboratory Blocks with Collateral Reading" (unpublished Doctor's dissertation. Madison: University of Wisconsin, 1964).

questions designed to measure scientific reasoning taken from Laboratory Block Tests were administered to measure scientific reasoning. Using an analysis of variance technique, no significant difference was found in subject matter achievement except on tests taken from the Laboratory Block Tests. These favored the class using Laboratory Block materials. There were no differences in scientific reasoning as measured by the Impact Test. Gennaro concluded that the addition of Laboratory Blocks to the Yellow Version did not affect the level of ability in scientific reasoning or achievement.

Behringer,[34] at the University of Texas, studied the effects of modified and unmodified BSCS Yellow Version programs on ability grouped biology classes in the San Antonio high schools. Three ability groups were established. Slow learner and accelerated groups were divided into classes using modified and classes using unmodified Yellow Version. The average groups used only the unmodified program. Although all groups showed gains in learning at the .01 level of significance, statistical evidence from scores on the Processes of Science Test and BSCS Comprehensive Final indicated that the modified materials did not result in significant learning differences over unmodified materials. Behringer concluded

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[34]Marjorie Perrin Behringer, "The Development of Differentiated Curricula for Ability Grouped Biology Classes, Including Teacher Training and Program Evaluation" (unpublished Doctor's dissertation. Austin: University of Texas, 1966).

in her review of the literature that:

> Research during the last ten years tends to confirm the idea that grouping accompanied by differential curriculum and instruction is advantageous but that grouping per se has little or no value.[35]

It is worth noting that Behringer's study did not directly support the above conclusion.

Lewis,[36] at Montana State University, evaluated the effects of four methods of teaching high school biology on achievement. A sample of 510 students, from five high schools, was divided into groups which were taught by one of three BSCS Versions or a "traditional" approach. Students were tested using the Biology Achievement Examination for Secondary Schools Form 4. No statistically significant difference was found in final achievement between the traditional and any of the BSCS methods. Lewis concluded that BSCS Versions did not represent significant improvement over the traditional approach to teaching high school biology.

Cook,[37] at the University of Iowa, studied the effects of methodology on achievement in Blue Version high school biology classes. Using seventeen classes of the Iowa City area schools, Cook analyzed the effects on critical thinking,

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[35] Ibid., p. 17.

[36] William Altz Lewis, "An Evaluation of Four Selected Approaches to Teaching High School Biology" (unpublished Doctor's dissertation. Missoula: Montana State University, 1966).

[37] Robert Earl Cook, "The Effect of Teacher Methodology Upon Certain Achievements of Students in Secondary School Biology" (unpublished Doctor's dissertation. Iowa City: University of Iowa, 1967).

understanding of science and knowledge of subject matter of teaching methodology as identified by the Flanders' Interaction Analysis. Students were pretested and posttested using the BSCS Comprehensive Final, the Processes of Science Test, and Watson-Glaser Critical Thinking Appraisal, and the Iowa Test of Educational Development. Significant differences were found at the .05 level for all pairs of means for the eight teaching methodologies on the three tests used. Cook concluded that this supported the important role of the teacher in determining student outcomes. He also concluded that the direct teacher can cause students to learn subject matter equally as well as the indirect teacher.

In 1960 Klopfer and Cooley,[38] at Harvard University, under contract with the United States Office of Education studied the comparative effects of using History of Science Cases (HOSC) as a supplement to a regular biology, physics, and chemistry program on student achievement and understanding of science and scientists. Analysis was made using total and sub-scores of the TEST on Understanding Science (TOUS), the Otis Quick Scoring Mental Ability Tests, and the Cooperative Biology Test for the biology section of the three part experiment. Nineteen experimental and twenty-two control biology classes were randomly selected. Class means were analyzed

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[38]Leopold E. Klopfer and William W. Cooley, "The History of Science Cases for High Schools in the Development of Student Understanding of Science and Scientists," Journal of Research in Science Teaching 1 (1963), 33-47.

by a three-way analysis of covariance, holding the Otis scores constant. Highly significant results in favor of the experimental group (HOSC) were found in understanding of science as measured by total and sub-scores of the TOUS Test. It was found that the control group not using HOSC showed significantly greater achievement as measured by the Cooperative Biology Test. Klopfer and Cooley concluded that the History of Science Cases instructional materials were effective in increasing understanding of science and scientists with little or no concomittant loss of achievement in the usual content of high school science courses.

Summary. The studies reported on achievement as an objective of biology teaching have consistently supported several basic conclusions. According to the research of Newman (28), Oliver (29), Lisonbee (30), Lance (31), Moore (32), Gennaro (33), Behringer (34), and Lewis (36) method of instruction in high school biology appears to have no measurable gross effects on achievement in terms of factual knowledge and application of principles in comparative method studies. Cook (37) found conflicting evidence which supported significant differences in achievement when methodology of teachers was analyzed rather than gross curriculum effects which ignore different teaching styles. All groups in all studies appear to have gained significantly in knowledge regardless of the method of instruction, and IQ level appears to be significantly related to level of achievement.

According to Lance (31) and Moore (32), sex is a factor in science achievement. In both studies males out-perform females.

Studies involving the use of tests specifically designed for a given method of biology instruction tend to produce significance in favor of that program. Lisonbee (30) and Moore (32) found significance in favor of BSCS methods on BSCS tests, but not on other tests. Klopfer and Cooley (38) found significant differences in favor of the HOSC group on the TOUS test, while traditional groups achieved more on a traditional test. Gennaro (33) and Behringer (34) found no significant difference when BSCS tests were used in comparison of two BSCS programs having similar objectives and for which the test was appropriately designed. Lisonbee (30) and Lance (31) found conflicting evidence concerning schools as a factor in achievement when comparing BSCS and "traditional" methods.

None of the studies concerned with achievement in biology attempted to determine the degree of achievement as an objective of a single program. All of the reviewed studies used a comparative method approach which led to significance when tests were specific to the design of the program and no significance when tests were not specific to the program.

<u>Evaluation of critical thinking as an objective of secondary biology curricula</u>. Another area often studied as an objective of science instruction is critical thinking.

Although this term has a variety of definitions, the basic concept always appears to involve an evaluation of reasoning of a complex form which leads to solution of a problem. In the evaluation of biology curricula, three studies have been done which specifically attempted to determine the comparative effects of method on critical thinking ability.

Kastrinos,[39] at Purdue University, studied the relationship of methods to development of critical thinking in high school biology. The textbook-recitation method was compared to the principles-critical thinking method using two classes of regular biology, college preparation, and two classes of advanced biology, second year, at Glenbard High School in Illinois. One class of each type was exposed to each method. The classes were sub-grouped by IQ. Data were collected using the Lorge-Thorndike Intelligence Test, Diagnostic Reading Test, Nelson Biology Test, University of Illinois Test of Ability to Judge Interpretation of Data, Watson-Glaser Critical Thinking Appraisal, Novàk's Problem Solving Test, and the Kastrinos Critical Thinking Test constructed by the researcher. The results showed that all groups improved in acquisition of factual materials although no significant differences were found between groups in factual knowledge gained. For all groups of students combined mean scores

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[39]William Kastrinos, Jr., "The Relationship of Methods of Instruction to the Development of Critical Thinking by High School Biology Students" (unpublished Doctor's dissertation. Lafayette: Purdue University, 1961).

improved significantly from pretest to posttest on all critical thinking tests used. Sub-groups showed a degree of variation in significance. The advanced biology principles-critical thinking group had a significantly greater mean score on the Kastrinos Critical Thinking Test than the textbook-recitation group. The principles-critical thinking group improved significantly in all areas of the University of Illinois Test of Ability to Judge Interpretation of Data, but the textbook-recitation group did not improve. In no area did the textbook-recitation group exceed the principles-critical thinking group significantly. Kastrinos concluded that a critical thinking approach to teaching biology can produce significant change in critical thinking ability, as well as a significant change in subject matter mastery. He also concluded that critical thinking tests used varied in ability to test critical thinking ability for various IQ groups.

George,[40] at the University of Kansas, studied the comparative effects of a "conventional" program and the three BSCS Versions on critical thinking ability. A sample of 391 high school pupils in nineteen biology classes in four Chicago suburban high schools was used. The analysis of covariance was used to analyze data from the Watson-Glaser Critical Thinking Appraisal and Otis Quick Scoring Mental

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[40]Kenneth D. George, "An Experimental Evaluation of BSCS and Conventional Biology by Comparing Their Effect on Critical-Thinking Ability" (unpublished Doctor's dissertation. Lawrence: University of Kansas, 1964).

Ability Test. George found no significant difference between Green Version and "conventional" biology and no difference between Yellow Version and "conventional" biology in critical thinking ability. A significant difference was found for Blue Version over the "conventional" biology program at the .01 level. Significant differences at the .01 level were found between versions. Pupils in Blue Version achieved greater gains than pupils in Yellow Version, and the Yellow Version greater gains than pupils in Green Version. In no case was "conventional" biology significant over BSCS. George concluded that these results tend to confirm the basic assumption of the BSCS program that conventional biology stresses the facts and conclusion of science. However, BSCS doesn't always produce greater ability to think critically.

Sorensen,[41] at Oregon State University, studied the comparative effects of laboratory-centered and lecture-demonstration-centered patterns of instruction on critical thinking in high school biology. A sample of twenty biology classes was randomly selected from four high schools in Salt Lake City. Ten classes were taught by each method. The content consisted of two Laboratory Blocks developed by BSCS. Data were collected using the Otis Quick Scoring Mental Ability Test, Watson-Glaser Critical Thinking Appraisal, Cornell

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[41]LaVar Leonard Sorensen, "Change in Critical Thinking Between Students in Laboratory-Centered and Lecture-Demonstration-Centered Patterns of Instruction in High School Biology" (unpublished Doctor's dissertation. Corvallis: Oregon State University, 1966).

Critical Thinking Test, Dogmatism Scale, and Test on Understanding Science. Significant change was found at the .05 level of critical thinking and understanding of science in laboratory-centered instruction, but not in lecture-demonstration-centered instruction. Mental ability was not found to be directly related to change in critical thinking or understanding of science. Changes in dogmatism were significant at the .05 level for the laboratory-centered classes, but not in the lecture-demonstration centered classes.

Summary. Results of studies of critical thinking as related to evaluation of biology curricula established the common conclusion that gains in critical thinking take place regardless of method. However, degrees of change can be effected by teaching methodology as found by Cook (37) in a study reported earlier, by BSCS Version as found by George (40), by the laboratory-centered approach as reported by Sorensen (41), and by a critical thinking approach as reported by Kastrinos (39).

The available data raises a question concerning comparative testing of ability groups using a common test which may favor gains for a given group. It appears that critical thinking can be taught for and measurable gains for variations due to methods can be detected with available tests.

Evaluation of interests as an objective of secondary science curricula. Increasing science interest and interest in scientific careers are generally considered one of the major objectives of science courses in secondary schools. Interest has been one of the most studied objectives of science instruction in the secondary schools. The studies included in this review have centered on subject preference, change in science interest, and factors effecting science interest.

Few studies have been done in the area of interest as related to biology curriculum evaluation. Those studies reported will include both general studies involving subject preference and changing interest in science; as well as studies specific to biology curriculum evaluation.

Blanc,[42] at Gove Junior High School in Denver, Colorado, studied the biology interests of tenth and eleventh grade pupils. A questionnaire developed by Blanc was used to determine student interest in twelve major areas isolated from biology texts. A sample of 120 students classified as to sex, grade level, and grade received in biology was selected. A critical ratio test was applied to the number of positive and negative responses to each area in the questionnaire. Based on this analysis Blanc drew the following conclusions:

1. There was no consistent correlation between the emphasis given topics by textbook writers and the expressed interests of pupils.

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[42] Sam S. Blanc, "Biology Interests of Tenth and Eleventh Grade Pupils," Science Education 42 (March 1958), 151-9.

2. Regardless of how the data was treated, there was, in most cases, a high agreement between various categories and groups in the likes and dislikes for the specific items listed on the questionnaire.

3. In general "A Group" pupils were most inclined to express interest in topics in agreement with emphasis in textbooks, and the "D Group" was least inclined to agree with the emphasis in textbooks.

4. The higher the grade received in first-semester biology the greater the number of expressed interests in topics which appeared on the questionnaires.

5. No hard and fast conclusions should be drawn from this study until a wide geographic sampling of pupils is studied. What may be true in this local situation may not be true in others.[43]

Shepler,[44] at the University of Pittsburgh, studied scholastic achievement in secondary school natural science in relation to relative subject preference. The Terman-McNemar Test of Mental Ability, The Scholastic Preference Interview, and the Harvy-Durost Essential High School Content Battery were given. A statistical analysis of 827 cases was made using correlation techniques. The analysis of variance was used to test the following hypotheses:

1. On the same levels of mental ability, student accomplishment in science study increases with increase in degree of subject proference.

2. On the same levels of subject preference student accomplishment in science increases with increase in degree of mental ability.[45]

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[43] Ibid., p. 159.

[44] Warren Davis Shepler, "A Study of Scholastic Achievement in Secondary School Science in Relation to Pupils' Relative Preference for This Subject," Dissertation Abstracts 16:1376; No. 8. 1956.

[45] Ibid.

Shepler drew the following conclusions based on the data collected:

1. Both of the hypotheses stated above are supported in satisfactory degree.

2. As a predictor of science accomplishment in groups with heterogeneous mental ability, level of mental ability is the best indicator of level of potential accomplishment.

3. In groups homogeneous as to mental ability, level of preference for science study is the best predictor of an individual's potential accomplishment in science study for his level of mental ability.

4. Preference for science study was found to be somewhat higher with higher levels of mental ability, and higher for boys than girls. Also there is close correspondence between number of years of science study and level of preference for this subject.[46]

Bolvin,[47] at the University of Pittsburgh, studied the interrelation of mental ability and subject preference to scholastic achievement. One phase of this study involved science. A sample of 250 cases of twelfth grade students was drawn from three Pittsburgh high schools. Data were collected using the Terman-McNemar Test of Mental Ability, Essential High School Content Battery, and Scholastic Preference Interview. Bolvin found mental ability and subject preference associated with accomplishment, but they were independent of each other. He also found that relative subject preference

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[46]*Ibid.*

[47]John Orvard Bolvin, "The Interrelation of Mental Ability and Subject Preference in Scholastic Achievement," *Dissertation Abstracts* 19:1241; No. 6. 1958.

was a delimiting factor on the influence of mental ability, and that when mental ability was held constant relative subject preference was a predictor of accomplishment. Bolvin concluded that mental ability and interest both independently and in interaction are related to a student's accomplishment in a given subject area.

Wynn,[48] at the University of Georgia, studied factors related to gains and loss of science interest during high school. Using a sample of 325 junior and senior students, an analysis was made of Kuder Preference Record and California Short Form Test of Mental Maturity scores. No significant change was shown over a years time in interest in science. However, 21 percent of the sample underwent significant change in individual scores. A sex difference in means was noted with males favoring science. No significant relationships were found between science interest change and mental ability, academic achievement, science achievement, biology achievement, occupational level of father, and educational level of father and mother. Only pretest scores were found to be predictors of science interest. No trend of increasing science interest was found over five years for freshman classes from 1958-1962. Wynn concluded that science interest of high school students was more stable than realized and that the extreme emphasis placed on science and science

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[48]Dan Camp Wynn, "Factors Related to Gain and Loss of Scientific Interest During High School," Dissertation Abstracts 24:4491; No. 11. 1964.

education during recent years has not resulted in greater interest in science.

Pennington,[49] at Florida State University, studied factors affecting high school seniors' interest in science. Data were collected by questionnaire from a sample of 502 students in ten Georgia high schools. Sixty percent of the sample was interested in science and forty percent was not interested in science. Factors showing a relationship to science interest included residential background, vocational preference, membership in science related organizations, hobbies, radio and TV, reading, good teaching in science, science clubs and fairs, field trips, laboratory equipment, course organization in science, bulletin boards, and number of science and math courses taken. No relationship was established with parent's occupation.

Bull,[50] at the University of Missouri, studied the activities and background of pupils with dominant science interest. Case history studies were made of 100 high school pupils with dominant science interest selected by their science teachers. Personal interviews were used to collect data. Bull found that pupils dominant in science interest developed their interest at an early age and were superior in

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[49] Tully Sanford Pennington, "A Study of Factors which Affected High School Seniors' Interest in Science," Dissertation Abstracts 20:4344; No. 11. 1960.

[50] Galen William Bull, "The Activities and Backgrounds of Pupils with Dominant Science Interests," Dissertation Abstracts 15:61; No. 1. 1954.

scholastic ability, preferred physical science, had good social poise, avoided physical activity found in typical secondary schools, devoted more time to their interests and hobbies than usual adolescent activities, exhibited keen curiosity about the working of scientific apparatus, were readers of science literature, and were encouraged in their interest in science by parents or science teachers. Bull concluded that early science training and exposure is needed since science interest develops early and follow-up encouragement and guidance is needed to expose students to science occupations.

Powell,[51] at the University of Alabama, studied high school seniors' attitudes toward science in nine Alabama high schools. A sample of 775 seniors was tested with the Sims Field of Study Motivation Record, the Otis Quick Scoring Mental Ability Test, and a questionnaire. An analysis was made using chi square. Science was ranked sixth out of ten fields, but had a favorable attitude mean for all students. Females ranked science eighth with an unfavorable mean. Males ranked science third with a highly favorable mean. The difference in interest in science was significant at the .01 level for males and females. A significant difference was found for students favoring science when considering parental education, socio-economic level, and intelligence.

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[51]James D. Powell, "High School Seniors' Attitudes Toward Science," National Association of Secondary School Principals Bulletin 46 (November 1962), 82-7.

Powell concluded that the subject a student finds interesting and in which he meets success is the subject he prefers. He also concluded that schools exercise little or no influence over some variables which influence interest in science. Hence the tendency to "blame" the schools for failing to do an adequate job in teaching science may be misplaced.

Summary. Several basic findings concerning interest in science can be summarized from the literature reported. Blanc (42), Shepler (44), Bolvin (47), Bull (50), and Powell (51) found a positive relationship between achievement and interest or subject preference for science. Wynn (48) in contradiction found no significant relationship between interest in science and academic achievement, science achievement or biology achievement. Both Shepler (44) and Bolvin (47) found subject preference a delimiting factor on mental ability as a determiner of achievement in science.

Shepler (44), Wynn (48), and Powell (51) found a sex influence in relation to interest in science at the secondary level. All three reported higher interest among males.

Bull (50) reported evidence for early development of science interest and is supported by Wynn's (48) evidence of early interest and stability of science interest over a five year period.

Wallace (15), Oliver (29) and Moore (32) report little difference in comparative effects of teaching methods including BSCS on science attitudes and interests.

A wide variety of factors have been reported as positively related to interest in science. In many studies the problem is to determine if interest is the antecedent or result of the reported factors. Interest as reported in these studies is not measured as an objective of a specific curriculum, but is presented in a comparative method frame of reference or an analysis of interrelationships of factors. The present study is an attempt to evaluate basic change in interest and subject preference as a pre-determined objective of a specific curriculum without reference to any other curriculum.

Summary of categories. In the review of pertinent literature, a broad spectrum of related studies has been cited. Basic conclusions have been presented from studies in five related categories.

Studies related to objective achievement in biology curricula reported evidence for method effect and a variety of factors significant in objective achievement. BSCS evaluation projects provided evidence to support the feasibility, appropriateness, and effects of a variety of BSCS Versions. Sex differences in performance and the specific relationship of BSCS tests to BSCS programs were established. The three basic BSCS Versions were found to develop no greater achievement in basic knowledge or change in attitude or interest than "traditional" programs, except on BSCS oriented testing materials. A definite relationship was established between reading and success on BSCS testing materials.

Studies emphasizing a single objective of biology instruction were presented in three categories, achievement, critical thinking, and interest. Achievement studies reported no difference in basic effects of comparative methods on achievement. All methods produced measurable gains in knowledge. Mental ability and sex were established as factors in level of achievement. Test materials designed for specific programs, as previously reported, produced significant results for the program for which they were designed while other tests did not.

Critical thinking studies consistently reported gains in critical thinking regardless of method. But degree of change did appear to be affected by teaching methodology, BSCS Version, laboratory-centered approach, and critical thinking approach to the teaching of biology. All of the studies produced evidence to support the contention that critical thinking can be taught.

Interest studies reported evidence, although not unanimous, of the positive relationship between achievement, interest, and subject preference. Evidence was reported that sex is a factor in the degree of science interest developed. Early development and stability of science interest, as reported, support the evidence of no significant change in interest in comparative method studies.

CHAPTER III

IMPLEMENTATION OF THE STUDY

The organizational plan of the study is presented in this chapter. The background, design, populations, samples, and evaluation instruments are described. The chapter concludes with a summary of research hypotheses with related null hypotheses and a description of models used in analyses of the data.

Background and general features of the study. The study was conducted with students in the Cherry Hill High Schools during the academic year 1968-69 by the investigator. There were two high schools in the system and the investigator was the Biology Department Chairman of one of the high schools. As early as 1967, the basic need for the study was recognized and tentative plans for conducting the study were formulated by the investigator.

In the Cherry Hill High Schools, from 1957 to 1968, the investigator noted that several curricular changes and revisions had taken place in the first year biology program. However, it was apparent that the curriculum studies and revision had been done on an informal basis with little statistical evaluation. While the combined biology staffs of

the two high schools had developed general objectives for the first year biology courses, the question of future revision of the curriculum had not considered whether these objectives were being achieved by the program which was in effect in 1967. It was thought that the achievement of the general objectives of the present courses should be determined before considering any curriculum revisions. Consequently, a proposal for evaluation of objective achievement by students in the existing first year biology courses was formulated with tentative approval by Cherry Hill school administrators in October 1967. On January 18, 1968 the Coordinating Committee for the two high schools studied the problem in conjunction with the ingestigator and gave approval for a recommendation concerning procedure to the principals of both high schools. On January 30, 1968 administrative approval was given. After approval, the first procedure was the selection of control groups. At this point, the problem of staffing in the changing of over 100 student schedules had to be considered. Fewer science students and increased numbers of history students had an impact on class sizes in history and biology. Plans for guidance involvement were formulated for the setting up of lists for student selection by ability group and for adjustment of control group student schedules. On January 31, 1968, form letters were printed with permission slips for those students randomly selected for the control groups.[1]

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[1]Copy of form letter and permission slip found in Appendix F.

These permission slips gave the school authority to manipulate schedules for those students taking no science course for one year. On February 9, 1968, a meeting was held in each high school of the 150 randomly selected A, B, and C control group students to explain the permission slips and the student's responsibilities in the study.

A delay in the progress of the study developed on February 15, 1968, when the Assistant Superintendent informed the investigator of the need for Board of Education approval. After consultation and communication with board members, central administration approval was given on April 4, 1968.

With this approval, final volunteer figures were established for the sizes of the A, B, and C control groups, and experimental A, B, and C groups equal in size with the control groups were randomly selected from all tenth grade students scheduled for A, B, and C biology courses for 1968-69. At this point in the organization of the study, there were 206 students in the study. As a result of scheduling error for one student, 104 students ended up in the experimental groups and 102 students ended up in the three control groups.

Following selection of the groups the students were pretested. The students met one day before the testing program to encourage attendance and reduce fears. To reduce bias, the investigator did not take part in all meetings to follow involving testing. On June 4-5, 1968, a two day testing program using seven evaluation instruments[2] was given in both high schools.

The treatments started with the opening of school in September 1968. There were 206 students in the study at the beginning of the year. The A study group consisted of 52 students with 27 in the experimental group exposed to the Blue Version BSCS Biology course and 25 in the control group taking no science course. The B study group consisted of 80 students with 40 in the experimental group exposed to the Yellow Version BSCS Biology course and 40 in the control group taking no science course. The C study group consisted of 74 students with 37 in the experimental group exposed to a general survey Biology course and 37 in the control group taking no science course. In place of the science course the control students substituted a history course or a study period.

On April 15-16, 1969 a posttesting program using the same seven evaluation instruments concluded the experiment. Due to a mortality of twenty-nine students, the posttested group included 177 students. In the summer of 1969 computer analysis of the data collected from the testing program was performed with the assistance of the Michigan State University Computer Laboratory.

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[2]These evaluation instruments are described in detail on pages 76-89.

General design of the study. This study was developed using a nonequivalent control group design.[3] This particular design was chosen because a volunteer sample had to be used for the A, B, and C control groups. The study was designed to evaluate objective achievement, gains from pretest to posttest, and the relationship of sex to objective achievement for each ability group exposed to its respective biology course. No attempt was made to compare ability groups. The design as implemented is diagrammed[4] below:

$$A \quad \begin{array}{ccc} O_1 & X_a & O_2 \\ \hline O_1 & & O_2 \end{array}$$

$$B \quad \begin{array}{ccc} O_1 & X_b & O_2 \\ \hline O_1 & & O_2 \end{array}$$

$$C \quad \begin{array}{ccc} O_1 & X_c & O_2 \\ \hline O_1 & & O_2 \end{array}$$

Where:

A, B, C is ability group

X_a is treatment
Blue Version Course

X_b is treatment
Yellow Version Course

X_c is treatment
general survey course

O_1 is pretest
seven instruments

O_2 is posttest
seven instruments

Community and schools. The community under study was Cherry Hill, New Jersey. Cherry Hill is a predominantly residential suburban community of approximately 25 square

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[3]Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally and Company, 1963), p. 47.

[4]Modified from Campbell and Stanley.

miles in the greater Philadelphia urban complex. In 1968 its population exceeded 50,000.[5] It is one of the fastest growing communities in the state of New Jersey. The residents had a median age of 29.5 years, with above average educational level and above average income.[6] More than 16,000 children were enrolled in the Cherry Hill Public Schools in 1968-69.[7] The Cherry Hill schools are organized on the 6-2-4 plan. There were two high schools, two junior schools, and fourteen elementary schools.

Cherry Hill High School West, established in 1956, had approximately 2,700 students in grades 9-12 in 1968-69 with an average class size of 27 and a drop-out rate below 2 percent.[8] Cherry Hill High School East, established in 1966, had an enrollment of approximately 1,700 in grades 9-11 in 1968-69 with an average class size of 27.[9] In the academic areas of both schools, students were grouped into honors, A, B, and C levels of study. Follow-up studies of the graduating class of 1967 at Cherry Hill High School West revealed 74 per cent continuing education and 62 percent attending four year colleges. This class had median

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[5]Cherry Hill School System, "Cherry Hill High Schools East and West." (brochure)

[6]League of Women Voters of Camden County, Cherry Hill (Cherry Hill: League of Women Voters of Camden County, 1965), p. 5.

[7]Cherry Hill School System, loc. cit.

[8]Ibid.

[9]Ibid.

Scholastic Aptitude Test scores of 469.3 verbal and 490.4 mathematics. The class produced nine National Merit Scholarship finalists.[10]

Populations, samples, and mortality. The three populations under study were a part of the sophomore class in both Cherry Hill High Schools in 1968-69. The total number of sophomores was 1027 with 520 in Cherry Hill High School East and 557 in Cherry Hill High School West. Of this total, 283 were designated for Biology IA, 664 for Biology IB, and 201 for Biology IC.

From these three populations, three experimental and three control groups were selected and independently evaluated. The sample selection was attempted using a random number table, but, since parental and student approval and schedule adjustments were necessary, the control group samples became volunteer samples. Initially fifty A students, fifty B students and fifty C students were randomly selected for the control groups. These students were selected from lists of students designated to be scheduled as A, B, and C level biology students by the guidance departments of both high schools. Of these students, 26 A students, 40 B students and 37 C students agreed to take part in the study. The schedules of these subjects were adjusted with a substitute of history or a study period in place of the science

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[10] Ibid.

course. From the remaining students in the A, B, and C populations, three groups of students, equal in size to the control groups, who had been scheduled for the A, B, and C biology courses were randomly selected. In the process of scheduling, one of the 26 A students in the control group was mistakenly scheduled for biology and thus changed the balance to 27 experimental and 25 control students in the A samples. The A sample comprised 18.38 percent of the A population. The B sample comprised 12.06 percent of the B population. The C sample comprised 36.81 percent of the C population.

The characteristics of school, sex, average age, average IQ, age range, IQ range, by treatment group for the 177 subjects remaining at the conclusion of the study are summarized in Appendix E.

There was a net loss of 29 subjects from the three study groups from June 1968 to April 1969. There was a mortality of four or 7.69 percent for the A groups, ten or 12.50 percent for the B groups, and 15 or 20.27 percent for the C groups. Table 1 provides a listing of reasons for and percentages of mortality for all ability groups. The high mobility of the residents of the community is evident from the 8 percent mortality due to moving to other states and communities.

Table 1. Reasons for and percentages of mortality for all ability groups.

Reason	Number of Loss	Percentage of Loss
Moved		
out of state	10	.05
within state	6	.025
between schools	1	.005
vocational school	2	.01
Illness	2	.01
Work	2	.01
Repeat of 9th grade	1	.005
Absent during testing	3	.015
Army	1	.005
Age (drop-out)	1	.005
Total	29	.141

Ability grouping and treatment. Three separate treatments were used in the study. Three biology courses were evaluated in terms of objective achievement, sex relationship to objective achievement, and gains from pretest to posttest. The three treatments were not being compared since each was being evaluated in terms of a different ability group.

The three ability groups under study were referred to previously as A, B, and C. The Biology A group was exposed to the BSCS Blue Version course as a treatment. The Biology B group was exposed to the BSCS Yellow Version course as a treatment. The Biology C group was exposed to a locally developed general survey Biology course as a treatment.

The basis of ability grouping in the biology courses in the Cherry Hill High Schools was a combination of past performance, IQ, Differential Aptitude scores, reading scores, and teacher recommendations from past science courses. These criteria were used as the basis of recommendations for ability group placement. However, parental and student desires were the final deciding factors and could overrule the other factors in a public school. Students could move between groups during the early part of the academic year if they found a given course unsuitable.

In all three courses, the emphasis in method was on inquiry or discovery teaching. The processes of science received as much attention as the content of science. Variety in activities and materials was fostered. A behavioral objective orientation for all courses was in the developmental stages. The staffs of both high schools were organized into A, B, and C teams. Each team had a leader who guided scheduled team planning meetings. Most teaching was done in average size classes of about 25 students, but some large group instruction was provided through team teaching. Group work and individual project activities were also provided.

The text used in the Biology A treatment was Biological Science Molecules to Man.[11] The course was taught in six periods per week with a double laboratory period of 88 minutes and four single periods of 44 minutes each. The basic content organization and method was that recommended by BSCS with some variations in emphasis and with the addition of supplemental materials.

The text used in the Biology B treatment was Biological Science An Inquiry into Life.[12] The course was also taught in six periods per week with a double laboratory period of 88 minutes and four single periods of 44 minutes each. The basic content organization and method was that recommended by BSCS with some variation in emphasis and extensive reorganization and extensive addition of supplemental materials.

The text used in the Biology C treatment was Living Things.[13] It was taught in five 44 minute periods per week. One period was for laboratory work and four for recitation. The content and organization emphasized understanding and application of basic biological principles with a practical orientation. The course was student activity centered.

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[11]Biological Sciences Curriculum Study, Biological Science Molecules to Man (New York: Houghton Mifflin Company, 1963).

[12]Biological Sciences Curriculum Study, Biological Science An Inquiry into Life (New York: Harcourt, Brace and World, Inc., 1963).

[13]Frederick L. Fitzpatrick and Thomas D. Bain, Living Things (New York: Holt, Rinehart and Winston, Inc., 1958).

A general rationale and course outline for each of the three treatment courses as used in the Cherry Hill High Schools are found in Appendix B. Sample unit plans from each course are found in Appendix C.

Teachers. Fifteen teachers were involved in teaching the three biology courses -- eight in Cherry Hill High School East and seven in Cherry Hill High School West. Seven teachers were involved in teaching Biology A. Eight were involved in teaching Biology B and three were involved in teaching Biology C. Three teachers taught both the A and B courses. All of the other teachers taught only one course. As a result of one teacher changing positions in January, a new teacher was hired and a shift in schedules was required for three A teachers. A summary of the characteristics of marital status, sex, age, course work, degrees earned, and experience for the fifteen teachers by ability group is found in Appendix D.

Facilities. The facilities and instructional supplies were above average in both high schools. Three laboratories exist in each high school, thus students received some class instruction in regular classrooms. Individual students were provided with microscopes, dissection sets, and other appropriate equipment.

Evaluation instruments. Seven evaluation instruments were used for measurements indicative of achievement of the general objectives[14] under study. The general objectives evaluated in the study and the evaluation instruments used to measure their achievement are listed below.

General objectives:

1. To build the student's scientific literacy for future responsible citizenship.

   Tests used: Nelson Biology Test[15]

   Comprehensive Final Examination

   Test on Understanding Science--total and subtests

2. To develop student understanding of and ability to use the processes of science.

   Tests used: Processes of Science Test

   Watson-Glaser Critical Thinking Appraisal--total and subtests

4. To develop student interest in science in general and biology in particular.

   Tests used: Kuder Preference Record Vocational Outdoor and Scientific subtests

   A Scale to Measure Attitude Toward Any School Subject

The evaluation instruments used were selected on the basis of content validity, reliability, objectivity of scoring, cost, and time for implementation. A summary of pertinent data for each of the instruments follows in the order of consideration for the hypotheses tested.

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[14]Copy of all General Objectives is found in Appendix A.

[15]Specific test forms are footnoted for each instrument in the following paragraphs.

The Nelson Biology Test Revised Edition Form E[16] was selected as indicative of achievement of the first objective, scientific literacy, and in particular part 1a of this objective which is concerned specifically with the development of knowledge, comprehension and ability to apply basic biological principles.

The content validity was acceptable because the knowledge and question form compared favorably, in the opinion of the investigator, with the courses of study and the methods of the biology courses in the Cherry Hill High Schools. The relationship of the test content to the objective, scientific literacy, being evaluated in this study was shown by the following statement from the test manual.

> Three major cognitive categories--knowledge, comprehension, and application--were considered by the author to be broad enough in scope to encompass the important measurable objectives commonly found in high school biology. . . .[17]

The reliabilities published for this test were determined with the Spearman Brown split-half method. The values for a norm group consisting of students enrolled in high school biology courses were calculated for a conventional, BSCS, and total biology group. The values for Form E were .91, .92,

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[16]Clarence H. Nelson, Nelson Biology Test Revised Edition Form E (New York: Harcourt, Brace and World, Inc., 1965).

[17]Walter N. Durost (ed.), Nelson Biology Test Revised Edition Manual (New York: Harcourt, Brace and World, Inc., 1965), p. 3.

and .92 respectively.[18] In this study, the reliabilities were calculated by the investigator using a test-retest coefficient of stability method,[19] based on the Pearson product-moment correlation coefficient. The Bastat Routine[20] was used to perform this computer analysis. The coefficients for the A, B, C and total for all ability groups were .53, .52, .22, and .69 respectively.[21] These lower values could be expected since there were probably smaller ranges of talent in the ability groups under study than in the general biology groups used for the test norms. Seashore indicates that such a condition could result in lower values.[22] According to Cronbach lower values could also result from a difference in method used to calculate the coefficients, one being based on a single sitting and the other with a lengthy period of time between two sittings.[23]

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

[19]Lee J. Cronbach, *Essentials of Psychological Testing* (New York: Harper and Row, 1960), p. 139.

[20]Agricultural Experiment Station, *Calculation of Basic Statistics on the Bastat Routine* (East Lansing: Michigan State University, 1968).

[21]A summary of reliability coefficients is found in Appendix I for all ability groups on all total and part scores for all instruments used in this study.

[22]Harold G. Seashore (ed.), "Reliability and Confidence," *Test Service Bulletin* 44 (May 1952), 3.

[23]Cronbach, *op. cit*., p. 139.

The scoring for this test is objective with no scorer judgment required. The maximum time for administering the test was forty minutes.

The Comprehensive Final Examination Revised Form J[24] prepared for the Biological Sciences Curriculum Study was also selected as indicative of achievement of the first objective, scientific literacy, and in particular part 1a of this objective, which is concerned specifically with the development of knowledge, comprehension and ability to apply basic biological principles. This second test for objective one was chosen to provide for evaluation of the objective in terms of the concepts accepted by the developers of the BSCS programs being used in the A and B Biology courses of the Cherry Hill High Schools. The test was also used for the C Biology course since the same basic objective applied to this course.

The test was assumed to have high curricular validity since the test was constructed by individuals associated with BSCS. The reliabilities published for the test were determined in two ways. The value for a random sample of 40 tenth graders calculated using the Kuder-Richardson Formula 20 was .82 for form J. The median value for the sample of tenth graders studied using the alternate form

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[24]Biological Sciences Curriculum Study, Comprehensive Final Examination Revised Form J (New York: The Psychological Corporation, 1965).

method was .79.[25] In this study, the reliabilities were calculated using the test-retest coefficient of stability method as described previously. The coefficients for the A, B, C, and total of all ability groups were .52, .27, .22, and .55 respectively. The lower values could have resulted for the same reasons cited for the Nelson Biology Test.

The scoring for this test is objective with no scorer judgment required. The maximum time for administering the test was forty-five minutes.

The Test on Understanding Science Form W[26] (TOUS) was likewise selected as indicative of achievement of the first objective, scientific literacy, and in particular parts 1b and 1c, which are specifically concerned with the understanding of the biological basis of problems and understanding and appreciation of scientists and their work. This test provides three subscores which are understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science, as well as a total score for understanding of science.

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[25]Biological Sciences Curriculum Study, Manual for the Comprehensive Final Examination in First-Year Biology (New York: The Psychological Corporation, 1966), pp. 7-8.

[26]W. W. Cooley and L. E. Klopfer, TOUS Test On Understanding Science Form W (Princeton: Educational Testing Service, 1961).

Curricular validity was assumed for the test. The reliabilities published for the total and subtests were determined using the Kuder Richardson Formula 20 for 2535 students from 9-12th grade. The values for the understandings about the scientific enterprise, understandings about scientists, understandings about the methods and aims of science, and total understanding of science were .58, .52, .58, and .76 respectively.[27] In this study, the reliabilities were calculated using a test-retest coefficient of stability. The coefficients for the A, B, C, and total of all ability groups for understandings of scientific enterprise were .45, .55, .30, and .61 respectively. The coefficients for understandings about scientists were .51, .49, .39, and .61 respectively. The coefficients for understandings about the methods and aims of science were .34, .29, .14, and .45 respectively. The coefficients for total understanding of science were .51, .64, .48, and .73 respectively.

The scoring for this test is objective with no scorer judgment required. The maximum time for administering the test was forty minutes.

The Processes of Science Test Form A[28] (POST) was

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[27]W. W. Cooley and L. E. Klopfer, TOUS Test on Understanding Science Form W Manual for Administering, Scoring, and Interpreting Scores (Princeton: Educational Testing Service, 1961), p. 10.

[28]Biological Sciences Curriculum Study, Processes of Science Test Form A (New York: The Psychological Corporation, 1962).

selected as indicative of achievement of the second general objective, understanding of and ability to use the processes of science, and in particular parts 2a and 2b, which are concerned specifically with the development of the basic skills necessary in the study of science in general and biology in particular and critical thinking or problem solving.

The content validity was favorable because the test was consistent in skills and form with the biology courses and objectives under study. The consistency with the objective under study can be identified in the following statement from the test manual:

> . . . Although the scientific principles are framed in a setting of biological science, knowledge of biology is not a prerequisite for scoring high on the test. By avoiding reliance on specific facts of biology, and on terms which could be known only after studying a particular biological science curriculum, POST puts a premium on a grasp of the essentials of a scientific method and attitude.[29]

The reliabilities published for this test were determined in two ways. The value for the internal consistency measurement using a split-half correlation coefficient based on the Spearman-Brown formula calculated on a sample of 300 high school biology students was .82. The values for the test-retest method, based on 12,602 students taking BSCS courses and 5363 students taking conventional courses, were both

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[29]Biological Sciences Curriculum Study, Manual Processes of Science Test (New York: The Psychological Corporation, 1965), p. 3.

.72.[30] In this study, the reliabilities were calculated using a test-retest coefficient of stability method. The values for the A, B, C, and total of all ability groups were .71, .48, .60, and .78 respectively.

The scoring for the test is objective with no scorer judgment required. The maximum time for administering the test was thirty-five minutes.

The Watson-Glaser Critical Thinking Appraisal Form YM[31] was also selected as indicative of achievement of general objective two, understanding of and ability to use the processes of science, and in particular parts 2a and 2b, which are specifically concerned with the development of basic skills necessary in the study of science in general and biology in particular and critical thinking or problem solving.

The content validity was favorable since the test is consistent in skills desired with the objective and biology courses under study. The subtests of inference, assumption, deduction, interpretation, and evaluation of argument are found expressed in some form as desired skills in the elaboration of general objective two of the Cherry Hill program. The basis of the content of this test is found stated in the manual as follows:

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[30] Ibid., pp. 7-8.

[31] Goodwin Watson and Edward M. Glaser, Watson-Glaser Critical Thinking Appraisal Form YM (New York: Harcourt, Brace and World, Inc., 1964).

One such list proposed by the Cooperative Study of Evaluation in General Education (10) sets forth the following abilities that appear to be related to the concept of critical thinking:

A Brief List of Critical Thinking 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 inferences.

Judgments of qualified persons and results of research studies (26, 31) support the authors' belief that the items in the Critical Thinking Appraisal represent an adequate sample of the above five abilities and that the total score yielded by the test represents a valid estimate of the proficiency of individuals with respect to these aspects of critical thinking.[32]

A comparison of these five abilities with general objective two shows a direct relationship of goals for the test and the biology courses. While this test uses limited scientific information, it was considered appropriate in this study since the intent of the objective was to develop thinking skills and transfer them to any problem solving situations.

The reliabilities published for the total and subtests were determined by the split-half method using the Spearman-Brown formula. The value for a normative sample of 2947 tenth graders on Form YM was .86. The values for the subtests of inference, assumption, deduction, interpretation,

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[32]Goodwin Watson and Edward M. Glaser, Manual for Forms YM and ZM Watson-Glaser Critical Thinking Appraisal (New York: Harcourt, Brace and World, Inc., 1964), p. 10.

and argument were .61, .74, .53, .67, and .62 respectively for the same sample of tenth graders.[33] In this study, the reliabilities were calculated using a test-retest coefficient of stability method. The values for the total critical thinking scores for the A, B, C, and total of all ability groups were .67, .46, .55, and .70 respectively. For the subtests of inference, assumption, deduction, interpretation, and argument the coefficients values for the A, B, C, and total of all ability groups are summarized in Table 2.

Table 2. Test-retest reliability coefficients for A, B, C, and total of all ability groups for the subtests of the W-G Critical Thinking Appraisal.

Subtest	Ability Group A	B	C	Total
Inference	.62	.17	.50	.53
Assumption	.14	.41	.36	.30
Deduction	.58	.28	.25	.46
Interpretation	.48	.36	.32	.52
Argument	.38	.25	.11	.35

The scoring for this test is objective with no scorer judgment required. A time sequence of thirteen minutes for inference, six minutes for assumption, eleven minutes for deduction, twelve minutes for interpretation, and eight

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[33] Ibid., pp. 13-14.

minutes for argument was recommended. However, since this was a power test, additional time may be permitted for completion of the test.

The Outdoor and Scientific subtests of the Kuder Preference Record Vocational Form CH[34] were selected as indicative of achievement of general objective four, interest in science in general and biology in particular, and in particular parts 4a and 4b, which are concerned specifically with the development of awareness of and interest in biological careers and development of interest in biologically oriented leisure time activities.

The subtests are defined as follows in the manual:

> Outdoor: Indicates a preference for work that keeps one outside most of the time, usually dealing with animals and growing things.
>
> Scientific: Indicates a preference for discovering new facts and solving problems.[35]

These definitions, support the assumption of content validity whereby their existed a direct relationship between the objective under study and the course intent and the contents of the tests. The reliabilities for the subtests of Outdoor and Scientific were calculated using the Kuder Richardson formula for internal consistency and a coefficient of

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[34]G. Frederic Kuder, Kuder Preference Record Vocational Form CH (Chicago: Science Research Associates, Inc., 1948).

[35]G. Frederic Kuder, Vocational Form C Administrator's Manual Kuder Preference Record (Chicago: Science Research Associates, Inc., 1960), p. 2.

stability method. The values for males and females on the Outdoor and Scientific subtests for internal consistency were .90, .89, .89, and .90 respectively. The coefficients of stability for ninth and tenth grade male and female students for the Outdoor and Scientific subtests were .78, .69, .77, and .72 respectively.[36] In this study, the reliabilities were calculated using a test-retest coefficient of stability method. The values for the Outdoor and Scientific subtests for the A, B, C, and total of all ability groups were .81, .66, .69, and .76 respectively for the Outdoor subtest and .83, .72, .73, and .76 respectively for the Scientific subtest.

The scoring for the test was objective with no scorer judgment required. There was no time requirement. Subjects were to be given sufficient time to complete the inventory.

A Scale to Measure Attitude Toward Any School Subject[37] was also used as indicative of achievement of the fourth general objective, interest in science in general and biology in particular, and in particular part 4c, which is specifically concerned with enjoyment of learning in the biology classroom.

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[36]Xerox copy of pages from Technical Manual out of print provided by Kuder Editor, Marilyn Grinager.

[37]H. H. Remmers, A Scale To Measure Attitude Toward Any School Subject (Lafayette: Purdue University Book Store, 1960).

The content validity, in the opinion of the investigator, was favorable due to consistency in purpose and question type with the objective under consideration. Reliabilities were not provided for the given scale used in terms of the selected subject area of biology. Reliability coefficients for full-length scales of forty items for various population samples ranged from .71 to .92.[38] Hancock's study supports the contention that the scale reduction to seventeen items does not appreciably lower the reliabilities of the instrument.[39] Remmers stated the following about the reliabilities of this instrument, "For Group studies--the usual use of these scales--the reliabilities of means will generally be quite adequate."[40] In this study, the reliabilities were calculated using the test-retest coefficient of stability method. The coefficients for the A, B, C, and total of all ability groups were .41, .56, .37, and .44 respectively.

The scoring for this test was objective with no scorer judgment required. There was no set time required to administer this test.

Testing procedure. The testing program was composed of a pretest program on June 4-5, 1968 and a posttest program on April 15-16, 1969. The instruments were given in a prescribed order with four tests given one day and three the

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[38]H. H. Remmers, Manual for the Purdue Master Attitude Scales (Lafayette: Purdue University Book Store, 1960), p. 6.

[39]Ibid.

[40]Ibid.

other. All of the students in a given school were given the tests in the same room. The testing program was run at approximately the same time in both high schools. The tests were administered by guidance personnel with the assistance of volunteer teachers. Make-up tests were given for those students absent within the week. Students who did not complete the testing during this period were not included in the final analysis.

Tests were hand scored by the investigator. A randomly selected sample of ten percent of the papers for each ability group for each instrument were rescored. Scoring errors were zero in all but one case, the Kuder Preference Record. This set of tests was completely rescored. The scores from all tests for all subjects were recorded on a specially constructed form,[41] and later punched on IBM cards for future computer analysis.

Hypotheses and models used to test the hypotheses. For the purpose of analyzing the data collected, the following research hypotheses and related null hypotheses were used. The hypotheses are organized into four groups: those testing objective achievement, those testing sex relationship to objective achievement, those testing pretest to posttest gains for experimental biology groups, and those testing pretest to posttest gains for control non-science groups.

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[41]Copy of data form found in Appendix G.

The Blue Version BSCS Biology course, Yellow Version BSCS Biology course, and the general survey Biology course are referred to as Blue, Yellow, and general respectively for the A, B, and C ability groups in the hypotheses.

<u>Hypotheses related to objective achievement</u>.

Research hypothesis one:

1. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue Yellow, general) as a part of their regular school program achieve greater scientific literacy than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

$H_1 : SL_e > SL_c$

Null hypotheses:

There is no difference in mean achievement of scientific literacy as measured by the

1a Nelson Biology Test Revised Edition Form E
1b Comprehensive Final Examination Revised Form J
1c Test on Understanding Science Form W
1d Understandings about the scientific enterprise subtest
1e Understandings about scientists subtest
1f Understandings about the methods and aims of science subtest

between ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program and ability grouped (A, B, C) tenth grade students exposed to no science course for the same period of time.

Null hypotheses la-lf were tested separately for each of the evaluation instruments. The formulae for hull hypotheses la-lf were:

$H_{0_{1a}}$: ${}^{n}SL_{e} = {}^{n}SL_{c}$

$H_{0_{1b}}$: $cf_{SL_e} = cf_{SL_c}$

$H_{0_{1c}}$: $tous_{SL_e} = tous_{SL_c}$

$H_{0_{1d}}$: ${}^{e}SL_{e} = {}^{e}SL_{c}$

$H_{0_{1e}}$: ${}^{s}SL_{e} = {}^{s}SL_{c}$

$H_{0_{1f}}$: ${}^{ma}SL_{e} = {}^{ma}SL_{c}$

Research hypothesis two:

2. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater understanding of and ability to use the processes of science than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

   H_2 : $P_e > P_c$

   Null hypotheses:

   There is no difference in mean achievement of understanding of and ability to use the processes of science as measured by the

   2a Processes of Science Test Form A
   2b Watson-Glaser Critical Thinking Appraisal Form YM
   2c Inference subtest
   2d Assumption subtest
   2e Deduction subtest
   2f Interpretation subtest
   2g Argument subtest

   between ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program and ability grouped (A, B, C) tenth grade students exposed to no science course for the same period of time.

Null hypotheses 2a-2g were tested separately for each of the evaluation instruments. The formulae for null hypotheses 2a-2g were:

$H_{0_{2a}}$: $post_{P_e} = post_{P_c}$

$H_{0_{2b}}$: $ct_{P_e} = ct_{P_c}$

$H_{0_{2c}}$: $i_{P_e} = i_{P_c}$

$H_{0_{2d}}$: $a_{P_e} = a_{P_c}$

$H_{0_{2e}}$: $d_{P_e} = d_{P_c}$

$H_{0_{2f}}$: $in_{P_e} = in_{P_c}$

$H_{0_{2g}}$: $ar_{P_e} = ar_{P_c}$

Research hypothesis three:

3. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue Yellow, general) as a part of their regular school program achieve greater interest in science in general and biology in particular than tenth grade ability grouped (A, B, C) students exposed to no science course for the same period of time.

H_3 : $I_e > I_c$

Null Hypotheses:

There is no difference in mean achievement of interest in science in general and biology in particular as measured by the

3a Kuder Preference Record Vocational Form CH--Outdoor subtest
3b Kuder Preference Record Vocational Form CH--Scientific subtest
3c A Scale to Measure Attitude Toward Any School Subject

between ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program and ability grouped (A, B, C) tenth grade students exposed to no science course for the same period of time.

Null hypotheses 3a-3c were tested separately for each of the evaluation instruments. The formulae for null hypotheses 3a-3c were:

$$H_{O_{3a}} : o_{I_e} = o_{I_c}$$

$$H_{O_{3b}} : s_{I_e} = s_{I_c}$$

$$H_{O_{3c}} : at_{I_e} = at_{I_c}$$

The model used to evaluate the hypotheses for objective achievement for the A, B, and C ability groups was a co-variant t test. Research hypotheses one, two and three were evaluated using pretest as covariant. Since each of the sixteen null hypotheses for research hypotheses one, two, and three were evaluated for each ability group, a total of 48 null hypotheses were tested. The formula used for the t test was developed with the assistance of Dr. Maryellen McSweeney of Michigan State University. The basic formula was as follows:

$$t_{df} = \frac{\overline{Y}_1' - \overline{Y}_2'}{\sqrt{MS_w'}\sqrt{\frac{1}{N_1} + \frac{1}{N_2} + \frac{(\overline{X}_{1.} - \overline{X}_{2.})^2}{\sum_j \sum_i (X_{ij} - \overline{X}_{.j})^2}}}$$

$\overline{Y}_1'$ is posttest adjusted mean for experimental group.

$\overline{Y}_2'$ is posttest adjusted mean for control group.

MS_w' is within group adjusted mean square.

$\overline{X}_1.$ is pretest mean for experimental group.

$\overline{X}_2.$ is pretest mean for control group.

N_1 is number of subjects in control group.

N_2 is number of subjects in experimental group.

X_{ij} is individual pretest score.

$\overline{X}_j$ is group pretest mean.

df is degrees of freedom (N - 3).

This formula was a basic t formula for two samples adapted using adjusted means and mean square with a correction factor for the error term based on Guenther's estimated error variance for contrasts.[42] The correction factor was necessary because the experimental and control group adjusted means and mean square were calculated using the same method of adjustment thus correlating the groups and affecting the error term. The adjusted means and mean square were calculated using the LS Routine computer program.[43] The t test calculations were completed manually by the investigator as no computer program was available for the constructed formula.

The t test model was chosen for this study to permit the use of directional hypotheses. The covariant t test was used because the design did not provide for random assignment

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[42]William C. Guenther, Analysis of Variance (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964), p. 150.

[43]Agricultural Experiment Station, Analysis of Covariance and Analysis of Variance with Unequal Frequencies Permitted in the Cells--(LS Routine) (East Lansing: Michigan State University, 1967).

to experimental and control groups. The covariant of pre-test was used to control for initial differences between the experimental and control groups. The accepted alpha level for all hypotheses tested using the covariant t test model was .05.

The assumptions of normality and homogeneity of variance were tested using a two-tailed Kolmogorov-Smirnov[44] one-sample test of normality on all significant results, and the Snedecor[45] variance ratio test for equality of variance. The Kolmogorov-Smirnov test was chosen because of the small size of the samples. The Snedecor test was chosen because it was for a two sample comparison. All calculations for both tests were done manually by the investigator using data from the Bastat Routine[46] computer program. The results for the Kolmogorov-Smirnov test are found in Appendix J. The results for the Snedecor test are found in Appendix K.

Hypotheses related to sex and objective achievement.

Research hypothesis four:

4. There is a difference in achievement of scientific literacy between male tenth grade ability grouped (A, B, C) students exposed to a first

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[44]Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, Inc., 1956), pp. 47-52.

[45]Quinn McNemar, Third Edition Psychological Statistics (New York: John Wiley and Sons, Inc., 1963), pp. 246-249.

[46]Agricultural Experiment Station, Calculation of Basic Statistics on the Bastat Routine, loc. cit.

year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

$H_4 \; : \; SL_m \neq SL_f$

Null hypotheses:

There is no difference in mean achievement of scientific literacy as measured by the

- 4a Nelson Biology Test Revised Edition Form E
- 4b Comprehensive Final Examination Revised Form J
- 4c Test on Understanding Science Form W
- 4d Understandings about the scientific enterprise subtest
- 4e Understandings about scientists subtest
- 4f Understandings about the methods and aims of science subtest

between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

Null hypotheses 4a-4f were tested separately for each of the evaluation instruments. The formulae for null hypotheses 4a-4f were:

$$H_{O_{4a}} \; : \; n_{SL_m} = n_{SL_f}$$

$$H_{O_{4b}} \; : \; cf_{SL_m} = cf_{SL_f}$$

$$H_{O_{4c}} \; : \; tous_{SL_m} = tous_{SL_f}$$

$$H_{O_{4d}} \; : \; e_{SL_m} = e_{SL_f}$$

$H_{O_{4e}} : s_{SL_m} = s_{SL_f}$

$H_{O_{4f}} : ma_{SL_m} = ma_{SL_f}$

Research hypothesis five:

5. There is a difference in achievement of understanding of and ability to use the processes of science between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

   $H_5 : P_m \neq P_f$

   Null hypotheses:

   There is no difference in mean achievement of understanding of and ability to use the processes of science as measured by the

   5a Processes of Science Test Form A
   5b Watson-Glaser Critical Thinking Appraisal Form YM
   5c Inference subtest
   5d Assumption subtest
   5e Deduction subtest
   5f Interpretation subtest
   5g Argument subtest

   between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue Yellow, general) as a part of their regular school program or no science course for the same period of time.

   Null hypotheses 5a-5g were tested separately for each of the evaluation instruments. The formulae for null hypotheses 5a-5g were:

$H_{0_{5a}}$: $post_{P_m} = post_{P_f}$

$H_{0_{5b}}$: $ct_{P_m} = ct_{P_f}$

$H_{0_{5c}}$: $i_{P_m} = i_{P_f}$

$H_{0_{5d}}$: $a_{P_m} = a_{P_f}$

$H_{0_{5e}}$: $d_{P_m} = d_{P_f}$

$H_{0_{5f}}$: $in_{P_m} = in_{P_f}$

$H_{0_{5g}}$: $ar_{P_m} = ar_{P_f}$

Research hypothesis six:

6. There is a difference in achievement of interest in science in general and biology in particular between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

H_6 : $I_m \neq I_f$

Null hypotheses:

There is no difference in mean achievement of interest in science in general and biology in particular as measured by the

6a Kuder Preference Record Vocational Form CH--Outdoor subtest
6b Kuder Preference Record Vocational Form CH--Scientific subtest
6c A Scale to Measure Attitude Toward Any School Subject

between male tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time and female tenth grade ability grouped (A, B, C) students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program or no science course for the same period of time.

Null hypotheses 6a-6c were tested separately for each of the evaluation instruments. The formulae for null hypotheses 6a-6c were:

$$H_{0_{6a}} : o_{I_m} = o_{I_f}$$

$$H_{0_{6b}} : s_{I_m} = s_{I_f}$$

$$H_{0_{6c}} : at_{I_m} = at_{I_f}$$

The model used to evaluate the sixteen null hypotheses for research hypotheses four, five, and six concerned with sex and objective achievement for the A, B, and C ability groups was a two-way analysis of variance for unequal groups. The calculations were performed using the LS Routine computer program.[47]

The assumptions of normality and equality of variances were not tested because of the small size of the groups and the large inequality in numbers in each group and in certain subgroups. This should be considered in evaluation of these data. The alpha level was set at the .05 level for all hypotheses tested with the two-way analysis of variance model. In cases of significant results, the sex determined

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[47]Agricultural Experimental Station, Analysis of Covariance and Analysis of Variance with Unequal Frequencies Permitted in the Cells--(LS Routine), loc. cit.

to achieve the greater gains was determined by inspection of means.

Hypotheses related to pretest to posttest gains for the experimental group.

Research hypothesis seven:

7. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater scientific literacy on posttest evaluation than on pretest evaluation using the same evaluation instrument.

$H_7 \; : \; SL_{post-e} > SL_{pre-e}$

Null Hypotheses:

There is no difference in mean achievement of scientific literacy as measured by the

7a Nelson Biology Test Revised Edition Form E
7b Comprehensive Final Examination Revised Form J
7c Test on Understanding Science Form W
7d Understandings about the scientific enterprise subtest
7e Understandings about scientists subtest
7f Understandings about the methods and aims of science subtest

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program.

Null hypotheses 7a-7f were tested separately for each of the evaluation instruments. The formulae for null hypotheses 7a-7f were:

$$H_{O_{7a}} \; : \; n_{SL_{post-e}} = n_{SL_{pre-e}}$$

$$H_{O_{7b}} \; : \; cf_{SL_{post-e}} = cf_{SL_{pre-e}}$$

$$H_{O_{7c}} \; : \; tous_{SL_{post-e}} = tous_{SL_{pre-e}}$$

$H_{0_{7d}}$: $e_{SL_{post-e}} = e_{SL_{pre-e}}$

$H_{0_{7e}}$: $s_{SL_{post-e}} = s_{SL_{pre-e}}$

$H_{0_{7f}}$: $ma_{SL_{post-e}} = ma_{SL_{pre-e}}$

Research hypothesis eight:

8. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue Yellow, general) as a part of their regular school program achieve greater understanding of and ability to use the processes of science on posttest evaluation than on pretest evaluation using the same evaluation instrument.

H_8 : $P_{post-e} > P_{pre-e}$

Null hypotheses:

There is no difference in mean achievement of understanding of and ability to use the processes of science as measured by the

8a Processes of Science Test Form A
8b Watson-Glaser Critical Thinking Appraisal Form YM
8c Inference subtest
8d Assumption subtest
8e Deduction subtest
8f Interpretation subtest
8g Argument subtest

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program.

Null hypotheses 8a-8g were tested separately for each of the evaluation instruments. The formulae for null hypotheses 8a-8g were:

$H_{0_{8a}}$: $post_{P_{post-e}} = post_{P_{pre-e}}$

$H_{0_{8b}}$: $ct_{P_{post-e}} = ct_{P_{pre-e}}$

$H_{0_{8c}}$: $^{i}P_{post-e} = {}^{i}P_{pre-e}$

$H_{0_{8d}}$: $^{a}P_{post-e} = {}^{a}P_{pre-e}$

$H_{0_{8e}}$: $^{d}P_{post-e} = {}^{d}P_{pre-e}$

$H_{0_{8f}}$: $^{in}P_{post-e} = {}^{in}P_{pre-e}$

$H_{0_{8g}}$: $^{ar}P_{post-e} = {}^{ar}P_{pre-e}$

Research hypothesis nine:

9. Ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program achieve greater interest in science in general and biology in particular on posttest evaluation than on pretest evaluation using the same evaluation instrument.

H_9 : $I_{post-e} > I_{pre-e}$

Null hypotheses:

There is no difference in mean achievement of interest in science in general and biology in particular as measured by the

9a Kuder Preference Record Vocational Form CH--Outdoor subtest
9b Kuder Preference Record Vocational Form CH--Scientific subtest
9c A Scale to Measure Attitude Toward Any School Subject

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to a first year biology course (Blue, Yellow, general) as a part of their regular school program.

Null hypotheses 9a-9c were tested separately for each of the evaluation instruments. The formulae for null hypotheses 9a-9c were:

$H_{0_{9a}} : o_{I_{post-e}} = o_{I_{pre-e}}$

$H_{0_{9b}} : s_{I_{post-e}} = s_{I_{pre-e}}$

$H_{0_{9c}} : at_{I_{post-e}} = st_{I_{pre-e}}$

Hypotheses related to pretest to posttest gains for the control group.

Research hypothesis ten:

10. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater scientific literacy on posttest evaluation than on pretest evaluation using the same evaluation instrument.

$H_{10} : SL_{post-c} > SL_{pre-c}$

Null hypotheses:

There is no difference in mean achievement of scientific literacy as measured by the

10a Nelson Biology Test Revised Edition Form E
10b Comprehensive Final Examination Revised Form J
10c Test on Understanding Science Form W
10d Understandings about the scientific enterprise subtest
10e Understandings about scientists subtest
10f Understandings about the methods and aims of science subtest

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year.

Null hypotheses 10a-10f were tested separately for each of the evaluation instruments. The formulae for null hypotheses 10a-10f were:

$H_{0_{10a}} : n_{SL_{post-c}} = n_{SL_{pre-c}}$

$H_{0_{10b}} : cf_{SL_{post-c}} = cf_{SL_{pre-c}}$

$H_{0_{10c}}$: $tous_{SL_{post-c}} = tous_{SL_{pre-c}}$

$H_{0_{10d}}$: $e_{SL_{post-c}} = e_{SL_{pre-c}}$

$H_{0_{10e}}$: $s_{SL_{post-c}} = s_{SL_{pre-c}}$

$H_{0_{10f}}$: $ma_{SL_{post-c}} = ma_{SL_{pre-c}}$

Research hypothesis eleven:

11. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater understanding of and ability to use the processes of science on posttest evaluation than on pretest evaluation using the same evaluation instrument.

H_{11} : $P_{post-c} > P_{pre-c}$

Null hypotheses:

There is no difference in mean achievement of understanding of and ability to use the processes of science as measured by the

11a Processes of Science Test Form A
11b Watson-Glaser Critical Thinking Appraisal Form YM
11c Inference subtest
11d Assumption subtest
11e Deduction subtest
11f Interpretation subtest
11g Argument subtest

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year.

Null hypotheses 11a-11g were tested separately for each of the evaluation instruments. The formulae for null hypotheses 11a-11g were:

$H_{0_{11a}}$: $post_{P_{post-c}} = post_{P_{pre-c}}$

$H_{0_{11b}}$: $ct_{P_{post-c}} = ct_{P_{pre-c}}$

$H_{O_{11c}}$: ${}^{i}P_{post-c}$ = ${}^{i}P_{pre-c}$

$H_{O_{11d}}$: ${}^{a}P_{post-c}$ = ${}^{a}P_{pre-c}$

$H_{O_{11e}}$: ${}^{d}P_{post-c}$ = ${}^{d}P_{pre-c}$

$H_{O_{11f}}$: ${}^{in}P_{post-c}$ = ${}^{in}P_{pre-c}$

$H_{O_{11g}}$: ${}^{ar}P_{post-c}$ = ${}^{ar}P_{pre-c}$

Research hypothesis twelve:

12. Ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year achieve greater interest in science in general and biology in particular on posttest evaluation than on pretest evaluation using the same evaluation instrument.

H_{12} : $I_{post-c} > I_{pre-c}$

Null hypotheses:

There is no difference in mean achievement of interest in science in general and biology in particular as measured by the

12a Kuder Preference Record Vocational Form CH--Outdoor subtest
12b Kuder Preference Record Vocational Form CH--Scientific subtest
12c A Scale to Measure Attitude Toward Any School Subject

between posttest evaluation and pretest evaluation for ability grouped (A, B, C) tenth grade students exposed to no science course for one academic year.

Null hypotheses 12a-12c were tested separately for each of the evaluation instruments. The formulae for null hypotheses 12a-12c were:

$H_{O_{12a}}$: ${}^{o}I_{post-c}$ = ${}^{o}I_{pre-c}$

$$H_{0_{12b}} : s_{I_{post-c}} = s_{I_{pre-c}}$$

$$H_{0_{12c}} : at_{I_{post-c}} = at_{I_{pre-c}}$$

The model used to evaluate the ninety-six null hypotheses related to research hypotheses seven through twelve concerned with gains from pretest to posttest was a t test for the significance of the difference between two means for correlated samples.[48] The alpha level used for evaluation of hypotheses concerned with mean gains from pretest to posttest evaluation was .05.

No attempt was made to test the assumption of normality for hypotheses seven through twelve. This should be considered in evaluation of the conclusions concerning this data.

The results were calculated manually by the investigator using data from the Bastat Routine computer program.[49]

The t test used to evaluate gains from pretest to posttest is generally used to evaluate the following type of null hypothesis:

$H_0 : \bar{D} = 0$

$\bar{D}$ is difference between means

In this study the type of null hypothesis used was:

$H_0 : SL_{post} = SL_{pre}$

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[48]George A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, Inc., 1959), pp. 138-140.

[49]Agricultural Experiment Station, Calculation of Basic Statistics on the Bastat Routine, loc. cit.

SL_{post} is posttest mean

SL_{pre} is pretest mean

According to McNemar[50] analysis testing the null hypothesis,

$$H_0 : \bar{D} = 0$$

is in fact the same as testing the null hypothesis,

$$H_0 : SL_{post} = SL_{pre}$$

Summary. In this chapter the background and general design of the study were outlined. The community, populations, samples, and treatments were described. Evaluation instruments were described and methods of collecting data were explained. A list of research and related null hypotheses was provided with a description of models used for testing them.

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[50]McNemar, *op. cit.*, pp. 80-83.

CHAPTER IV

RESULTS AND EVALUATION

The data used in testing the twelve research hypotheses of this study were analyzed using three basic models: a covariant t test; a two-way analysis of variance; and a t test for the difference between correlated means. Seven evaluation instruments were used in collecting the data pertinent to the study. The tabulated data were analyzed using computer and manual calculations. The analyses of the data which follow were organized according to the sequence of the established general objectives reported in Chapter III. The data analyzed were based on scores for 177 students. The final make up of the groups under study is found in Table 3.

Table 3. Posttest composition of the A, B, and C experimental and control samples.

Ability Group	Treatment Group		
	Experimental	Control	Total
A	27	21	48
B	33	37	70
C	30	29	59
Total	90	87	177

Analyses of research hypotheses one, two, and three relative to the achievement of objectives for the A, B, and C ability groups. Analyses of the following null hypotheses were based on six scores for scientific literacy, seven scores for processes of science, and three scores for interest in science for the A, B, and C ability groups.

The formula for research hypothesis one was:

$$H_1 \ : \ SL_e > SL_c$$

The formulae for null hypotheses relative to research hypothesis one were:

$$H_{O_{1a}} \ : \ n_{SL_e} = n_{SL_c}{}^{*}$$

$$H_{O_{1b}} \ : \ cf_{SL_e} = cf_{SL_c}$$

$$H_{O_{1c}} \ : \ tous_{SL_e} = tous_{SL_c}$$

$$H_{O_{1d}} \ : \ e_{SL_e} = e_{SL_c}$$

$$H_{O_{1e}} \ : \ s_{SL_e} = s_{SL_c}$$

$$H_{O_{1f}} \ : \ ma_{SL_e} = ma_{SL_c}$$

Analyses of data relative to research hypothesis one for the A ability group. Analyses of null hypotheses 1a through

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*The following letters indicate the instruments used in all formulae for scientific literacy.

n - Nelson Biology Test
cf - Comprehensive Final Examination
tous - Test on Understanding Science
e - Enterprise subtest
s - Scientists subtest
ma - Methods and Aims subtest

1f were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 1a and 1b were rejected, while 1c, 1d, 1e, and 1f were not rejected. Table 4 contains pertinent data relative to these hypotheses.

The assumptions of normality and homogeneity of variance for all significant results were met in all cases except the equal variance test for the Nelson Biology Test of Null hypothesis 1a. Pertinent data on normality and equality of variance are found in Appendices J and K respectively.

Based on the rejections, tenth grade A ability grouped students exposed to the Blue Version BSCS course achieved significantly greater gains than non-science tenth grade A ability grouped students in knowledge, comprehension, and application of basic biological principles as measured by a test specifically designed for the course, Comprehensive Final Examination and as measured by a test not so designed, Nelson Biology Test. However, in the areas of understanding of science, understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science no significant differences were identified. Thus tenth grade A ability grouped students exposed to a Blue Version BSCS course were apparently able to achieve the objective of increased scientific literacy only partially.

Table 4. Data relative to achievement of scientific literacy for the A ability group for the covariant t test.

H_o	Evaluation Instrument	Control Posttest Mean	Control Adjusted Mean	Experimental Posttest Mean	Experimental Adjusted Mean	Adjusted Mean Square	t	Sig.	Rejection
1a	Nelson	33.47	32.77	47.59	48.14	42.20	8.445	$< .01$	r
1b	Comprehensive Final	23.71	23.88	32.00	31.87	18.24	6.658	$< .01$	r
1c	TOUS	35.17	35.30	37.56	37.47	23.53	1.595	$> .05$	nr
1d	Enterprise	11.24	11.25	11.96	11.96	6.62	.986	$> .05$	nr
1e	Scientists	11.76	11.89	12.74	12.64	2.96	1.562	$> .05$	nr
1f	Methods Aims	12.19	12.17	12.85	12.87	6.58	.972	$> .05$	nr

$\alpha = .05$ N = 48
$t_{.05} = 1.681$ df = 45
$t_{.01} = 2.415$ covariant = pretest

Analyses of data relative to research hypothesis one for the B ability group. Analyses of null hypotheses 1a through 1f were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 1a, 1b, 1c, and 1d were rejected, while 1e and 1f were not rejected. Table 5 contains pertinent data relative to these hypotheses.

The assumptions of normality and homogeneity of variance for all significant results were met. Pertinent data on normality and equality of variance are found in Appendices J and K respectively.

Based on the rejections, tenth grade B ability grouped students exposed to the Yellow Version BSCS course achieved significantly greater gains than non-science tenth grade B ability grouped students in knowledge, comprehension, and ability to apply basic biological principles as measured by a test specifically designed for the course, Comprehensive Final Examination and as measured by a test not so designed, Nelson Biology Test. In the area of understanding science significantly greater gains for B ability grouped tenth grade students exposed to the Yellow Version BSCS course were found for understanding science, and understandings about scientific enterprise, while no significant differences were found for understandings about scientists and understandings about the

Table 5. Data relative to achievement of scientific literacy for the B ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
1a	Nelson	21.59	20.68	31.12	32.14	41.17	7.441	< .01	r
1b	Comprehensive Final	18.41	18.10	21.88	22.22	18.06	4.039	< .01	r
1c	TOUS	28.24	26.83	27.61	29.19	23.30	1.873	< .05	r
1d	Enterprise	8.68	8.31	9.00	9.41	4.97	2.037	< .05	r
1e	Scientists	9.73	9.32	9.52	9.98	5.84	1.476	> .05	nr
1f	Methods Aims	9.84	9.65	9.09	9.30	7.95	-.479	> .05	nr

$\alpha = .05$ N = 70

$t_{.05} = 1.669$ df = 67

$t_{.01} = 2.386$ Covariant = pretest

methods and aims of science. Tenth grade B ability grouped students exposed to a Yellow Version BSCS course were apparently able to achieve the objective of increased scientific literacy only partially, but did exhibit significant gains on some measures for the two areas tested under general objective one.

Analyses of data relative to research hypothesis one for the C ability group. Analyses of null hypotheses 1a through 1f were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypothesis 1a was rejected, while 1b, 1c, 1d, 1e, and 1f were not rejected. Table 6 contains pertinent data relative to these hypotheses.

The assumptions of normality and homogeneity of variance for all significant results were met. Pertinent data on normality and equality of variance are found in Appendices J and K respectively.

Based on the rejection, tenth grade C ability grouped students exposed to a general survey Biology course achieved significantly greater gains than non-science tenth grade C ability grouped students in knowledge, comprehension, and ability to apply basic biological principles as measured by the Nelson Biology Test, but not as measured by the Comprehensive Final Examination. In the areas of understanding

Table 6. Data relative to achievement of scientific literacy for the C ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
1a	Nelson	15.21	15.26	18.87	18.82	32.45	2.405	$< .01$	r
1b	Comprehensive Final	15.41	15.41	15.57	15.57	14.97	.158	$> .05$	nr
1c	TOUS	22.10	21.66	22.63	22.06	25.90	.303	$> .05$	nr
1d	Enterprise	6.58	6.44	6.67	6.81	6.95	.536	$> .05$	nr
1e	Scientists	7.38	7.28	6.97	7.06	7.03	-.318	$> .05$	nr
1f	Methods Aims	8.14	8.10	8.00	8.03	6.40	-.106	$> .05$	nr

$\alpha = .05$ N = 59

$t_{.05} = 1.674$ df = 56

$t_{.01} = 2.397$ Covariant = pretest

science, understandings about scientific enterprise, understandings about scientists, and understandings about the methods and aims of science no significant differences were found. Tenth grade C ability grouped students exposed to a general survey Biology course were apparently able to achieve only one phase of the objective of increased scientific literacy.

Summary hypothesis one. Increased scientific literacy, as an objective of each of the three biology courses for the given ability groups, was not totally achieved by any of the three ability groups. The area under general objective one identified as knowledge, comprehension, and ability to apply basic biological principles was achieved in all ability groups, but the area of understanding science was achieved on a limited basis only by the B ability group exposed to the Yellow Version BSCS course.

The formula for research hypothesis two was:

$$H_2 \; : \; P_e > P_c$$

The formulae for null hypotheses relative to research hypothesis two were:

$$H_{O_{2a}} \; : \; post_{P_e} \; = \; post_{P_c}{}^{*}$$

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*The following letters indicate the instrument used in all formulae for the processes of science.

post - Processes of Science Test
ct - Watson-Glaser Critical Thinking Appraisal
i - Inference subtest
a - Assumption subtest
d - Deduction subtest
in - Interpretation subtest
ar - Argument subtest

$H_{O_{2b}}$: $ct_{P_e} = ct_{P_c}$

$H_{O_{2c}}$: $i_{P_e} = i_{P_c}$

$H_{O_{2d}}$: $a_{P_e} = a_{P_c}$

$H_{O_{2e}}$: $d_{P_e} = d_{P_c}$

$H_{O_{2f}}$: $in_{P_e} = in_{P_c}$

$H_{O_{2g}}$: $ar_{P_e} = ar_{P_c}$

Analyses of data relative to research hypothesis two for the A ability group. Analyses of null hypotheses 2a through 2g were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 2a through 2g were not rejected. Table 7 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade A ability grouped students exposed to the Blue Version BSCS Biology course exhibited no significant differences from non-science A ability grouped tenth grade students in understanding of and ability to use the processes of science as measured by the Processes of Science Test or as measured by the Watson-Glaser Critical Thinking Appraisal total score for critical thinking and the subscores for Inference, Assumption, Deduction, Interpretation, and Argument. A grouped tenth grade

Table 7. Data relative to achievement of understanding of and ability to use the processes of science for the A ability group for the covariant t test.

H_o	Evaluation Instrument	Control Posttest Mean	Control Adjusted Mean	Experimental Posttest Mean	Experimental Adjusted Mean	Adjusted Mean Square	t	Sig.	Rejection
2a	POST	30.00	30.57	31.44	31.00	8.25	.537	> .05	nr
2b	Critical Thinking	74.14	73.19	73.59	74.33	39.26	.647	> .05	nr
2c	Inference	12.19	12.20	12.33	12.33	4.43	.220	> .05	nr
2d	Assumption	11.33	11.25	11.33	11.40	17.99	.126	> .05	nr
2e	Deduction	19.76	19.49	19.67	19.88	4.83	.629	> .05	nr
2f	Interpretation	20.00	19.88	19.48	19.59	5.11	-.460	> .05	nr
2g	Argument	10.86	10.80	10.52	10.56	3.31	-.470	> .05	nr

$\alpha = .05$ N = 48

$t_{.05} = 1.681$ df = 45

$t_{.01} = 2.415$ Covariant = pretest

students exposed to the Blue Version BSCS course were unable to achieve the objective of increased understanding of and ability to use the processes of science.

Analyses of data relative to research hypothesis two for the B ability group. Analyses of null hypotheses 2a through 2g were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypothesis 2a was rejected, while 2b through 2g were not rejected. Table 8 contains pertinent data relative to these hypotheses.

The assumptions of normality and homogeneity of variance for all significant results were met. Pertinent data on normality and equality of variance are found in Appendices J and K respectively.

Based on the rejection of null hypothesis 2a, tenth grade B ability grouped students exposed to the Yellow Version BSCS course achieved significantly greater gains than non-science tenth grade B ability grouped students in understanding of the processes of science as measured by the Processes of Science Test, but exhibited no significant differences in critical thinking ability or understanding of and ability to use inferences, assumptions, deductions, interpretations, or arguments. B ability grouped tenth grade students exposed to the Yellow Version BSCS course were able to partially achieve the objective of increased understanding of and ability to use the processes of science.

Table 8. Data relative to achievement of understanding of and ability to use the processes of science for the B ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
2a	POST	23.73	23.20	24.45	25.05	17.69	1.831	$<$ .05	r
2b	Critical Thinking	64.73	64.03	62.76	63.51	56.19	-.305	$>$ .05	nr
2c	Inference	10.51	10.43	9.45	9.55	7.94	-1.294	$>$ .05	nr
2d	Assumption	11.00	10.76	10.00	10.27	9.38	-.671	$>$ .05	nr
2e	Deduction	17.35	17.40	17.09	17.04	7.74	-.537	$>$ .05	nr
2f	Interpretation	16.68	16.60	17.00	17.08	9.13	.666	$>$ .05	nr
2g	Argument	9.19	9.14	9.21	9.27	2.84	.317	$>$ .05	nr

$\alpha = .05$ N = 70

$t_{.05} = 1.669$ df = 67

$t_{.01} = 2.386$ Covariant = pretest

<u>Analyses of data relative to research hypothesis two for the C ability group</u>. Analyses of null hypotheses 2a through 2g were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 2a through 2g were not rejected. Table 9 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade C ability grouped students exposed to a general survey Biology course did not exhibit greater understanding of and ability to use the processes of science than non-science tenth grade C ability grouped students. C grouped tenth grade students exposed to a general survey Biology course were unable to achieve the objective of increased understanding of and ability to use the processes of science.

<u>Summary hypothesis two</u>. Increased understanding of and ability to use the processes of science as an objective of each of the three biology courses for the given ability groups was not achieved by the A and C ability groups and only partially achieved by the B ability group.

The formula for research hypothesis three was:

$$H_3 : I_e > I_c$$

The formulae for null hypotheses relative to research hypothesis three were:

Table 9. Data relative to achievement of understanding of and ability to use the processes of science for the C ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
2a	POST	18.07	17.33	15.70	16.41	23.63	-.730	> .05	nr
2b	Critical Thinking	59.83	58.40	52.97	54.35	58.51	-2.035	> .05	nr
2c	Inference	9.72	9.44	7.27	7.54	6.01	-2.968	> .05	nr
2d	Assumption	10.03	10.13	8.97	8.88	7.49	-1.760	> .05	nr
2e	Deduction	16.00	15.84	14.53	14.69	7.96	-1.455	> .05	nr
2f	Interpretation	15.62	15.43	14.83	15.02	11.00	-.476	> .05	nr
2g	Argument	8.45	8.42	7.43	7.46	5.10	-1.523	> .05	nr

$\alpha = .05$ N = 59

$t_{.05} = 1.674$ df = 56

$t_{.01} = 2.397$ Covariant = pretest

$$H_{0_{3a}} : o_{I_e} = o_{I_c} \; *$$

$$H_{0_{3b}} : s_{I_e} = s_{I_c}$$

$$H_{0_{3c}} : at_{I_e} = at_{I_c}$$

Analyses of data relative to research hypothesis three for the A ability group. Analyses of null hypotheses 3a through 3c were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 3a through 3c were not rejected. Table 10 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade A ability grouped students exposed to the Blue Version BSCS Biology course exhibited no significant differences from non-science A ability grouped tenth grade students in increased interest in outdoor activities, scientific activities, or attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. Tenth grade A ability grouped students exposed to the Blue Version BSCS

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*The following letters indicate the instruments used in all formulae for interest in science.

o - Kuder Outdoor subtest
s - Kuder Scientific subtest
at - A Scale to Measure Attitude Toward Any School Subject

Table 10. Data relative to achievement of interest in science in general and biology in particular for the A ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
3a	Outdoor	38.29	36.49	37.96	39.36	74.30	1.190	> .05	nr
3b	Scientific	37.00	35.28	35.81	37.15	50.55	.939	> .05	nr
3c	Attitude	7.05	7.02	6.91	6.94	2.05	-.200	> .05	nr

$\alpha = .05$ N = 48

$t_{.05} = 1.681$ df = 45

$t_{.01} = 2.415$ Covariant = pretest

Biology course did not achieve the objective of increased interest in science in general and biology in particular.

Analyses of data relative to research hypothesis three for the B ability group. Analyses of null hypotheses 3a through 3c were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 3a through 3g were not rejected. Table 11 contains data relative to these hypotheses.

Based on the lack of rejections, tenth grade B ability grouped students exposed to the Yellow Version BSCS Biology course exhibited no significant differences from non-science B ability grouped tenth grade students in interest in outdoor activities, scientific activities, or attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. Tenth grade B ability grouped students exposed to the Yellow Version BSCS Biology course did not achieve the objective of increased interest in science in general and biology in particular.

Analyses of data relative to research hypothesis three for the C ability group. Analyses of null hypotheses 3a through 3c were made using a covariant t test with pretest as covariant and a pre-established rejection level set at .05.

Table 11. Data relative to achievement of interest in science in general and biology in particular for the B ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
3a	Outdoor	33.30	35.04	39.00	37.04	103.53	.819	$> .05$	nr
3b	Scientific	34.43	33.10	33.85	35.34	78.54	1.051	$> .05$	nr
3c	Attitude	6.34	6.26	6.57	6.66	2.46	1.052	$> .05$	nr

$\alpha = .05$ N = 70

$t_{.05} = 1.669$ df = 67

$t_{.01} = 2.386$ Covariant = pretest

Results of the analyses indicated that null hypotheses 3b and 3c were rejected, while 3a was not rejected. Table 12 contains pertinent data relative to these hypotheses.

The assumptions of normality and homogeneity of variance for all significant results were met. Pertinent data on normality and equality of variance are found in Appendices J and K respectively.

Based on the rejections, tenth grade C ability grouped students exposed to a general survey Biology course exhibited significantly greater interest in scientific activities and positive attitude toward a biology course as measured by the Kuder Preference Record Scientific subtest and A Scale to Measure Attitude Toward Any School Subject than tenth grade C ability grouped non-science students. C ability grouped tenth grade students exposed to a general survey Biology course exhibited no significant difference from non-science tenth grade C ability grouped students in interest in outdoor activities. C ability grouped tenth grade students exposed to a general survey Biology course were able to achieve two phases of the objective of increased interest in science in general and biology in particular.

Summary hypothesis three. Increased interest in science in general and biology in particular as an objective of each of the three biology courses for the given ability groups was achieved only by C ability grouped students exposed to a general survey Biology course. The A and B ability grouped

Table 12. Data relative to achievement of interest in science in general and biology in particular for the C ability group for the covariant t test.

H_o	Evaluation Instrument	Control		Experimental		Adjusted Mean Square	t	Sig.	Rejection
		Posttest Mean	Adjusted Mean	Posttest Mean	Adjusted Mean				
3a	Outdoor	32.28	34.66	38.10	35.79	45.68	.642	$> .05$	nr
3b	Scientific	26.69	28.33	34.47	32.88	47.40	2.541	$< .01$	r
3c	Attitude	5.40	5.55	6.75	6.61	3.61	2.163	$< .05$	r

$\alpha = .05$ N = 59

$t_{.05} = 1.674$ df = 56

$t_{.01} = 2.397$ Covariant = pretest

students exposed to the Blue Version BSCS Biology course and the Yellow Version BSCS Biology course respectively did not achieve the objective of increased interest in science in general and biology in particular.

Analyses of research hypotheses four, five, and six relative to sex and objective achievement for the A, B, and C ability groups. Analyses of the following null hypotheses are based on six scores for scientific literacy, seven scores for processes of science, and three scores for interest in science for the A, B, and C ability groups. The male and female composition of the groups under study is found in Table 13.

Table 13. Male and female posttest composition of the A, B, and C experimental and control groups.

Ability Group	Treatment Group	Male	Female	Total
A	Experimental	14	13	27
	Control	12	9	21
B	Experimental	17	16	33
	Control	18	19	37
C	Experimental	16	14	30
	Control	8	21	29

The formula for research hypothesis four was:

$$H_4 : SL_m \neq SL_f$$

The formulae for null hypotheses relative to research hypothesis four were:

$$H_{O_{4a}} : n_{SL_m} = n_{SL_f}\ ^{*}$$

$$H_{O_{4b}} : cf_{SL_m} = cf_{SL_f}$$

$$H_{O_{4c}} : tous_{SL_m} = tous_{SL_f}$$

$$H_{O_{4d}} : e_{SL_m} = e_{SL_f}$$

$$H_{O_{4e}} : s_{SL_m} = s_{SL_f}$$

$$H_{O_{4f}} : ma_{SL_m} = ma_{SL_f}$$

Analyses of data relative to research hypothesis four for the A ability group. Analyses of null hypotheses 4a through 4f were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 4a through 4f were not rejected for sex or interaction of sex and treatment. Tables 14 through 19 contain pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade A ability grouped male students exposed to a Blue Version BSCS Biology course or no science course for the same period of time and female tenth grade A ability grouped students exposed to

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*The following letters indicate sex groups for hypotheses four through six.

m - male
f - female

Table 14. Two-way analysis of variance for the A ability group for sex and treatment on the Nelson Biology Test.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	2.52	2.52	.03	.871	nr
Treatment	1	2310.42	2310.42	24.43	<0.005	r
Interaction	1	.05	.05	.0005	.982	nr
Error	44	4161.24	94.57			
Total	47	6474.23				

$\alpha = .05$

Table 15. Two-way analysis of variance for the A ability group for sex and treatment on the Comprehensive Final Examination.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	5.47	5.47	.18	.673	nr
Treatment	1	779.29	779.29	25.64	<0.0005	r
Interaction	1	11.25	11.25	.37	.546	nr
Error	44	1337.41	30.40			
Total	47	2133.42				

$\alpha = .05$

Table 16. Two-way analysis of variance for the A ability group for sex and treatment on the TOUS.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	51.51	51.51	1.62	.210	nr
Treatment	1	54.49	54.49	1.71	.197	nr
Interaction	1	.97	.97	.03	.862	nr
Error	44	1398.39	31.78			
Total	47	1505.36				

$\alpha = .05$

Table 17. Two-way analysis of variance for the A ability group for sex and treatment on the TOUS understandings about scientific enterprise subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	1.20	1.20	.14	.707	nr
Treatment	1	5.96	5.96	.71	.404	nr
Interaction	1	1.42	1.42	.17	.683	nr
Error	44	369.74	8.40			
Total	47	378.32				

$\alpha = .05$

Table 18. Two-way analysis of variance for the A ability group for sex and treatment on the TOUS understandings about scientists subtest.

Variance Source	df	SS	MS	F	Sig.	Rejec. tion
Sex	1	9.23	9.23	2.42	.127	nr
Treatment	1	8.88	8.88	2.33	.134	nr
Interaction	1	2.91	2.91	.76	.387	nr
Error	44	168.05	3.82			
Total	47	189.07				

$\alpha = .05$

Table 19. Two-way analysis of variance for the A ability group for sex and treatment on the TOUS understandings about the methods and aims of science subtest.

Variance Source	df	SS	MS	F	Sig.	Rejec-tion
Sex	1	.22	.22	.03	.864	nr
Treatment	1	3.84	3.84	.52	.476	nr
Interaction	1	9.25	9.25	1.24	.271	nr
Error	44	327.39	7.44			
Total	47	340.70				

$\alpha = .05$

a Blue Version BSCS Biology course or no science course for the same period of time exhibited no significant differences in knowledge, comprehension, and ability to apply basic biological principles, in understanding of science, in understandings about the scientific enterprise, in understandings about scientists, and in understandings about the methods and aims of science. Sex was not a significant factor in achievement of increased scientific literacy for A ability grouped students.

Analyses of data relative to research hypothesis four for the B ability group. Analyses of null hypotheses 4a through 4f were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 4a through 4f were not rejected for sex or interaction of sex and treatment. Tables 20 through 25 contain pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade B ability grouped male students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time and female tenth grade B ability grouped students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time exhibited no significant differences in knowledge, comprehension, and ability to apply basic biological principles, in understanding of science, in understandings about the scientific enterprise, in understandings about scientists, and in understandings about the

Table 20. Two-way analysis of variance for the B ability group for sex and treatment on the Nelson Biology Test.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	6.37	6.37	.08	.778	nr
Treatment	1	1575.27	1575.27	19.87	$<$0.005	r
Interaction	1	30.81	30.81	.39	.535	nr
Error	66	5232.75	79.28			
Total	69	6845.20				

$\alpha = .05$

Table 21. Two-way analysis of variance for the B ability group for sex and treatment on the Comprehensive Final Examination.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	13.58	13.58	.67	.416	nr
Treatment	1	206.88	206.88	10.18	.002	r
Interaction	1	48.74	48.74	2.40	.126	nr
Error	66	1340.86	20.32			
Total	69	1610.06				

$\alpha = .05$

Table 22. Two-way analysis of variance for the B ability group for sex and treatment on the TOUS.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	16.62	16.62	.39	.533	nr
Treatment	1	6.45	6.45	.15	.698	nr
Interaction	1	2.72	2.72	.06	.801	nr
Error	66	2796.06	42.36			
Total	69	2821.85				

$\alpha = .05$

Table 23. Two-way analysis of variance for the B ability group for sex and treatment on the TOUS understandings about the scientific enterprise subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	2.60	2.60	.34	.560	nr
Treatment	1	1.97	1.97	.26	.611	nr
Interaction	1	5.96	5.96	.79	.377	nr
Error	66	497.98	7.55			
Total	69	508.51				

$\alpha = .05$

Table 24. Two-way analysis of variance for the B ability group for sex and treatment on the TOUS understandings about scientists subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	7.47	7.47	.97	.329	nr
Treatment	1	.67	.67	.09	.769	nr
Interaction	1	3.40	3.40	.44	.510	nr
Error	66	510.05	7.73			
Total	69	521.59				

$\alpha = .05$

Table 25. Two-way analysis of variance for the B ability group for sex and treatment on the TOUS understandings about the methods and aims of science subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.07	.07	.01	.928	nr
Treatment	1	9.76	9.76	1.12	.294	nr
Interaction	1	1.10	1.10	.13	.723	nr
Error	66	574.54	8.71			
Total	69	585.47				

$\alpha = .05$

methods and aims of science. Sex was not a significant factor in achievement of increased scientific literacy for B ability grouped students.

Analyses of data relative to research hypothesis four for the C ability group. Analyses of null hypotheses 4a through 4f were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 4b through 4f were not rejected for sex, but 4f was rejected for interaction of sex and treatment and 4a was rejected for sex but not interaction of sex and treatment. Tables 26 through 31 contain pertinent data relative to these hypotheses.

Based on the rejection of null hypothesis 4a, tenth grade C ability grouped male students exposed to a general survey Biology course or no science course for the same period of time and female tenth grade C ability grouped students exposed to a general survey Biology course or no science course for the same period of time exhibited significant differences in increased knowledge, comprehension, and ability to apply basic biological principles as measured by the Nelson Biology Test with males achieving greater means on posttest evaluation than females in both experimental and control groups.[1] In the areas of understanding of science, understandings about the scientific enterprise, understandings

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[1]Pretest and posttest means for male and female students are found in Appendix H.

Table 26. Two-way analysis of variance for the C ability group for sex and treatment on the Nelson Biology Test.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	214.79	214.79	6.98	.011	r
Treatment	1	79.95	79.95	2.60	.113	nr
Interaction	1	.02	.02	.0007	.980	nr
Error	55	1691.80	30.76			
Total	58	1986.56				

$\alpha = .05$

Table 27. Two-way analysis of variance for the C ability group for sex and treatment on the Comprehensive Final Examination.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	32.49	32.49	2.13	.150	nr
Treatment	1	3.05	3.05	.20	.657	nr
Interaction	1	16.44	16.44	1.08	.304	nr
Error	55	838.37	15.24			
Total	58	890.35				

$\alpha = .05$

Table 28. Two-way analysis of variance for the C ability group for sex and treatment on the TOUS.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	70.43	70.43	2.24	.140	nr
Treatment	1	32.13	32.13	1.02	.316	nr
Interaction	1	94.96	94.96	3.02	.088	nr
Error	55	1727.71	31.41			
Total	58	1925.23				

$\alpha = .05$

Table 29. Two-way analysis of variance for the C ability group for sex and treatment on the TOUS understandings about the scientific enterprise subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.12	.12	.02	.901	nr
Treatment	1	.08	.08	.01	.921	nr
Interaction	1	8.73	8.73	1.14	.290	nr
Error	55	420.97	7.65			
Total	58	429.90				

$\alpha = .05$

Table 30. Two-way analysis of variance for the C ability group for sex and treatment on the TOUS understandings about scientists subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	19.88	19.88	2.48	.121	nr
Treatment	1	9.34	9.34	1.17	.285	nr
Interaction	1	3.02	3.02	.38	.542	nr
Error	55	440.44	8.01			
Total	58	472.68				

$\alpha = .05$

Table 31. Two-way analysis of variance for the C ability group for sex and treatment on the TOUS understandings about the methods and aims of science subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	12.86	12.86	2.14	.149	nr
Treatment	1	5.45	5.45	.91	.345	nr
Interaction	1	25.53	25.53	4.24	4.24	r
Error	55	330.89	6.02			
Total	58	374.73				

$\alpha = .05$

about scientists, and understandings about the methods and aims of science no significant differences were found between the sexes except interaction of sex and treatment for understandings about the methods and aims of science. Sex was a significant factor in achievement of scientific literacy on two measures for C ability grouped students.

<u>Summary hypothesis four</u>. Sex as a factor in achievement of scientific literacy was found to be significant only with C ability grouped students exposed to a general survey Biology course or no science course for the same period of time. Interaction of sex and treatment was found to be a factor only in understanding of methods and aims of science for the C ability grouped students. Sex was not a factor in achievement of scientific literacy for the A and B ability grouped students.

The formula for research hypothesis five was:

$$H_5 : P_m \neq P_f$$

The formulae for null hypotheses relative to research hypothesis five were:

$$H_{0_{5a}} : post_{P_m} = post_{P_f}$$

$$H_{0_{5b}} : ct_{P_m} = ct_{P_f}$$

$$H_{0_{5c}} : i_{P_m} = i_{P_f}$$

$$H_{0_{5d}} : a_{P_m} = a_{P_f}$$

$$H_{0_{5e}} : d_{P_m} = d_{P_f}$$

$H_{0_{5f}}$: $in_{P_m} = in_{P_f}$

$H_{0_{5g}}$: $ar_{P_m} = ar_{P_f}$

Analyses of data relative to research hypothesis five for the A ability group. Analyses of null hypotheses 5a through 5g were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 5a, 5b, 5e, and 5g were rejected, while 5c, 5d, and 5f were not rejected for sex or interaction of sex and treatment. Tables 32 through 37 contain pertinent data relative to these hypotheses.

Based on the rejections, tenth grade A ability grouped male students exposed to a Blue Version BSCS Biology course or no science course for the same period of time and female tenth grade A ability grouped students exposed to a Blue Version BSCS Biology course or no science course for the same period of time exhibited significant differences in understanding of the processes of science, critical thinking, ability to recognize deductions, and ability to evaluate arguments, but did not exhibit significant differences in ability to recognize inferences, assumptions, and make valid interpretations of data as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Females exhibited greater means on significant results. Sex was a significant factor in achievement of increased

Table 32. Two-way analysis of variance for the A ability group for sex and treatment on the POST.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	73.42	73.42	4.92	.032	r
Treatment	1	17.31	17.31	1.16	.287	nr
Interaction	1	.01	.01	.0003	.986	nr
Error	44	656.05	14.91			
Total	47	746.79				

$\alpha = .05$

Table 33. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	487.03	487.03	7.99	.007	r
Treatment	1	12.71	12.71	.21	.650	nr
Interaction	1	31.96	31.96	.52	.473	nr
Error	44	2682.38	60.96			
Total	47	3214.08				

$\alpha = .05$

Table 34. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal inference subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	22.31	22.31	3.40	.072	nr
Treatment	1	.04	.04	.01	.939	nr
Interaction	1	6.45	6.45	.98	.327	nr
Error	44	288.66	6.56			
Total	47	317.46				

$\alpha = .05$

Table 35. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal assumption subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	52.18	52.18	3.01	.090	nr
Treatment	1	.26	.26	.02	.902	nr
Interaction	1	6.63	6.63	.38	.539	nr
Error	44	761.69	17.31			
Total	47	820.76				

$\alpha = .05$

Table 36. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal deduction subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	31.16	31.16	4.66	.036	r
Treatment	1	.61	.61	.09	.763	nr
Interaction	1	.70	.70	.10	.748	nr
Error	44	294.09	6.68			
Total	47	326.56				

$\alpha = .05$

Table 37. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal interpretation subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	2.46	2.46	.37	.549	nr
Treatment	1	3.74	3.74	.56	.460	nr
Interaction	1	.18	.18	.03	.871	nr
Error	44	296.23	6.73			
Total	47	302.61				

$\alpha = .05$

Table 38. Two-way analysis of variance for the A ability group for sex and treatment on the W-G Critical Thinking Appraisal argument subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	15.14	15.14	4.28	.044	r
Treatment	1	2.11	2.11	.60	.444	nr
Interaction	1	1.09	1.09	.31	.581	nr
Error	44	155.66	3.54			
Total	47	174.00				

$\alpha = .05$

Table 39. Two-way analysis of variance for the B ability group for sex and treatment on the POST.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	2.43	2.43	.10	.753	nr
Treatment	1	8.87	8.87	.36	.548	nr
Interaction	1	2.62	2.62	.11	.744	nr
Error	66	1606.70	24.34			
Total	69	1620.62				

$\alpha = .05$

understanding of and ability to use the processes of science on most measures for the A ability grouped students.

Analyses of data relative to research hypothesis five for the B ability group. Analyses of null hypotheses 5a through 5g were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 5a through 5g were not rejected for sex or interaction of sex and treatment. Tables 39 through 45 contain pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade B ability grouped male students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time and female tenth grade B ability grouped students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time exhibited no significant differences in understanding of the processes of science, critical thinking, ability to recognize inferences, assumptions, deductions, interpretations, and evaluate arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Sex was not a significant factor in achievement of understanding of and ability to use the processes of science for tenth grade B ability grouped students.

Table 40. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	30.81	30.81	.43	.513	nr
Treatment	1	65.17	65.17	.91	.343	nr
Interaction	1	.95	.95	.01	.909	nr
Error	66	4706.12	71.30			
Total	69	4803.05				

$\alpha = .05$

Table 41. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal inference subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	14.32	14.32	1.84	.180	nr
Treatment	1	18.55	18.55	2.38	.128	nr
Interaction	1	13.50	13.50	1.73	.193	nr
Error	66	515.10	7.80			
Total	69	561.47				

$\alpha = .05$

Table 42. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal assumption subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	11.47	11.47	1.06	.308	nr
Treatment	1	16.67	16.67	1.53	.220	nr
Interaction	1	11.47	11.47	1.06	.308	nr
Error	66	717.66	10.87			
Total	69	757.27				

$\alpha = .05$

Table 43. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal deduction subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	3.65	3.65	.45	.505	nr
Treatment	1	1.29	1.29	.16	.692	nr
Interaction	1	22.26	22.26	2.74	.103	nr
Error	66	536.13	8.12			
Total	69	563.33				

$\alpha = .05$

Table 44. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal interpretation subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.30	.30	.03	.866	nr
Treatment	1	1.78	1.78	.17	.683	nr
Interaction	1	3.92	3.92	.37	.545	nr
Error	66	699.99	10.61			
Total	69	705.99				

$\alpha = .05$

Table 45. Two-way analysis of variance for the B ability group for sex and treatment on the W-G Critical Thinking Appraisal argument subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.71	.71	.24	.629	nr
Treatment	1	.01	.01	.005	.947	nr
Interaction	1	4.21	4.21	1.40	.240	nr
Error	66	198.06	3.00			
Total	69	202.99				

$\alpha = .05$

Analyses of data relative to research hypothesis five for the C ability group. Analyses of null hypotheses 5a through 5g were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 5a through 5g were not rejected for sex or interaction of sex and treatment. Tables 46 through 52 contain pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade C ability grouped male and female students exposed to a general survey Biology course or no science course for the same period of time exhibited no significant differences in understanding of the processes of science, critical thinking, ability to recognize inferences, assumptions, deductions, interpretations, and evaluate arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Sex was not a significant factor in achievement of understanding of and ability to use the processes of science for tenth grade C ability grouped students.

Summary hypothesis five. Sex was a factor in achievement of understanding of and ability to use the processes of science for tenth grade A ability grouped students. Females exhibited a consistently greater mean achievement on all significant results. Sex was not a significant factor in achievement of understanding of and ability to use the processes of science for tenth grade B and C ability grouped students on any variables tested.

Table 46. Two-way analysis of variance for the C ability group for sex and treatment on the POST.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.58	.58	.02	.899	nr
Treatment	1	91.37	91.37	2.56	.115	nr
Interaction	1	26.14	26.14	.73	.395	nr
Error	55	1960.00	35.64			
Total	58	2078.09				

$\alpha = .05$

Table 47. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	86.35	86.35	1.16	.286	nr
Treatment	1	853.65	853.65	11.46	.001	r
Interaction	1	131.33	131.33	1.76	.190	nr
Error	55	4096.12	74.47			
Total	58	5167.45				

$\alpha = .05$

Table 48. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal inference subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	2.08	2.08	.27	.602	nr
Treatment	1	96.96	96.96	12.78	.001	r
Interaction	1	13.39	13.39	1.77	.189	nr
Error	55	417.24	7.59			
Total	58	529.67				

$\alpha = .05$

Table 49. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal assumption subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	5.27	5.27	.60	.440	nr
Treatment	1	24.09	24.09	2.76	.102	nr
Interaction	1	6.29	6.29	.72	.400	nr
Error	55	479.61	8.72			
Total	58	515.26				

$\alpha = .05$

Table 50. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal deduction subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.004	.004	.0005	.983	nr
Treatment	1	31.00	31.00	3.73	.059	nr
Interaction	1	3.71	3.71	.45	.507	nr
Error	55	457.67	8.32			
Total	58	492.384				

$\alpha = .05$

Table 51. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal interpretation subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	34.81	34.81	2.97	.091	nr
Treatment	1	23.05	23.05	1.96	.167	nr
Interaction	1	2.50	2.50	.21	.646	nr
Error	55	645.40	11.73			
Total	58	705.76				

$\alpha = .05$

Table 52. Two-way analysis of variance for the C ability group for sex and treatment on the W-G Critical Thinking Appraisal argument subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.32	.32	.06	.805	nr
Treatment	1	14.57	14.57	2.85	.097	nr
Interaction	1	4.25	4.25	.83	.366	nr
Error	55	281.62	5.12			
Total	58	300.76				

$\alpha = .05$

Table 53. Two-way analysis of variance for the A ability group for sex and treatment on the Kuder outdoor subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	1.05	1.05	.01	.944	nr
Treatment	1	5.33	5.33	.03	.874	nr
Interaction	1	603.05	603.05	2.89	.096	nr
Error	44	9187.13	208.80			
Total	47	9796.56				

$\alpha = .05$

The formula for research hypothesis six was:

$$H_6 : I_m \neq I_f$$

The formulae for null hypotheses relative to research hypothesis six were:

$$H_{0_{6a}} : {}^{o}I_m = {}^{o}I_f$$

$$H_{0_{6b}} : {}^{s}I_m = {}^{s}I_f$$

$$H_{0_{6c}} : at_{I_m} = at_{I_f}$$

Analyses of data relative to research hypothesis six for tha A ability group. Analyses of null hypotheses 6a through 6c were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypothesis 6b was rejected, while 6a and 6c were not for sex and interaction of sex and treatment. Tables 53 through 55 contain pertinent data relative to these hypotheses.

Based on the rejection of null hypothesis 6b, tenth grade A ability grouped male students exposed to a Blue Version BSCS Biology course or no science course for the same period of time and female tenth grade A ability grouped students exposed to a Blue Version BSCS Biology course or no science course for the same period of time exhibited a significant difference in interest in scientific activities. Males achieved greater means than females as measured by the Kuder Preference Record Scientific subtest. No significant differences were found in interest in outdoor activities or attitude toward a biology course as measured by the Kuder

Table 54. Two-way analysis of variance for the A ability group for sex and treatment on the Kuder scientific subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	850.80	850.80	5.59	.022	r
Treatment	1	.93	.93	.01	.938	nr
Interaction	1	75.54	75.54	.50	.485	nr
Error	44	6692.10	152.09			
Total	47	7619.37				

$\alpha = .05$

Table 55. Two-way analysis of variance for the A ability group for sex and treatment on A scale to Measure Attitude Toward Any School Subject.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	5.47	5.47	2.14	.151	nr
Treatment	1	.42	.42	.16	.687	nr
Interaction	1	.68	.68	.27	.608	nr
Error	44	112.51	2.56			
Total	47	119.08				

$\alpha = .05$

Preference Record and A Scale to Measure Attitude Toward Any School Subject. Sex was a significant factor on at least one measure of interest in science in general and biology in particular for tenth grade A ability grouped students.

Analyses of data relative to research hypothesis six for the B ability group. Analyses of null hypotheses 6a through 6c were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypothesis 6b was rejected, while 6a and 6c were not rejected for sex and interaction of sex and treatment. Tables 56 through 58 contain pertinent data relative to these hypotheses.

Based on the rejection of null hypothesis 6b, tenth grade B ability grouped male students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time and female tenth grade A ability grouped students exposed to a Yellow Version BSCS Biology course or no science course for the same period of time exhibited a significant difference in interest in scientific activities. Males achieved greater means than females as measured by the Kuder Preference Record Scientific subtest. No significant differences were found in interest in outdoor activities or attitude toward a biology course as measured by the Kuder Preference Record and A Scale to Measure Attitude Toward Any School Subject. Sex was a significant factor on at least one measure of interest in science in general and biology in particular for tenth grade B ability grouped students.

Table 56. Two-way analysis of variance for the B ability group for sex and treatment on the Kuder outdoor subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	524.19	524.19	3.03	.086	nr
Treatment	1	536.21	536.21	3.10	.083	nr
Interaction	1	9.87	9.87	.06	.812	nr
Error	66	11401.65	172.75			
Total	69	12471.92				

$\alpha = .05$

Table 57. Two-way analysis of variance for the B ability group for sex and treatment on the Kuder scientific subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	4711.55	4711.55	48.62	<0.0005	r
Treatment	1	19.51	19.51	.20	.655	nr
Interaction	1	50.67	50.67	.52	.472	nr
Error	66	6395.57	96.90			
Total	69	11177.30				

$\alpha = .05$

Table 58. Two-way analysis of variance for the B ability group for sex and treatment on A scale to Measure Attitude Toward Any School Subject.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	3.37	3.37	.94	.335	nr
Treatment	1	.78	.78	.22	.642	nr
Interaction	1	3.09	3.09	.87	.356	nr
Error	66	235.56	3.57			
Total	69	242.80				

$\alpha = .05$

Table 59. Two-way analysis of variance for the C ability group for sex and treatment on the Kuder outdoor subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	1242.33	1242.33	11.05	.002	r
Treatment	1	178.49	178.49	1.59	.213	nr
Interaction	1	279.70	279.70	2.49	.121	nr
Error	55	6185.38	112.46			
Total	58	7885.90				

$\alpha = .05$

<u>Analyses of data relative to research hypothesis six for the C ability group</u>. Analyses of null hypotheses 6a through 6c were made using a two-way analysis of variance with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 6a and 6b were rejected for sex but not interaction of sex and treatment, while 6c was not rejected for sex or interaction of sex and treatment. Tables 59 through 61 contain pertinent data relative to these hypotheses.

Based on the rejections tenth grade C ability grouped male students exposed to a general survey Biology course or no science course for the same period of time and female tenth grade C ability grouped students exposed to a general survey Biology course or no science course for the same period of time exhibited significant differences in interest in outdoor activities and scientific activities as measured by the <u>Kuder Preference Record</u> outdoor and Scientific subtests. Males achieved greater means than females on both measures. No significant difference was found in attitude toward a biology course as measured by <u>A Scale to Measure Attitude Toward Any School Subject</u>. Sex was a significant factor in achievement of interest in science in general and biology in particular for C ability grouped students.

<u>Summary hypothesis six</u>. Sex as a factor in achievement of increased interest in science in general and biology in particular was found in all three ability groups on at least

Table 60. Two-way analysis of variance for the C ability group for sex and treatment on the Kuder scientific subtest.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	1720.54	1720.54	26.47	<0.0005	r
Treatment	1	210.31	210.31	3.24	.078	nr
Interaction	1	84.25	84.25	1.30	.260	nr
Error	55	3575.07	65.00			
Total	58	5590.17				

$\alpha = .05$

Table 61. Two-way analysis of variance for the C ability group for sex and treatment on A Scale to Measure Attitude Toward Any School Subject.

Variance Source	df	SS	MS	F	Sig.	Rejection
Sex	1	.23	.23	.06	.810	nr
Treatment	1	25.25	25.25	6.28	.015	r
Interaction	1	3.28	3.28	.82	.370	nr
Error	55	221.05	4.02			
Total	58	249.81				

$\alpha = .05$

one measure. In all cases males achieved greater means than females.

<u>Analyses of research hypotheses seven, eight, and nine relative to mean gains and objective achievement for the experimental A, B, and C ability groups</u>. Analyses were made using pretest to posttest mean gains for the experimental A, B, and C ability groups. Analyses of the following null hypotheses were based on six scores for scientific literacy, seven scores for processes of science, and three scores for interest in science for the A, B, and C ability groups.

The formula for research hypothesis seven was:

$$H_7 : SL_{post} > SL_{pre}$$

The formulae for null hypotheses relative to research hypothesis seven were:

$$H_{0_{7a}} : {}^{n}SL_{post-e} = {}^{n}SL_{pre-e} \; *$$

$$H_{0_{7b}} : {}^{cf}SL_{post-e} = {}^{cf}SL_{pre-e}$$

$$H_{0_{7c}} : {}^{tous}SL_{post-e} = {}^{tous}SL_{pre-e}$$

$$H_{0_{7d}} : {}^{e}SL_{post-e} = {}^{e}SL_{pre-e}$$

$$H_{0_{7e}} : {}^{s}SL_{post-e} = {}^{s}SL_{pre-e}$$

$$H_{0_{7f}} : {}^{ma}SL_{post-e} = {}^{ma}SL_{pre-e}$$

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*The following letters indicate the test and treatment group for hypotheses seven through nine.

pre-e - pretest experimental group
post-e - posttest experimental group

Analyses of data relative to research hypothesis seven for the experimental A ability group. Analyses of null hypotheses 7a through 7f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 7a, 7b, 7c, and 7e were rejected, while 7d, and 7f were not rejected. Table 62 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade experimental A ability grouped students exposed to the Blue Version BSCS Biology course exhibited significant gains in knowledge, comprehension, and ability to apply basic biological principles, understanding of science and understandings about scientists as measured by the Nelson Biology Test, the Comprehensive Final Examination, and the Test On Understanding Science. No significant gains were made in understandings about the scientific enterprise or understandings about the methods and aims of science. Experimental A grouped students exposed to a Blue Version BSCS Biology course were able to achieve the objective of increased scientific literacy on most measures.

Analyses of data relative to research hypothesis seven for the experimental B ability group. Analyses of null hypotheses 7a through 7f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Table 62. Data relative to mean gains from pretest to posttest for scientific literacy for the experimental A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
7a	Nelson	27.41	47.59	20.19	50.98	14.421	$< .01$	r
7b	Comprehensive Final	21.78	32.00	10.22	23.14	10.872	$< .01$	r
7c	TOUS	34.78	37.56	2.78	25.50	2.808	$< .01$	r
7d	Enterprise	11.07	11.96	.89	8.01	1.589	$> .05$	nr
7e	Scientists	11.59	12.74	1.15	5.15	2.555	$< .01$	r
7f	Methods Aims	12.11	12.85	.74	8.41	1.298	$> .05$	nr

$\alpha = .05$ $N = 27$

$t_{.05} = 1.706$ $df = 26$

$t_{.01} = 2.479$

Results of the analyses indicated that null hypotheses 7a through 7e were rejected, while 7f was not rejected. Table 63 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade experimental B ability grouped students exposed to the Yellow Version BSCS Biology course exhibited significant gains in knowledge, comprehension, and ability to apply basic biological principles, understanding of science, understandings about the scientific enterprise, and understandings about scientists as measured by the Nelson Biology Test, the Comprehensive Final Examination, and the Test on Understanding Science. No significant gain was made on understandings about the methods and aims of science. Experimental B grouped students exposed to a Yellow Version BSCS Biology course were able to achieve the objective of increased scientific literacy on all but one measure.

Analyses of data relative to research hypothesis seven for the experimental C ability group. Analyses of null hypotheses 7a through 7f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 7b through 7f were not rejected, while 7a was rejected. Table 64 contains pertinent data relative to these hypotheses.

Based on the rejection of hypothesis 7a, tenth grade experimental C ability grouped students exposed to a general

Table 63. Data relative to mean gains from pretest to posttest for scientific literacy for the experimental B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
7a	Nelson	16.97	31.12	14.15	47.75	11.598	$< .01$	r
7b	Comprehensive Final	18.21	21.88	3.67	33.64	3.598	$< .01$	r
7c	TOUS	25.18	27.61	2.42	24.30	2.781	$< .01$	r
7d	Enterprise	7.88	9.00	1.12	6.60	2.434	$< .05$	r
7e	Scientists	8.55	9.52	.97	7.95	1.940	$< .05$	r
7f	Methods Aims	8.76	9.09	.33	14.52	.492	$> .05$	nr

$\alpha = .05$ N = 33

$t_{.05} = 1.694$ df = 32

$t_{.01} = 2.451$

Table 64. Data relative to mean gains from pretest to posttest for scientific literacy for the experimental C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
7a	Nelson	15.23	18.87	3.63	47.20	2.835	$< .01$	r
7b	Comprehensive Final	15.37	15.57	.20	19.71	.243	$> .05$	nr
7c	TOUS	21.63	21.63	.00	32.26	.000	$> .05$	nr
7d	Enterprise	6.57	6.67	.10	10.30	.166	$> .05$	nr
7e	Scientists	7.23	6.97	-.26	6.92	-.520	$> .05$	nr
7f	Methods Aims	8.00	8.00	.00	10.96	.000	$> .05$	nr

$\alpha = .05$ N = 30

$t_{.05} = 1.699$ df = 29

$t_{.01} = 2.462$

survey Biology course exhibited significant gains in knowledge, comprehension, and ability to apply basic biological principles as measured by the Nelson Biology Test but not by the Comprehensive Final Examination. No significant gains were made in understanding of science, understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science as measured by the Test on Understanding Science. Experimental C ability grouped students exposed to a general survey Biology course were able to achieve the objective of increased scientific literacy on only one measure.

Summary hypothesis seven. The three experimental ability groups made significant gains on at least one measure of increased scientific literacy. The A group made significant gains on all measures except understandings about the scientific enterprise and understandings about the methods and aims of science. The B group made significant gains on all variables but understandings about the methods and aims of science. The C group made a significant gain only in knowledge, comprehension, and ability to apply basic biological principles.

The Formula for research hypothesis eight was:

$$H_8 : P_{post} > P_{pre}$$

The formulae for null hypotheses relative to research hypothesis eight were:

$$H_{0_{8a}} : post_{P_{post-e}} = post_{P_{pre-e}}$$

$$H_{0_{8b}} : ct_{P_{post-e}} = ct_{P_{pre-e}}$$

$$H_{0_{8c}} : i_{P_{post-e}} = i_{P_{pre-e}}$$

$$H_{0_{8d}} : a_{P_{post-e}} = a_{P_{pre-e}}$$

$$H_{0_{8e}} : d_{P_{post-e}} = d_{P_{pre-e}}$$

$$H_{0_{8f}} : in_{P_{post-e}} = in_{P_{pre-e}}$$

$$H_{0_{8g}} : ar_{P_{post-e}} = ar_{P_{pre-e}}$$

Analyses of data relative to research hypothesis eight for the experimental A ability group. Analyses of null hypotheses 8a through 8g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 8a, 8b, 8d, 8e, and 8f were rejected, while 8c and 8g were not rejected. Table 65 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade A ability grouped experimental students exposed to the Blue Version BSCS Biology course exhibited significant gains in understanding of the processes of science, critical thinking, assumptions, deductions, and interpretations, but did not achieve significant gains in understandings concerning inferences and argument as measured by the Processes of Science Test and the

Table 65. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the experimental A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
8a	POST	27.92	31.44	3.52	9.73	5.770	$< .01$	r
8b	Critical Thinking	66.00	73.59	7.59	54.61	5.234	$< .01$	r
8c	Inference	11.37	12.33	.96	8.35	1.684	$> .05$	nr
8d	Assumption	9.07	11.33	2.26	35.76	1.931	$< .05$	r
8e	Deduction	17.41	19.67	2.26	4.20	5.650	$< .01$	r
8f	Interpretation	18.11	19.48	1.37	7.40	2.584	$< .01$	r
8g	Argument	10.04	10.52	.48	4.20	1.200	$> .05$	nr

$\alpha = .05$ N = 27

$t_{.05} = 1.706$ df = 26

$t_{.01} = 2.479$

Watson-Glaser Critical Thinking Appraisal. Tenth grade experimental A grouped students exposed to the Blue Version BSCS Biology course were able to achieve the objective of increased understanding of and ability to use the processes of science on most measures.

Analyses of data relative to research hypothesis eight for the experimental B ability group. Analyses of null hypotheses 8a through 8g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 8a, 8b, 8e, 8f, and 8g were rejected, while 8c and 8d were not rejected. Table 66 contains pertinent data relative to these hypotheses.

Based on the rejections, the experimental B ability grouped students exposed to the Yellow Version BSCS Biology course exhibited significant gains in understanding of the processes of science, critical thinking, deductions, interpretations, and arguments, but not in understanding of inferences and assumptions as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Experimental B grouped tenth grade students exposed to the Yellow Version BSCS Biology course were able to achieve the objective of increased understanding of and ability to use the processes of science on most measures.

Table 66. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the experimental B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
8a	POST	19.18	24.45	5.27	24.01	6.057	$< .01$	r
8b	Critical Thinking	57.21	62.76	5.55	92.16	3.264	$< .01$	r
8c	Inference	9.00	9.45	.45	15.44	.652	$> .05$	nr
8d	Assumption	8.97	10.00	1.03	16.81	1.410	$> .05$	nr
8e	Deduction	15.58	17.09	1.52	14.67	2.235	$< .05$	r
8f	Interpretation	15.27	17.00	1.73	13.54	2.661	$< .01$	r
8g	Argument	8.39	9.21	.82	4.20	2.277	$< .05$	r

$\alpha = .05$ N = 33

$t_{.05} = 1.694$ df = 32

$t_{.01} = 2.451$

Analyses of data relative to research hypothesis eight for the experimental C ability group. Analyses of null hypotheses 8a through 8g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 8a through 8g were not rejected. Table 67 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, the experimental C ability grouped students exposed to a general survey Biology course did not exhibit significant gains in understanding of the processes of science, critical thinking, inferences, assumptions, deductions, interpretations, and arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. Experimental tenth grade C ability grouped students exposed to a general survey Biology course did not achieve the objective of increased understanding of and ability to use the processes of science.

Summary hypothesis eight. The A and B experimental ability groups made significant gains for most variables indicative of increased understanding of and ability to use the processes of science. The C experimental group did not achieve the objective of increased understanding of and ability to use the processes of science.

Table 67. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the experimental C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
8a	POST	15.30	15.70	.40	24.80	.430	> .05	nr
8b	Critical Thinking	51.07	52.97	1.90	82.08	1.130	> .05	nr
8c	Inference	6.97	7.27	.30	8.29	.555	> .05	nr
8d	Assumption	9.17	8.97	-.20	10.37	-.333	> .05	nr
8e	Deduction	14.03	14.53	.50	10.30	.833	> .05	nr
8f	Interpretation	13.63	14.83	1.20	20.34	1.428	> .05	nr
8g	Argument	7.27	7.43	.17	13.32	.250	> .05	nr

$\alpha = .05$ N = 30

$t_{.05} = 1.699$ df = 29

$t_{.01} = 2.462$

The formula for research hypothesis nine was:

$$H_9 \; : \; I_{post} > I_{pre}$$

The formulae for null hypotheses relative to research hypothesis nine were:

$$H_{0_{9a}} \; : \; o_{I_{post-e}} = o_{I_{pre-e}}$$

$$H_{0_{9b}} \; : \; s_{I_{post-e}} = s_{I_{pre-e}}$$

$$H_{0_{9c}} \; : \; at_{I_{post-e}} = at_{I_{pre-e}}$$

Analyses of data relative to research hypothesis nine for the experimental A ability group. Analyses of null hypotheses 9a through 9c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 9a through 9c were not rejected. Table 68 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, the experimental A ability grouped students exposed to the Blue Version BSCS Biology course did not exhibit significant gains in interest in outdoor activities, scientific activities, and attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. Experimental A grouped tenth grade students exposed to the Blue Version BSCS Biology course did not achieve the objective of increased interest in science in general and biology in particular.

Table 68. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the experimental A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
9a	Outdoor	34.33	37.96	3.63	111.09	.753	> .05	nr
9b	Scientific	35.33	35.81	.48	75.34	.282	> .05	nr
9c	Attitude	6.93	6.91	-.02	3.50	-.055	> .05	nr

$\alpha = .05$ N = 27

$t_{.05} = 1.706$ df = 26

$t_{.01} = 2.479$

Analyses of data relative to research hypothesis nine for the experimental B ability group. Analyses of null hypotheses 9a through 9c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 9a through 9c were not rejected. Table 69 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, the experimental B ability grouped students exposed to the Yellow Version BSCS Biology course did not exhibit significant gains in interest in outdoor activities, scientific activities, and attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. Experimental B grouped tenth grade students exposed to the Yellow Version Biology course did not achieve the objective of increased interest in science in general and biology in particular.

Analyses of data relative to research hypothesis nine for the experimental C ability group. Analyses of null hypotheses 9a through 9c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 9a through 9c were not rejected. Table 70 contains pertinent data relative to these hypotheses.

Table 69. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the experimental B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
9a	Outdoor	38.70	39.00	.30	120.12	.154	$> .05$	nr
9b	Scientific	34.91	33.85	-1.06	122.10	-.543	$> .05$	nr
9c	Attitude	6.61	6.57	-.04	3.39	-.121	$> .05$	nr

$\alpha = .05$ N = 33
$t_{.05} = 1.694$ df = 32
$t_{.01} = 2.451$

Table 70. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the experimental C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
9a	Outdoor	37.03	38.10	1.07	47.25	.884	$> .05$	nr
9b	Scientific	35.17	34.47	-.70	82.99	-.414	$> .05$	nr
9c	Attitude	7.64	6.75	-.89	3.20	-2.696	$> .05$	nr

$\alpha = .05$ N = 30

$t_{.05} = 1.699$ df = 29

$t_{.01} = 2.462$

Based on the lack of rejections, the experimental C ability grouped students exposed to a general survey Biology course did not exhibit significant gains in interest in outdoor activities, scientific activities, and attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. Experimental C grouped tenth grade students exposed to a general survey Biology course did not achieve the objective of increased interest in science in general and biology in particular.

Summary hypothesis nine. None of the ability groups of experimental tenth grade students were able to achieve the objective of increased interest in science in general and biology in particular.

Analyses of research hypotheses ten, eleven, and twelve relative to mean gains and objective achievement for the control A, B, and C ability groups. Analyses were made using pretest to posttest mean gains for the control A, B, and C ability groups. Analyses of the following null hypotheses were based on six scores for scientific literacy, seven scores for processes of science, and three scores for interest in science for the A, B, and C ability groups.

The formula for research hypothesis ten was:

$$H_{10} : SL_{post-c} > SL_{pre-c}$$

The formulae for null hypotheses relative to research hypothesis ten were:

$H_{0_{10a}}$: $n_{SL_{post-c}} = n_{SL_{pre-c}}$*

$H_{0_{10b}}$: $cf_{SL_{post-c}} = cf_{SL_{pre-c}}$

$H_{0_{10c}}$: $tous_{SL_{post-c}} = tous_{SL_{pre-c}}$

$H_{0_{10d}}$: $e_{SL_{post-c}} = e_{SL_{pre-c}}$

$H_{0_{10e}}$: $s_{SL_{post-c}} = s_{SL_{pre-c}}$

$H_{0_{10f}}$: $ma_{SL_{post-c}} = ma_{SL_{pre-c}}$

Analyses of data relative to research hypothesis ten for the control A ability group. Analyses of null hypotheses 10a through 10f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 10a and 10b were rejected, while null hypotheses 10c through 10f were not rejected. Table 71 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade control A ability grouped students exposed to no science course for a year exhibited significant gains in knowledge, comprehension, and ability to apply basic biological principles as measured by the Nelson Biology Test and the Comprehensive Final Examination. No significant gains were made in understanding of

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*The following letters indicate the test and treatment group for hypotheses ten through twelve.

pre-c - pretest control group
post-c - posttest control group

Table 71. Data relative to mean gains from pretest to posttest for scientific literacy for the control A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
10a	Nelson	29.14	33.47	4.33	45.43	2.867	$< .01$	r
10b	Comprehensive Final	21.33	23.71	2.38	16.81	2.586	$< .01$	r
10c	TOUS	34.33	35.19	.86	50.84	.540	$> .05$	nr
10d	Enterprise	11.05	11.24	.19	7.24	.316	$> .05$	nr
10e	Scientists	11.05	11.76	.71	4.49	1.510	$> .05$	nr
10f	Methods Aims	12.24	12.19	-.05	16.73	-.054	$> .05$	nr

$\alpha = .05$ N = 21

$t_{.05} = 1.725$ df = 20

$t_{.01} = 2.528$

science, understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science as measured by the Test on Understanding Science. The control A ability grouped tenth grade students exposed to no science course for a year were able to achieve one phase of the objective of increased scientific literacy.

Analyses of data relative to research hypothesis ten for the control B ability group. Analyses of null hypotheses 10a through 10f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 10a and 10b were rejected, while 10c through 10f were not rejected. Table 72 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade control B ability grouped students exposed to no science course for a year exhibited significant gains in knowledge, comprehension and ability to apply basic biological principles as measured by the Nelson Biology Test and the Comprehensive Final Examination. No significant gains were made in understanding of science, understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science as measured by the Test on Understanding Science. The control B ability grouped tenth

Table 72. Data relative to mean gains from pretest to posttest for scientific literacy for the control B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
10a	Nelson	19.27	21.59	2.32	36.72	2.297	$< .05$	r
10b	Comprehensive Final	19.97	18.41	1.57	19.00	2.150	$< .05$	r
10c	TOUS	29.59	28.24	-1.35	29.48	-1.483	$> .05$	nr
10d	Enterprise	9.19	8.68	-.51	5.76	-1.275	$> .05$	nr
10e	Scientific	10.24	9.73	-.51	6.97	-1.159	$> .05$	nr
10f	Methods Aims	10.16	9.84	-.32	9.30	-.627	$> .05$	nr

$\alpha = .05$ N = 37

$t_{.05} = 1.689$ df = 36

$t_{.01} = 2.437$

grade students exposed to no science course for a year were able to achieve one phase of the objective of increased scientific literacy.

Analyses of data relative to research hypothesis ten for the control C ability group. Analyses of null hypotheses 10a through 10f were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 10a through 10f were not rejected. Table 73 contains pertinent data relative to these hypotheses.

Based on the lack of rejections, tenth grade control ability grouped students exhibited no significant gains in knowledge, comprehension, and ability to apply basic biological principles, understanding of science, understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science as measured by the Nelson Biology Test, the Comprehensive Final Examination, and the Test on Understanding Science. The control C ability group did not achieve the objective of increased scientific literacy as measured by mean gain for any of the measures.

Summary hypothesis ten. Increased scientific literacy as measured by mean gain was achieved for knowledge, comprehension, and ability to apply basic biological principles by the A and B control groups but not the C control group.

Table 73. Data relative to mean gains from pretest to posttest for scientific literacy for the control C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
10a	Nelson	14.86	15.21	.34	40.83	.280	$> .05$	nr
10b	Comprehensive Final	15.41	15.41	.00	24.60	.000	$> .05$	nr
10c	TOUS	23.66	22.10	-1.55	32.26	-1.448	$> .05$	nr
10d	Enterprise	7.41	6.58	-.83	8.94	-1.456	$> .05$	nr
10e	Scientists	7.72	7.38	-.34	12.60	-.501	$> .05$	nr
10f	Methods Aims	8.52	8.14	-.38	13.54	-.550	$> .05$	nr

$\alpha = .05$ N = 29

$t_{.05} = 1.701$ df = 28

$t_{.01} = 2.467$

On all other measures of increased scientific literacy the A, B, and C control groups exposed to no science course for a year did not achieve significant gains.

The formula for research hypothesis eleven was:

$$H_{11} : P_{post-c} > P_{pre-c}$$

The formulae for null hypotheses relative to research hypothesis eleven were:

$$H_{O_{11a}} : post_{P_{post-c}} = post_{P_{pre-c}}$$

$$H_{O_{11b}} : ct_{P_{post-c}} = ct_{P_{pre-c}}$$

$$H_{O_{11c}} : i_{P_{post-c}} = i_{P_{pre-c}}$$

$$H_{O_{11d}} : a_{P_{post-c}} = a_{P_{pre-c}}$$

$$H_{O_{11e}} : d_{P_{post-c}} = d_{P_{pre-c}}$$

$$H_{O_{11f}} : in_{P_{post-c}} = in_{P_{pre-c}}$$

$$H_{O_{11g}} : ar_{P_{post-c}} = ar_{P_{pre-c}}$$

Analyses of data relative to research hypothesis eleven for the control A ability group. Analyses of null hypotheses 11a through 11g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 11a, 11b, 11e, and 11f were rejected, while 11c, 11d, and 11g were not rejected. Table 74 contains pertinent data relative to these hypotheses.

Table 74. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the control A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
11a	POST	26.29	30.00	3.71	12.74	4.637	$< .01$	r
11b	Critical Thinking	68.62	74.14	5.52	39.94	3.914	$< .01$	r
11c	Inference	11.33	12.19	.86	5.81	1.592	$> .05$	nr
11d	Assumption	10.10	11.33	1.24	24.30	1.127	$> .05$	nr
11e	Deduction	18.33	19.76	1.43	10.24	2.014	$< .05$	r
11f	Interpretation	18.57	20.00	1.43	7.78	2.306	$< .05$	r
11g	Argument	10.29	10.86	.57	4.45	1.212	$> .05$	nr

$\alpha = .05$ N = 21

$t_{.05} = 1.725$ df = 20

$t_{.01} = 2.528$

Based on the rejections, tenth grade control A ability grouped students exposed to no science course for a year exhibited significant gains in understanding of the processes of science, critical thinking, deductions, and interpretations, but no significant gains in inferences, assumptions, and arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. The control A ability group exposed to no science course for a year was able to achieve the objective of increased understanding of and ability to use the processes of science on some measures of mean gains.

Analyses of data relative to research hypothesis eleven for the control B ability group. Analyses of null hypotheses 11a through 11 g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 11a, 11b, 11e, and 11f were rejected, while 11c, 11d, and 11g were not rejected. Table 75 contains pertinent data relative to these hypotheses.

Based on the rejections, tenth grade control B ability grouped students exposed to no science course for a year exhibited significant gains in understanding of the processes of science, critical thinking, deductions, and interpretations, but not in inferences, assumptions, and arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Appraisal. The control B ability group exposed to no

Table 75. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the control B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
11a	POST	21.24	23.73	2.49	19.54	3.410	$< .01$	r
11b	Critical Thinking	60.38	64.73	4.35	63.36	3.270	$< .01$	r
11c	Inference	10.30	10.51	.22	11.42	.386	$> .05$	nr
11d	Assumption	10.35	11.00	.65	11.97	1.140	$> .05$	nr
11e	Deduction	15.16	17.35	2.19	12.18	3.775	$< .01$	r
11f	Interpretation	15.65	16.68	1.03	9.80	1.980	$< .05$	r
11g	Argument	8.92	9.19	.27	6.35	.642	$> .05$	nr

$\alpha = .05$ N = 37

$t_{.05} = 1.689$ df = 36

$t_{.01} = 2.437$

science course for a year was able to achieve the objective of increased understanding of and ability to use the processes of science on some measures of mean gains.

Analyses of data relative to research hypothesis eleven for the control C ability group. Analyses of null hypotheses 11a through 11g were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 11b and 11c were rejected, while 11a, 11d, 11e, 11f, and 11g were not rejected. Table 76 contains data pertinent to these hypotheses.

Based on the rejections, tenth grade control C ability grouped students exposed to no science course for a year exhibited significant gains in critical thinking and inferences, but not in understanding of the processes of science, assumptions, deductions, interpretations, and arguments as measured by the Processes of Science Test and the Watson-Glaser Critical Thinking Appraisal. The control C ability group exposed to no science course for a year was able to achieve the objectives of increased understanding of and ability to apply the processes of science on a few measures of mean gain.

Summary hypothesis eleven. The control A, B, and C ability groups exhibited significant gains for some measures of increased understanding of and ability to use the processes of science, although they had no science course for a year.

Table 76. Data relative to mean gains from pretest to posttest for understanding of and ability to use the processes of science for the control C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
11a	POST	17.17	18.07	.90	23.62	.978	$> .05$	nr
11b	Critical Thinking	55.66	59.83	4.17	46.65	3.232	$< .01$	r
11c	Inference	7.93	9.72	1.79	5.38	4.068	$< .01$	r
11d	Assumption	8.72	10.03	1.31	91.20	.723	$> .05$	nr
11e	Deduction	15.59	16.00	.41	13.99	.577	$> .05$	nr
11f	Interpretation	14.79	15.62	.83	11.29	1.317	$> .05$	nr
11g	Argument	8.62	8.45	-.17	7.45	-.326	$> .05$	nr

$\alpha = .05$ $N = 29$

$t_{.05} = 1.701$ $df = 28$

$t_{.01} = 2.467$

The formula for research hypothesis twelve was:

$$H_{12} \; : \; I_{post-c} > I_{pre-c}$$

The formulae for null hypotheses relative to research hypothesis twelve were:

$$H_{O_{12a}} \; : \; {}^{o}I_{post-c} = {}^{o}I_{pre-c}$$

$$H_{O_{12b}} \; : \; {}^{s}I_{post-c} = {}^{s}I_{pre-c}$$

$$H_{O_{12c}} \; : \; {}^{at}I_{post-c} = {}^{at}I_{pre-c}$$

Analyses of data relative to research hypothesis twelve for the control A ability group. Analyses of null hypotheses 12a through 12c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 12a through 12c were not rejected. Table 77 contains data pertinent to these hypotheses.

Based on the lack of rejections, tenth grade control A ability grouped students did not achieve significant gains in interest in outdoor activities, scientific activities, or attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. The control A ability group students exposed to no science course for a year did not achieve the objective of increased interest in science in general and biology in particular as measured by mean gains.

Table 77. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the control A ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
12a	Outdoor	38.43	38.29	-.14	48.02	.090	> .05	nr
12b	Scientific	39.24	37.00	-2.24	36.36	-1.659	> .05	nr
12c	Attitude	7.05	7.05	-.004	1.10	.016	> .05	nr

$\alpha = .05$ $N = 21$

$t_{.05} = 1.725$ $df = 20$

$t_{.01} = 2.528$

Analyses of data relative to research hypothesis twelve for the control B ability group. Analyses of null hypotheses 12a through 12c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 12a through 12c were not rejected. Table 78 contains data pertinent to these hypotheses.

Based on the lack of rejections, tenth grade control B ability grouped students did not achieve significant gains in interest in outdoor activities, scientific activities, or attitude toward a biology course.as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. The control B ability group students exposed to no science course for a year did not achieve the objective of increased interest in science in general and biology in particular as measured by mean gains.

Analyses of data relative to research hypothesis twelve for the control C ability group. Analyses of null hypotheses 12a through 12c were made using a t test for the significance of mean gains with a pre-established rejection level set at .05.

Results of the analyses indicated that null hypotheses 12a through 12c were not rejected. Table 79 contains data pertinent to these hypotheses.

Table 78. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the control B ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
12a	Outdoor	33.22	33.30	.08	118.16	.044	> .05	nr
12b	Scientific	38.54	34.43	-4.11	50.84	-3.453	> .05	nr
12c	Attitude	6.87	6.34	-.53	2.04	-2.208	> .05	nr

$\alpha = .05$ N = 37

$t_{.05} = 1.689$ df = 36

$t_{.01} = 2.437$

Table 79. Data relative to mean gains from pretest to posttest for interest in science in general and biology in particular for the control C ability group.

H_o	Evaluation Instrument	Pretest Mean	Posttest Mean	Mean Difference	Variance	t	Sig.	Rejection
12a	Outdoor	31.55	32.28	.72	52.71	.525	>.05	nr
12b	Scientific	30.00	26.69	-3.31	43.03	-2.669	>.05	nr
12c	Attitude	6.98	5.40	-1.58	5.15	-3.761	>.05	nr

$\alpha = .05$ N = 29

$t_{.05} = 1.701$ df = 28

$t_{.01} = 2.467$

Based on the lack of rejections, tenth grade control C ability grouped students did not achieve significant gains in interest in outdoor activities, scientific activities, or attitude toward a biology course as measured by the Kuder Preference Record Outdoor and Scientific subtests and A Scale to Measure Attitude Toward Any School Subject. The control C ability group students exposed to no science course for a year did not achieve the objective of increased interest in science in general and biology in particular as measured by mean gains.

Summary hypothesis twelve. No significant gains were made by any of the three control ability groups for increased interest in science in general and biology in particular.

Summary of findings for hypotheses one through twelve. Summaries of the results for hypotheses one through twelve are found in Tables 80 through 83.

Table 80. Summary of results for hypotheses one, two, and three for the A, B, and C ability groups for the covariant t test.

H	H_o	Evaluation Instrument	Ability Group A	Ability Group B	Ability Group C
1	a	Nelson	r*	r	r
	b	Comprehensive Final	r	r	nr*
	c	TOUS	nr	r	nr
	d	Enterprise	nr	r	nr
	e	Scientists	nr	nr	nr
	f	Methods-Aims	nr	nr	nr
2	a	POST	nr	r	nr
	b	Critical Thinking	nr	nr	nr
	c	Inference	nr	nr	nr
	d	Assumption	nr	nr	nr
	e	Deduction	nr	nr	nr
	f	Interpretation	nr	nr	nr
	g	Argument	nr	nr	nr
3	a	Outdoor	nr	nr	nr
	b	Scientific	nr	nr	r
	c	Attitude	nr	nr	r

* r - rejected
nr - not rejected

Table 81. Summary of results for hypotheses four, five, and six for the male and female A, B, and C ability groups for the two-way analysis of variance.

H	H_o	Evaluation Instrument	Independent Variable	Ability Group A	Ability Group B	Ability Group C
4	a	Nelson	Sex	nr*	nr	r*
			Interaction	nr	nr	nr
	b	Comprehensive Final	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	c	TOUS	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	d	Enterprise	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	e	Scientists	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	f	Methods-Aims	Sex	nr	nr	nr
			Interaction	nr	nr	r
5	a	POST	Sex	r	nr	nr
			Interaction	nr	nr	nr
	b	Critical Thinking	Sex	r	nr	nr
			Interaction	nr	nr	nr
	c	Inference	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	d	Assumption	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	e	Deduction	Sex	r	nr	nr
			Interaction	nr	nr	nr
	f	Interpretation	Sex	nr	nr	nr
			Interaction	nr	nr	nr
	g	Argument	Sex	r	nr	nr
			Interaction	nr	nr	nr
6	a	Outdoor	Sex	nr	nr	r
			Interaction	nr	nr	nr
	b	Scientific	Sex	r	r	r
			Interaction	nr	nr	nr
	c	Attitude	Sex	nr	nr	nr
			Interaction	nr	nr	nr

* r - rejected
nr - not rejected

Table 82. Summary of results for hypotheses seven, eight and nine for mean gains for the experimental A, B, and C ability groups for the t test.

H	H_o	Evaluation Instrument	Ability Group		
			A	B	C
7	a	Nelson	r*	r	r
	b	Comprehensive Final	r	r	nr*
	c	TOUS	r	r	nr
	d	Enterprise	nr	r	nr
	e	Scientists	r	r	nr
	f	Methods-Aims	nr	nr	nr
8	a	POST	r	r	nr
	b	Critical Thinking	r	r	nr
	c	Inference	nr	nr	nr
	d	Assumption	r	nr	nr
	e	Deduction	r	r	nr
	f	Interpretation	r	r	nr
	g	Argument	nr	r	nr
9	a	Outdoor	nr	nr	nr
	b	Scientific	nr	nr	nr
	c	Attitude	nr	nr	nr

* r - rejected
nr - not rejected

Table 83. Summary of results for hypotheses ten, eleven, and twelve for mean gains for the control A, B, and C ability groups for the t test.

H	H_o	Evaluation Instrument	Ability Group A	B	C
10	a	Nelson	r*	r	nr*
	b	Comprehensive Final	r	r	nr
	c	TOUS	nr	nr	nr
	d	Enterprise	nr	nr	nr
	e	Scientists	nr	nr	nr
	f	Methods-Aims	nr	nr	nr
11	a	POST	r	r	nr
	b	Critical Thinking	r	r	r
	c	Inference	nr	nr	r
	d	Assumption	nr	nr	nr
	e	Deduction	r	r	nr
	f	Interpretation	r	r	nr
	g	Argument	nr	nr	nr
12	a	Outdoor	nr	nr	nr
	b	Scientific	nr	nr	nr
	c	Attitude	nr	nr	nr

* r - rejected
nr - not rejected

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study was designed to determine the achievement of selected general objectives by tenth grade students exposed to the A, B, and C ability level biology courses of the Cherry Hill School System. A nonequivalent control group design was developed using sixteen pretest and posttest scores selected as indicative of achievement of increased scientific literacy, increased understanding of and ability to use the processes of science, and increased interest in science in general and biology in particular. Null hypotheses were tested using a covariant t test for each ability group. Analyses of the significance of mean gains and sex relationships to objective achievement were also tested.

Summary of results for the A ability group. The tenth grade A ability grouped students exposed to the Blue Version BSCS Biology course achieved significantly greater gains than non-science tenth grade students in knowledge, comprehension and ability to apply basic biological principles thus achieving one phase of the objective of increased scientific literacy. The A biology group did not achieve significantly greater gains than the non-science group in understanding of and ability to use the processes of science or in interest in science in general and biology in particular.

Sex was not found to be a significant factor in achievement of increased scientific literacy for tenth grade A ability grouped male and female students exposed to the Blue Version BSCS Biology course or no science course. Sex was found to be a significant factor in achievement of understanding of and ability to use the processes of science and in interest in science in general and biology in particular on some of the measures indicative of achievement of these objectives. Males achieved greater means on the interest measures, while females achieved greater means on the processes of science measures. No significant interactions of sex and treatment were found.

Significant gains were made from pretest to posttest by experimental A grouped tenth grade students exposed to the Blue Version BSCS Biology course on most measures of increased scientific literacy and increased understanding of and ability to use the processes of science, but no significant gains were found from pretest to posttest in the area of increased interest in science in general and biology in particular.

Significant gains were found from pretest to posttest for the control A ability grouped non-science tenth grade students in knowledge, comprehension, and ability to apply basic biological principles, in understanding of science, and in critical thinking thus achieving some phases of increased scientific literacy and increased understanding of and ability to use the processes of science. No significant gains were found for increased interest in science in general and biology in particular.

Summary of results for the B ability group. The B ability level tenth grade students exposed to the Yellow Version BSCS Biology course achieved significantly greater gains than non-science tenth grade students in knowledge, comprehension, and ability to apply basic biological principles, in understanding of science, and in understanding of the processes of science thus achieving most facets of the objectives of increased scientific literacy, and one phase of increased understanding of and ability to use the processes of science. The B Biology group did not achieve significantly greater gains in the critical thinking phase of understanding of and ability to apply the processes of science, or in any phase of increased interest in science in general and biology in particular.

Sex was not found to be a significant factor in achievement of scientific literacy and understanding of and ability to use the processes of science for the tenth grade B ability grouped male and female students exposed to the Yellow Version BSCS Biology course or no science course. A significant difference for the sexes was found for interest in science in general and biology in particular. A greater mean was found for males on the Scientific subtest. No significant interactions for sex and treatment were found.

Significant gains were made from pretest to posttest by the experimental B ability grouped tenth grade students exposed to the Yellow Version BSCS Biology course in all but one phase of increased scientific literacy and in most measures of understanding of the processes of science, and the critical thinking phase of understanding of and ability to use the processes of science. No significant gains from pretest to posttest were found in interest in science in general and biology in particular.

Significant gains were made from pretest to posttest by control B ability grouped tenth grade non-science students in knowledge, comprehension, and ability to apply basic biological principles indicative of increased scientific literacy, but not in understanding of science. Significant gains were made on several measures of understanding of the processes of science and critical thinking indicative of increased understanding of and ability to use the processes of science. No significant gains were found for increased interest in science in general and biology in particular.

Summary of results for the C ability group. The C ability level tenth grade students exposed to a general survey Biology course achieved significantly greater gains than non-science students in knowledge, comprehension and ability to apply basic biological principles, in interest in scientific activities, and in positive attitude toward a biology course, thus achieving one phase of increased scientific literacy and two phases of increased interest in science in general and biology in particular. No significantly greater gains were found for any measures of increased understanding of and ability to use the processes of science.

Sex was found to be a significant factor in objective achievement for tenth grade male and female C ability grouped students exposed to a general survey Biology course or no science course for one phase of scientific literacy and for two phases of interest in science in general and biology in particular, but not in understanding of and ability to use the processes of science. Greater means were found for males in measures of scientific literacy and interest in science in general and biology in particular.

Significant gains were made from pretest to posttest by experimental C ability grouped tenth grade students exposed to a general survey Biology course in one phase of increased knowledge, comprehension, and ability to apply basic biological principles, but no significant gains were found in understanding of and ability to use the processes of science, and in interest in science in general and biology in particular.

Significant gains were made from pretest to posttest by control C ability grouped tenth grade non-science students in two phases of critical thinking indicative of increased understanding of and ability to use the processes of science, but no significant gains were found in scientific literacy and in interest in science in general and biology in particular.

Discussion. In addition to the limitation and assumptions previously enumerated in Chapter I some other considerations must be weighed when attempting to interpret these data internally as they pertain to the school system in question. These consideration should also be noted when attempting to generalize to other similar experimental situations.

One consideration is the fact that with a total of 192 hypotheses being tested the possibility of significant results due to chance must be noted at least at the level of alpha times 192 or ten possible significant results for the three parts of the experiment.

Although it appears that only the objective of increased scientific literacy was achieved by the experimental A ability grouped students when considering the control group comparison, significant growth in understanding of and ability to use the processes of science was identified using mean gain evaluation. This finding may be obscured in the control group comparison by the type of test used for critical thinking, which was of a social science format, and the possibility that other courses in the student's program may provide for similar gains in general critical thinking ability.

Although no significant gains were found in either the control group comparison or mean gain evaluation for the A group in the area of increased interest in science in general and biology in particular, means remained stable before and after exposure to the Blue Version BSCS Biology course and the mean for attitude toward a biology course remained above the indifference level of six for the A group.[1]

A finding to be noted is the significance of the mean gains by the tenth grade A ability group control students on both measures of increased scientific literacy. With no formal science course for a year, this particular level of student was able through their own efforts to learn a significant body of knowledge concerning biological facts and principles although not as much as those students in a formal biology course.

The B experimental group which failed to achieve increased critical thinking ability when compared to the control group does achieve significant mean gains from pretest to posttest evaluation in critical thinking. The significance may be obscured in the analyses by the type of test used for critical thinking, which was of a social science format, and the possibility that other courses in the student's program may provide for similar gains in general critical thinking ability.

Although significant gains were not found in interest in science in general and biology in particular, the tenth

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[1]H. H. Remmers, Manual for the Purdue Master Attitude Scales (Lafayette: Purdue University Book Store, 1960), p. 6.

grade B ability grouped students exhibited a stability of interest before and after exposure to the Yellow Version BSCS Biology course and maintained a mean above the indifference level of six concerning positive attitude toward a biology course.

A finding to be noted is the significance of the mean gains by the tenth grade B ability group control students on both measures of increased scientific literacy. With no formal science course for a year, this particular level of student was able through their own efforts to learn a significant body of knowledge concerning biological facts and principles although not as much as those students in a formal biology course.

The C ability group was a slow learner group. It was generally composed of students with limited reading ability. The tests used in this study were chosen for the reasons previously stated in Chapter III, but were apparently not the most suitable for groups of lower reading ability as noted for the Comprehensive Final and the Watson-Glaser Critical Thinking Appraisal.[2]

Sex was identified as a factor in achievement of scientific literacy and interest in science in general and biology

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[2]George M. Clark (ed.), "Evaluation Issue," BSCS Newsletter 30 (Boulder, Colorado: Biological Sciences Curriculum Study, January 1967), p. 7.

Goodwin Watson and Edward M. Glaser, Manual for Forms YM and ZM Watson-Glaser Critical Thinking Appraisal (New York: Harcourt, Brace and World, Inc., 1964), pp. 11-12.

in particular for C ability grouped students. This may have resulted from high mortality in the C groups especially among male students which resulted in extremely unequal numbers of males and females in the experimental and control groups.

Significant mean gains were not made by the experimental C group students exposed to a general survey Biology course, but in fact the means declined for all three measures of increased interest in science in general and biology in particular. In the control group comparison, results were significant for two measures since the control group means for interest in science and biology in particular declined to an even greater degree. Interest measures remained relatively stable for the C experimental group before and after exposure to a general survey Biology course and the mean for attitude toward a Biology course remained above the indifference level of six.

The control C ability group non-science students were not able to make significant gains in knowledge, comprehension, and ability to apply basic biological principles on their own when not exposed to a formal biology course as was found with the A and B ability groups.

<u>Conclusions</u>. It is to be noted that no cross comparisons were permitted between ability groups under the design of the study. Thus after analyses of the data, the following

conclusions concerning the twelve basic research hypotheses for the A, B, and C ability groups exposed to their respective biology courses were made.

1. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course partially achieved the objective of increased scientific literacy.

2. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course did not achieve the objective of increased understanding of and ability to use the processes of science.

3. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course did not achieve the objective of increased interest in science in general and biology in particular.

4. Sex was not a significant factor in the achievement of the objective of scientific literacy for tenth grade male and female A ability grouped students exposed to the Blue Version BSCS Biology course or no science course for the same period of time.

5. Sex was a significant factor on some measures in achievement of the objective of understanding of and ability to use the processes of science for tenth grade male and female A ability grouped students exposed to the Blue Version BSCS Biology course or no science course for the same period of time with females achieving greater means.

6. Sex was a significant factor on one measure in achievement of the objective of interest in science in general and biology in particular for tenth grade male and female A ability grouped students exposed to the Blue Version BSCS Biology course or no science course for the same period of time with males achieving greater means.

7. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course achieved significant mean gains from pretest to posttest on most measures of the objective of increased scientific literacy.

8. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course achieved significant mean gains from pretest to posttest on five of seven measures of the objective of increased understanding of and ability to use the processes of science.

9. A ability grouped tenth grade students exposed to a Blue Version BSCS Biology course did not achieve significant mean gains from pretest to posttest in the objective of increased interest in science in general and biology in particular.

10. A ability grouped tenth grade non-science students achieved significant mean gains from pretest to posttest on two measures of the objective of increased scientific literacy.

11. A ability grouped tenth grade non-science students achieved significant mean gains from pretest to posttest on most measures of the objective of increased understanding of the ability to use the processes of science.

12. A ability grouped tenth grade non-science students did not achieve significant mean gains from pretest to posttest in increased interest in science in general and biology in particular.

13. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course partially achieved the objective of increased scientific literacy.

14. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course partially achieved the objective of increased understanding of and ability to use the processes of science.

15. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course did not achieve the objective of increased interest in science in general and biology in particular.

16. Sex was not a significant factor in the achievement of the objective of scientific literacy for tenth grade male and female B ability grouped students exposed to the Yellow Version BSCS Biology course or no science course for the same period of time.

17. Sex was not a significant factor in the achievement of the objective of understanding of and ability to use the processes of science for tenth grade male and female B ability grouped students exposed to the Yellow Version BSCS Biology course or no science course for the same period of time.

18. Sex was a significant factor in the achievement of the objective of interest in science in general and biology in particular on one measure for tenth grade male and female B ability grouped students exposed to the Yellow Version BSCS Biology course or no science course for the same period of time with males achieving a greater mean.

19. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course achieved significant mean gains from pretest to posttest on all but one measure of the objective of increased scientific literacy.

20. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course achieved significant mean gains from pretest to posttest on most measures of the objective of increased understanding of and ability to use the processes of science.

21. B ability grouped tenth grade students exposed to a Yellow Version BSCS Biology course did not achieve significant mean gains from pretest to posttest in the objective of increased interest in science in general and biology in particular.

22. B ability grouped tenth grade non-science students achieved significant mean gains from pretest to posttest on two measures of the objective of increased scientific literacy.

23. B ability grouped tenth grade non-science students achieved significant mean gains from pretest to posttest on most measures of the objective of increased understanding of and ability to use the processes of science.

24. B ability grouped tenth grade non-science students did not achieve significant mean gains from pretest to posttest in the objective of increased interest in science in general and biology in particular.

25. C ability grouped tenth grade students exposed to a general survey Biology course achieved only one phase of the objective of increased scientific literacy.

26. C ability grouped tenth grade students exposed to a general survey Biology course did not achieve the objective of increased understanding of and ability to use the processes of science.

27. C ability grouped tenth grade students exposed to a general survey Biology course achieved the objective on two measures of increased interest in science in general and biology in particular, but did not achieve greater interest in outdoor activities.

28. Sex was a significant factor on one measure of achievement of the objective of scientific literacy for tenth grade male and female C ability grouped students exposed to a general survey Biology course or no science course for the same period of time.

29. Sex was not a significant factor in achievement of the objective of understanding of and ability to use the processes of science for tenth grade male and female C ability grouped students exposed to a general survey Biology course or no science course for the same period of time.

30. Sex was a significant factor in achievement of the objective of interest in science in general and biology in particular on two measures for tenth grade male and female C ability grouped students exposed to a general survey Biology course or no science course for the same period of time with males achieving greater means.

31. C ability grouped tenth grade students exposed to a general survey Biology course achieved significant mean gains from pretest to posttest on only one measure of the objective of increased scientific literacy.

32. C ability grouped tenth grade students exposed to a general survey Biology course did not achieve significant mean gains from pretest to posttest in the objective of increased understanding of and ability to use the processes of science.

33. C ability grouped tenth grade students exposed to a general survey Biology course did not achieve significant mean gains from pretest to posttest in the objective of increased interest in science in general and biology in particular.

34. C ability grouped tenth grade non-science students did not achieve significant mean gains from pretest to posttest in the objective of increased scientific literacy.

35. C ability grouped tenth grade non-science students achieved significant mean gains from pretest to posttest on two measures of the objectives of increased understanding of and ability to use the processes of science.

36. C ability grouped tenth grade non-science students did not achieve significant mean gains from pretest to posttest in the objective of increased interest in science in general and biology in particular.

Howe stated that teaching planned for objective achievement was more efficient than incidental teaching.[3] In this study, evidence was found to support the contention that biology courses can be developed and taught to provide for achievement of pre-determined general objectives. The evidence found in this study was more definitive in the cognitive areas of scientific literacy, but limited evidence was also found in the cognitive areas of critical thinking and the affective areas of interest in science and subject preference for biology. Each of the three ability levels exposed to its respective biology course was able to provide for increases in or a lack of reduction of the level of achievement in most areas of scientific literacy, understanding of and ability to use the processes of science, and interest in science in general and biology in particular.

Educational Implications. In this study, some basic findings were identified which are consistent with the theory

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[3]Robert Wilson Howe, "The Relationship of Learning Outcomes to Selected Teacher Factors and Teaching Methods in Tenth Grade Biology Classes in Oregon" (unpublished Doctor's dissertation, Corvallis: Oregon State University, 1964), p. 206.

established by previously reported research studies. Other findings were identified which are inconsistent with existing theory or new in their educational implications.

In the evaluation of achievement of scientific literacy, some basic consistencies and inconsistencies with previous research were found. In all previously reported studies of the gross method effect on achievement significant gains were made regardless of method. Increased knowledge, comprehension, and ability to apply basic biological principles was found for the A, B, and C ability groups in this study exposed to the Blue Version BSCS Biology course, Yellow Version BSCS Biology course and a general survey Biology course respectively, thus supporting the contention that gross method was capable of producing significant gains in achievement in scientific literacy regardless of method.

The achievement of increased scientific literacy by the A, and B ability groups using the Blue Version BSCS course and Yellow Version BSCS course respectively supports the contention of the conclusions of the BSCS evaluation projects of 1960 and 1961 that BSCS Versions were feasible and appropriate for average and above average tenth grade students.

In this study, significant gains on a non-BSCS test, the <u>Test on Understanding Science</u>, in achievement of scientific literacy were found for the A and B ability groups using BSCS courses. Such gains were not identified in the comparative method approach used in the BSCS evaluation project of 1961-62.

In both the BSCS evaluation projects of 1961-62 and 1964-65 and individual studies reported in Chapter II by Lance and Moore, males achieved higher means on both BSCS and non-BSCS tests used to evaluate achievement of scientific literacy. In this study inconsistencies were found in evaluation of sex as a factor in achievement of scientific literacy. In the A ability group females in both experimental and control groups consistently achieved higher means on pretesting and posttesting on almost all measures of scientific literacy. A factor to be considered in evaluation of these results is the higher average IQ level of the females. In the B and C ability groups males and females showed no consistency in achieving the higher means on measures of scientific literacy. However, sex was found to be significantly related to achievement of scientific literacy only with the C ability group as measured by the Nelson Biology Test.

The achievement of significant gains in scientific literacy as measured by mean gains from pretest to posttest on the Nelson Biology Test and the Comprehensive Final Examination for the control A and B non-science groups, raises a question concerning the degree of cognitive achievement in science which is attributable to formal science courses for average and above average students as reported in previous research studies. The evaluation of gains in comparative method studies fails to consider this finding.

More important is the evidence this provides to support the need for pre-evaluation in science courses to determine environmental effects on cognitive development in science.

As in all BSCS studies reported, the slow learner or C experimental and control ability groups in this study achieved no significant gains on the BSCS test of achievement. The identification by the BSCS study of 1963-64 that reading is highly correlated with achievement on the Comprehensive Final Examination may explain the failure of significant gains for the C group since one of the factors in placement in the C group is reading ability.

In the evaluation of increased understanding of and ability to use the processes of science, basic consistencies and inconsistencies with previous research were found. The contention that at least one phase of the processes of science, critical thinking, can be taught for and measured by the Watson-Glaser Critical Thinking Appraisal is partially supported by the results of this study.

As reported in Chapter II, Kastrinos, George, and Sorensen found significant gains in critical thinking for all methods tested in the teaching of biology. According to Cook the degree of change was found to be affected by methodology. In this study, significant mean gains were found on pretest to posttest measurements with the Watson-Glaser Critical Thinking Appraisal for the A and B experimental ability groups using the Blue and Yellow Versions of the BSCS Biology courses respectively. The C experimental group registered a mean loss in critical thinking, but the control A, B, and C groups achieved significant mean gains from pretest to posttest in critical thinking. Thus one may infer that absolute gains in critical thinking may be achieved through a variety of secondary school courses, and consequently may not be measurable as a gain of a given course in the design used in this study.

As reported in Chapter II, no significant differences were found in comparative method studies by BSCS, Gennaro, and Behringer on the Processes of Science Test. In this study, significant gains were found for the A and B ability groups exposed to the Blue Version BSCS Biology course and the Yellow Version BSCS Biology course respectively. Significant mean gains were also found for the A and B control non-science groups. These results raise a question as to the value of the Processes of Science Test as a measure of the processes of science unique to a science course.

In the evaluation of increased interest in science in general and biology in particular some basic consistencies and inconsistencies with previous research were found. Comparative method studies by Wallace, Oliver, Moore, and the BSCS evaluation project of 1961, as reported in Chapter II, found no significant differences in interest in science for a variety of teaching methods. In this study, significant differences were found only with the C ability group exposed to a general survey Biology course. Both the A and

B ability groups exposed to the Blue Version BSCS and Yellow Version BSCS Biology courses respectively did not achieve significant differences in increased interest in outdoor activities and scientific activities or positive attitude towards a biology course from control non-science groups. Mean gains from pretest to posttest were not found for interest in outdoor activities, scientific activities, or positive attitude towards a biology course for any of the ability groups exposed to their respective biology courses, but a level of attitude towards a biology course above the indifference score of six was maintained in all cases. These results support Wynn's contention, reported in Chapter II, that interest in science was stable for high school students.

As reported in Chapter II, Shepler, Wynn, and Powell found greater interest among males than females in science. Wynn and Shepler found greater means for males, while Powell found significant differences between male and female students in attitude towards a science course with males giving a higher ranking to science over other school subjects. In this study, sex was found to be a significant factor in achievement of scientific interest for the C ability group exposed to a general survey biology course as measured for interest in outdoor activities and scientific activities with males achieving greater means than females. Sex was found to be a significant factor in achievement of science interest as measured for interest in scientific activities for the A and B ability group students exposed to the Blue and Yellow Version BSCS Biology courses respectively with males achieving higher means than females. In general, for interest in outdoor activities and scientific activities, males achieved higher means than females for both experimental and control A, B, and C groups on the pretest and posttest except with the control A group. Higher means were found for males in measures of subject preference for a biology course for the B and C experimental ability groups, but a higher mean was found for females for the experimental A ability group.

Some problems for further research. Evaluation of science curricula in terms of objective achievement is a pressing need in all national and local projects. This study was an evaluation of two national BSCS courses and a locally developed biology course adapted to meet locally selected general objectives. Although the findings and conclusions of this study are limited in general to the system under study, further investigation is need, using this model, in evaluation of objective achievement in other science courses both national and local in origin in this system and in other school systems. Research is needed to develop a model for continuous evaluation of objective achievement to determine the consistency of objective achievement over several years under the unique circumstances of a given school system and a given course of study. Follow up studies are needed to determine the factors which influence the achievement of objectives and in particular for those objectives achieved in this study. Investigation is needed to determine the extent of cognitive achievement of understanding of the principles of science through methods other than formal secondary school science courses. Investigation is also needed to develop new evaluation instruments designed for evaluation of objective achievement especially in the affective area.

In the particular school system under study a behavioral objective approach is in the process of refinement. These behavioral objectives are designed to develop the general objectives evaluated in this study. Evaluation studies are needed to aid in the development and selection of behavioral objectives, to evaluate the methods of using behavioral objectives, and to evaluate the effectiveness of behavioral objectives in guiding the learner toward the achievement of general course objectives.

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APPENDICES

APPENDIX A

GENERAL OBJECTIVES

FOR

CHERRY HILL BIOLOGY COURSES

GENERAL OBJECTIVES

The Biology program of the Cherry Hill School System has been developed as one part of a total educational effort in science. It emphasizes the building of scientific literacy, understanding and skill in the use of scientific processes, cultivation of creative thought, increasing interest in science activities and the development of scientific attitudes.

The major objectives of this program are:

1. To build the student's <u>scientific literacy</u> for future responsible citizenship.

   a. Develop student knowledge, comprehension and ability to apply basic biological principles

      Evolution, Development, Genetic continuity of life, Diversity of type and unity of pattern of living things,
      Complementarity of organism and environment with emphasis on the human,
      Regulation and homeostasis

   b. Develop student understanding of the biological basis of problems in medicine, public health, agriculture, and conversation

   c. Development of student understanding and appreciation of scientists, their work, and the interrelationship of historical developments and contemporary technology in biology

2. To develop student understanding of and ability to use the <u>processes of science</u>.

   a. Develop the basic skills necessary in the study of science in general and biology in particular observation, classification, communication, inference measurement, prediction, space time relations and number relations

b. Develop student critical thinking or problem solving ability

Recognize problems, state problems, develop operational definitions, collect relevant data, interpret data, formulate hypotheses, experiment or test, draw valid conclusions, recognize basic assumptions

c. Develop student skill in the use of tools unique to biology

Microscope, Dissection, etc.

d. Develop student awareness of the role of mathematics and the other sciences as biological tools

3. To develop student <u>creativity</u>.

Encourage the student to develop original thinking, and foster the search for unique solutions to common problems

4. To develop student <u>interest</u> in science in general and biology in particular.

a. Develop student awareness of and interest in biological careers

b. Develop student interest in biologically oriented leisure time activities

c. Foster student enjoyment of learning in the biology classroom

5. To develop the student's <u>scientific attitudes</u>.

a. Foster student curiosity concerning scientific phenomena

b. Reduce student belief in superstition

c. Develop open-mindedness and reduce prejudice

d. Develop student awareness of the tentative nature of scientific data

APPENDIX B

GENERAL RATIONALE AND COURSE OUTLINES

FOR BIOLOGY IA, BIOLOGY IB, AND BIOLOGY IC COURSES

General Rationale*

At present the biological sciences are undergoing the greatest revolution in their history. There is four times as much significant biological knowledge today as in 1930, and about 16 times as much as in 1900. At this rate of increase there will be 100 times as much biological knowledge in the year 2000 as there was at the turn of this century. It is quite obvious, therefore, that we must be highly selective in our approach to teaching a modern secondary school biology course. We must include the most meaningful developments of the new biology together with the most profound insights of the older biology.

In the past the emphasis in the teaching of biology was placed upon authoritative content, fact, concepts, and principles. In BSCS Biology the emphasis is placed upon the investigative processes of the biological sciences and upon the history of scientific ideas as they apply to the biological sciences. Observation, experimentation, hypothesis, and verification are the cornerstones in a BSCS course.

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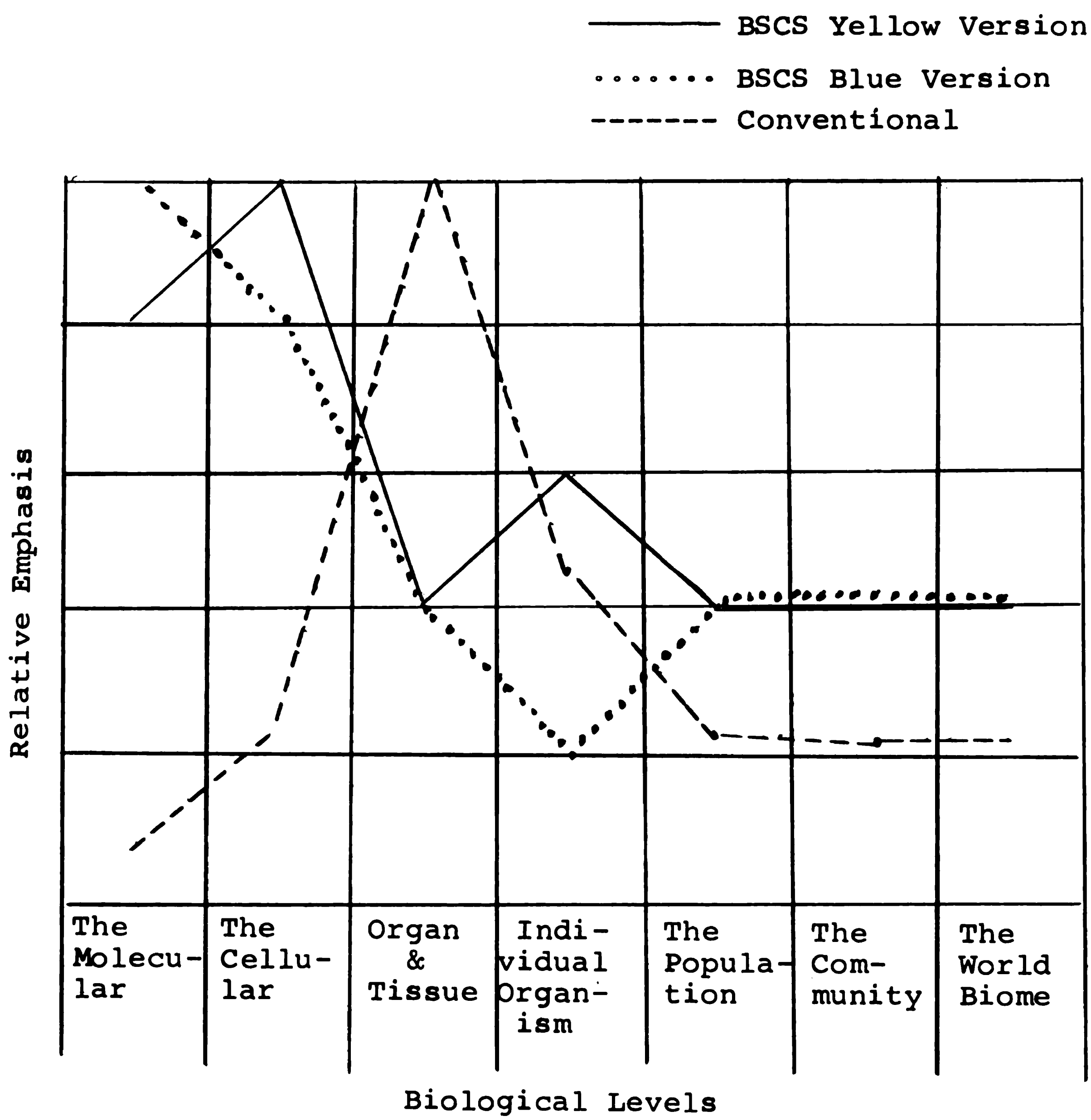
*Developed by the Biology Departments of the Cherry Hill High Schools.

The graph* below illustrates the comparative content and relative emphasis of the BSCS Yellow Version, BSCS Blue Version, and Conventional Biology textbooks.



*Taken from Biology Teachers' Handbook, Joseph J. Schwab. John Wiley and Sons, Inc., New York, 1963.

BSCS Blue Version

Biology I-A

The Blue Version is a course recently developed in the field of Biology by the Biological Sciences Curriculum Study Committee composed of scientists and educators through the auspicious of the National Science Foundation.

Major Aims

Recent exciting advances in Biology have come through an approach to its problems at the molecular or chemical level. Ths Blue Version has chosen to emphasize these recent advances by using a physiological, biochemical-evolution approach.

Although one of the major aims of this version is to describe the major contributions modern, molecular Biology has made to the general understanding of scientific problems, a second aim will also be apparent. Measured by almost any standard science has been, and continues to be, a powerful force in our society. A difficulty has arisen however. This difficulty arises from the fact that although many people may understand the products of science, at the same time they may be very ignorant of the nature of science and its methods of enquiry. It is probably a safe generalization to say that the understanding of the products of science cannot be attained unless the process is also understood. It is apparent that in a free society such as ours much will depend on the average citizen's evaluation of science. Since the high school biology course may be the last formal education in science for many of our citizens, it seems necessary that some attempt be made to illustrate the nature of science as well as its products.

As taught in the Cherry Hill High Schools, this course is specifically designed for the academically advanced student. It is recommended for students who have demonstrated superior ability and preparation in General Science A groups which provide desirable preparation in Chemistry.

Unifying Themes

The selection of these themes is based on two major factors.

1) An attempt to identify the characteristics, and concepts that provide the most comprehensive and reliable knowledge of living things as they are known to modern biology

2) A consideration of the needs of our nation and our fellow citizens

Themes

1. Change of living things through time; evolution

   a. Diversity of type and unity of pattern in living things

   b. Genetic continuity of life

2. The complementarity of organism and environment

   a. Biological roots of behavior

3. The complementarity of structure and function

4. Regulation and homeostasis: preservation of life in the face of change

5. Science as enquiry

6. The history of biological conceptions

Content

I. Interaction of facts and ideas

    a. Science as Inquiry

    b. Variety of living things

    c. Evolution - conflicting views

    d. Origin of living things

II. Evolution of the cell

    a. Forerunners of life

    b. Chemical energy for life

    c. Master molecules

    d. Biological code

III. Evolving Organism

    a. Light as Energy for life

    b. Evolved cell

    c. Cell theory

IV. Multicellular Organisms

    a. New Individuals

        1. Reproduction

        2. Development

    b. Genetic continuity

        1. Patterns of heredity

2. Genes and Chromosomes
3. Origin of New species
4. Human Species

c. Energy Utilization

1. Photosynthetic systems
2. Transport systems
3. Respiratory systems
4. Digestive systems
5. Excretory systems

d. Integrative systems

1. Regulatory systems
2. Nervous systems
3. Skeletal and muscular systems
4. Integrated organism and behavior

V. Higher levels of organization

a. Populations
b. Societies
c. Communities

Activities

Laboratory Investigations are correlated with the text materials. All exercises are designed as investigations and not for illustrative purposes. In each exercise the student learns to apply previous learning and discover new ideas.

Class activities include lecture, discussion, group work, demonstrations, etc.

Teaching Method

A coordinated team approach is used. A team of teachers plans and works as a unit. Large group instruction is periodically used on selected topics. An attempt is thus made to use each teacher's training and interests to the greatest possible advantage.

Evaluation

- Recitation section - (2/3rd of grade)
- Standardized exams
  - quarterly exams - multiple choice
  - Mid-year exam - part essay
  - Final - multiple choice
- Periodic tests
  - Teacher-made tests & quizzes - essay and objective
  - Teacher-pupil conferences
  - Class recitation
  - Laboratory section - (1/3rd of grade)
    - Laboratory reports - written in experimental form
    - Data Book - periodic grading
    - Laboratory performance

Supplementary activities

- Project - If desired by student
- Outside reading - selected science book

BSCS Yellow Version

Biology I-B

The Yellow Version approaches the study of biology from an investigative and problem solving base, and from the study of the historical progress in man's attempt to solve biological problems. It attempts to impart an understanding of biological inquiry, not merely the data of biology.

This approach is handled in each class by a team of teachers presenting the data of biology and a correlative laboratory experience. Four periods per week are spent in discussion and two periods per week in laboratory. Coordination of material is accomplished by weekly meetings of the teachers involved in this program.

Student evaluation is assessed by individual teacher quizzes and team-coordinated testing. BSCS Quarterly tests are used as the basis for the mid-term and final examination. Audio-visual materials are used as recommended in the BSCS Yellow Version program manuals. The BSCS Yellow Version course is offered primarily for the academic B level student. The outline of the Yellow Version Course of Study follows.

The BSCS Yellow Version attempts to give as much insight as possible into the major areas of modern biology. It does not attempt to emphasize one or a few areas to the disadvantage of others. Above all, it attempts to impart an understanding of biological inquiry, not merely the data it has yielded.

The Yellow Version stresses three major themes of study. They are: Unity of Life, Diversity of Life, and Continuity of Life. The first theme, Unity, attempts to demonstrate the basic similarities of all living things. The second, Diversity, concerns itself with the variations among living things. The third theme attempts to explain the Continuity of Life through heredity and evolution.

Content

I. Unity

a. A case history of a biological problem--man's most widespread and serious disease, malaria.

b. The implications of the biological question of spontaneous generation.

c. The unifying theory of cell structure and function.

d. The unity of the chemistry of life.

e. The unity of cell physiology.

f. The basic similarities of cellular reproduction.

g. The balance of nature--interaction and interdependence among living things.

II. Diversity

a. Microorganisms

1. The smallest living things--Viruses.

2. The pioneers of cellular organization--Bacteria.

3. The economic importance of microorganisms, and their control.

b. Plants

1. The fungi--molds, yeasts, and mushrooms.

2. The trend toward complexity--the evolution of algae.

3. The evolution of the bryophytes--the mosses and liverworts.

4. The link between two worlds--photosynthesis.

5. A study of complementarity of structure and function--stems and roots.

6. Flowering plants--a study in reproduction and development.

c. Animals

1. The dependence of animals upon plants; and the likenesses and differences between plants and animals.

2. Paramecium and the animal way of life.

3. The diversity among animals--a study of the bases of classification, and a survey of animal classification.

4. Digestion in multicellular animals.

5. Transportation within multicellular animals.

6. Respiration in multicellular animals.

7. Excretion in multicellular animals.

8. Coordination in multicellular animals.

9. Animal support and locomotion.

10. Reproduction in animals.

11. The development of animals.

12. An analysis of development in living things.

III. Continuity

a. Genetic continuity

1. Patterns of heredity--The work of Mendel, and probability in genetics.

2. The chromosome theory of heredity.

3. Genes and how they act.

4. Genes in populations.

b. Evolution

1. Darwinian evolution.

2. The mechanisms of evolution.

3. The origin and history of life.

4. The evolution of man.

5. The cultural evolution of man.

c. The living world--today and tomorrow

1. A study of basic ecology.

2. Man and the balance of nature.

3. A perspective of biology--a look at some present and future biological problems.

Laboratory

A student laboratory guide book is provided for each student's use during laboratory periods. This guide is adapted directly to the text and follows the same general outline. At present, two periods of 44 minutes each are alloted weekly for student laboratory exercises. It is hoped that as much laboratory work as possible will be completed in this, perhaps the most important, aspect of the course.

Supplementary tools for learning and for course enrichment

Books, periodicals, scientific journals, audio-visual aids, professional and community resource personnel, student projects and investigations, and any other worthwhile aids to learning and course enrichment are encouraged.

General Biology

Biology I-C

In this course Biology is examined through the discovery approach. It is designed to give the students a general idea of what biology is by emphasizing several of the important concepts and an idea of how our knowledge of biology is gathered through experimentation and changed through time. The emphasis is not on learning specific facts per se, but instead the course emphasizes the difference between facts (or observations) and interpretations. Various skills such as observation, organizing and interpreting data, etc. are also developed. In short, students learn about biology by being "placed into the scientific process." The word "science," then, becomes a verb not a noun.

Students are given an opportunity to "discover" some of the basic concepts by performing certain experiments. These serve as introductions to the concepts. Since the laboratories play such an important role in the structure of the course, ninety-five percent of the grade is determined, in the long run, by the work done in class. There are few "homework" assignments.

<u>Content</u>

I Unit I - Introduction

a. Definitions - Biology, Science

b. Topics studied - plants, animals, human

c. Skills - develop by doing exercises

observation, ordering, classification, measurement, inferring, predicting, communicating, experimenting (problem, hypothesis, testing, conclusions)

c. Life - define, compare, properties - develop by discovering

II Unit II - Variety

a. Observation of variety of familiar living things

b. Grouping and subgrouping - use of leaves (ordering, classifying)

c. Classification

1. developing a key -- leaves
2. use of a professional key
3. history and rational for classifying and keys
4. introduction to classification scheme for all living things

III Unit III - Similarity - Evolution

a. Develop concept from empirical observation - define - primitive, advanced, examples

b. Theory - history (film strip)
emphasis - Darwin and Lamark
evidence

c. Origin of life
abiogenesis (spontaneous generation), biogenesis
history
heterotroph hypothesis - experimental evidence - demonstrate

IV Unit IV - Similarity - Cell structure and function

a. Chemical nature of cell
DNA - structure and function

b. Physical nature of cell
Parts and functions - through observation and its extension
Mitosis and meiosis compared

V Unit V - Animal Kingdom

a. Characteristics - observation

b. Classes - classification

c. Collection of specimens

d. Habitat - locations

e. Economic importance - food, diseases, etc. - effect on man

f. Unique examples - interest

VI Unit VI - Plant Kingdom

a. Characteristics - observation

b. Classes - classification

c. Collection of specimens

d. Habitat - locations

e. Economic importance - food, diseases, etc. - effect on man

f. Unique examples - interest

VII Unit VII - Genetics

a. Cellular

b. Laws - probability, genetic

c. Problems - related to students, family traits, hybrid plants and animals

VIII Unit VIII - Human Biology

a. Systems - parts and functions (general terms) related to animal dissections

b. Diseases

C. Future of man

IX Unit IX - Ecology

a. Interrelationship of organisms and their environment
   Food chain, cycles

b. Problems - practical
   upsetting the balance of nature

APPENDIX C

BIOLOGY IA, BIOLOGY IB, AND BIOLOGY IC

SAMPLE UNIT PLANS

TEACHER'S UNIT PLAN

Teacher Mr. Cost - Mr. Schilling - Miss Albert

Date: Oct. 7, 1968 - Nov. 12, 1968

Subject Biology - Blue Grade 10 Section A

Unit 2 The Evolution of the Cell

Text Molecules to Man

I. Objectives

A. Behavioral Objectives

1. The student when presented with various substances of different pH's and the proper equipment (pH paper) will demonstrate his ability to determine the pH of these substances.

2. When presented with the significant steps in the heterotroph hypothesis (organic molecule formation, coacervates, primitive atmosphere, etc.), the student will be capable of ordering these events according to their assumed occurrence.

3. The student when presented with materials for coacervate formation is able to identify the importance of the changing environmental conditions (pH) for the formation of life.

4. The student when presented with the required materials (iodine, tes-tape, benedicts solution) will demonstrate his ability to test for the presence of starch and sugar.

5. The student when presented with a model of an amino acid is able to identify the various groups.

6. The student when presented with models of two amino acids is able to demonstrate his knowledge of a peptide bond and dehydration synthesis by directing the attachment of the two models in the formation of a peptide bond and release of a molecule of water.

7. The student when presented with a hypothetical or living changing osmotic system (ex. elodea cells, salt water) will demonstrate his ability to predict the direction of the movement of the molecules (i.e., into or out of the system).

8. The student through the microscopic observation of living and non-living yeast cells (stained with congo red) is able to identify the selective permeable nature of a living cell membrane.

9. The student through observation and mathematical surface area = volume calculations of two agar cubes (1 cc and 3 cc respectively) containing phenylthaline, both soaked in a NaOH solution for a given period of time, is able to identify the relationship (of the surface area - volume) to diffusion.

10. The student, after exposure to the basic chemical tests for foods, will be able to identify specific enzyme substrate interactions (Starch - ptyalin, etc.) through pre and post tests (iodine, benedicts, etc.) for the presence of specific foods.

11. The student, after development of definitions for a gene, an enzyme and analysis of their activity, will be able to construct a hypothetical interrelationship of genes and enzymes.

12. The student when presented with the problem of the structure of DNA will demonstrate his knowledge of this structure by constructing a DNA model made of materials of his choice.

13. The student when presented with a hypothetical DNA model with specific base sequence will demonstrate his understanding of the communicating system and the protein synthesis process in a cell by coding a messenger RNA model from the DNA and then constructing the proper polypeptide based on the code given.

14. The student when presented with a hypothetical polypeptide sequence of known amino acids with identified messenger RNA codons will be able to identify the types of mutations (rearrangement, omission, substitution, etc.) by citing examples of each, utilizing the condons given.

B. Non Behavioral

1. The student will come to view Science - Biology as a constantly changing process built on past experience.

2. The student will demonstrate a more inquiring mind.

3. The student will develop greater confidence in his ability to analyze and question.

II. Content

Overview: If it can be assumed that today's complex organisms are modified descendants of previous forms, then it might also be assumed that simple one-celled organisms have envolved from even simpler systems. These systems are the chemical systems outlined in this unit based upon various given hypotheses.

Investigation of the processes by which cells are built from atoms and molecules, pass life from one cell to another, and obtain and use energy will also be carried out in this unit.

A. Topics to be Studied	Major Concepts	Activities
1. The forerunners of Life a. Conditions on Earth before life began b. Evolution of organic compounds	Evolution a. Chemical evolution of Life b. Organic nature of life	Discussion Chapter 5 Lab #14 Coacervates #12 (part B) pH of Biological substances Skills: a, c, e Filmstrip: Early Atmosphere Skills: a Demonstration: Investigation #11 Electrolysis of Water Skills: a, c, d, e, f, g, h, i, j, k, l, m, n, o, p Demonstration: Chemical reaction potassium permanganate and glycerin. Used to develop concept of activation energy. Skills: a, e, g, h, j, o

Topics to be Studied	Major Concepts	Activities
		<u>Printed Material: Evolution of organic molecules</u> Skills: a, e <u>Supplement to #14 Coacervates</u> Brownian movement: milk drop in water on a slide. Heat mixture increase in motion of droplets. Skills: a, d, g, j, l, m, n, o, p <u>Demonstration</u>: Models: organic molecule kit H_2, NH_3, H_2O, Amino acids, peptide bond Dry Lab #13 Random Snythesis
2. Chemical Energy for Life		
a. Coacervates and Energy b. Energy release in primitive Heterotrophs c. Transfer of materials in living systems	Evolution-Energy Biological Systems Enzymes Transport	<u>Discussion Chapter 6</u> <u>Lab: Investigation #15 and 16. Activity of Enzymes</u>. Skills: a, e, g, h, i, j, k, l, m, n, o, p <u>Demonstration: Investigation #19 Fermentation</u> Skills: a, c, d, e, f, g, h, i, j, l-p <u>Demonstration: osmosis</u> a. potato slices in salt water solutions. 1 and 5%. b. Baggie (Sugar and starch solution) <u>Lab: Investigation #17 Activities of the Cell Membrane</u> Skills: a, d, e, g, h-p.

Topics to be Studied	Major Concepts	Activities
3. Master Molecules a. DNA (1) Structure (2) Function (3) Duplication b. Surface - volume c. cell duplication	Chemical Evolution to DNA Reproduction-Cellular	Discussion Chapter 7 Lab: Surface-Volume Relationship: Demonstrates importance of surface area and volume of diffusion. Skills: a, d, e, g, h, j, 1 - p. Student project: Construction of a DNA model Skills: e Demonstration: Model DNA Skills: a Filmstrip: DNA Skills: a
4. The Biological Code a. DNA Code b. Protein Synthesis c. Genes and Enzymes	Chemical Evolution Coding Protein Synthesis Mutation One gene one Enzyme	Discussion Chapter 8 Demonstration: Protein Synthesis (Model) Skills: a Filmstrip: DNA Coding Skills: a Lab: Investigation #20 Mutants in Bacteria Skills: a, e, f, g, h - k. Dry Lab: #20 Gentic Recombination in Bacteria Skills: f, g, h, j, l-p.

B. Skills Code

1. Basic Processes
   a. observing
   b. classifying
   c. measuring
   d. space-time relationships
   e. communicating
   f. predicting
   g. inferring

2. Integrated processes
   h. formulating hypothesis
   i. controlling and manipulating variables
   j. interpreting data
   k. experimenting

3. Problem solving processes
   l. recognizing and stating problems
   m. collecting relevant data
   n. recognizing basic assumptions
   o. formulating hypotheses
   p. drawing conclusions

C. Laboratory Exercises

Investigations:

11. Electrolysis of Water
12. (Part B.) pH of Biological Substances
13. Random Synthesis
14. Coacervates
15. Catalytic Activity of Enzymes in Living Materials
16. Effects of Various Factors on Enzyme Activity
17. Activities of the Cell Membrane
18. Fermentation
20. Mutations in Bacteria
21. Genetic Recombination in Bacteria

-- Surface - Volume Relationships

D. Audio-Visual Materials and Source

Films:

Osmosis*
Biochemical Genetics*
Thread of Life*
DNA Molecules of Heredity*

*Camden County Film Library

E. Major Equipment
1. Compound Microscope
2. Electrolysis Apparatus
3. Fermentation Apparatus
4. Atomic Models
5. DNA Kit
6. Protein Synthesis Kit

F. Living Things
1. *Bacillus cereus*, *Serratia marcescens*
2. elodea
3. yeast

G. Evaluation
1. Quizzes
   a. Lab Quiz Investigations #12-17 - (5)

2. Class Participation 2nd part of report period (5)
3. Laboratory Reports
   a. Investigation #11 (5)
      #14 + 12B (5)
      #15 + 16 (5)
      #17 (10) Formal Report
      #20 (5)
4. Teacher constructed Test (20) - Chapter 7 - 8
5. DNA Model (5)

TEACHER'S UNIT PLAN

Teacher Mr. Drann - Mr. Mastrangelo - Mr. Vranich - Mr. Schilling Dates: From Sept. to Oct. 1968

Subject Biology - Yellow Grade 10 Section B

Unit I Unity

Text Biological Science - An Inquiry Into Life

I. Objectives:

A. Behavioral

(1) The student, when presented with a list of other students' definitions, will be able to identify the common elements necessary in a working definition of biology.

(2) The student, when presented with three biological objects, will be able to describe their basic properties through observation.

(3) The student, after observing three objects (2 biological, 1 non-biological), will be able to distinguish between his observations and inferences.

(4) The student, when presented with a hypothetical verbal or non-verbal problem solving situation (Black box), will be able to order the information into steps involved in solving any similar scientific problem.

(5) The student, when presented with a hypothetical problem, will be able to construct a valid hypothesis.

(6) The student, after participating in an inquiry approach lesson (Invitation to Inquiry - BSCS Teacher's Handbook), will identify the existence of accidental trial and error discoveries in biology.

(7) The student, when presented with a model of the glucose molecule, will be able to identify the 3-D nature of a molecule.

(8) The student, when presented with a set of interacting molecular models (bonding active groups), will be able to identify the relationship between a molecule's structure and function.

(9) The student, after collecting data from a laboratory experiment on measurement, will be able to construct a simple bar graph of that data and any other quantitative data from other experiments.

(10) The student, after being presented with various identified specimens, will be able to identify plant and animal cells from similar specimens or diagrams.

(11) The student, when presented with a microscope, will be able to identify the various parts of this instrument.

(12) The student, when presented with a microscope, will be able to identify the functions of the various parts, through their demonstrated use.

(13) The student, when presented with ten specimens (biological and non-biological), will develop the ability to identify observational characteristics (criteria) of living and non-living specimens.

(14) The student will demonstrate the inadequacy of observational criteria by applying criteria established for living things to biological and non-biological specimens for which they do not work.

(15) The student, when presented with a graph or similar unfamiliar material will demonstrate his ability to answer questions based on that graph (graph interpretation).

(16) The student when presented with the required materials, will demonstrate his ability to correctly make a wet mount.

(17) The student, when presented with a prepared slide, properly focused, will demonstrate his ability to correctly observe and draw the specimen, according to established rules for lab drawings.

B. Non-Behavioral

(1) The student will come to appreciate the relationship of invention (tools) and science through his

reading, discussions in class, and working with various tools (ex. microscope).

(2) The student will come to appreciate the importance of previous recorded knowledge, ideas, and experimentation on work being carried out today.

(3) The student will come to view Science-Biology- as a constantly changing process built on past experience.

(4) The student will come to the realization that the scientist and his approach to the problems that he faces are not unlike the problems that the student faces in his everyday life.

II. Content

Overview: Unit I, through the use of various important biological concepts such as hypothesis, theory, data, experiment, food chains, etc., helps to demonstrate the Nature of Life, namely, that there is a common thread of Unity among the many diverse classes of organisms.

A. Topics to be Studied	Major Concepts	Activities
1. Science as Inquiry 2. Definition of Biology and Science 3. Origin of Scientific Problems 4. How Scientists Solve Problems	Nature of Science(Biology) Science as Inquiry	Discussion Chapter I Exercise on the Scientific Method-developing ideas of deduction, hypothesis and experiment. Exercise Observation Observation of 3 objects (2 living & 1 non-living)-technique used to develop skill of observing. Skill: a Black Box Technique -used to develop concept of science as inquiry. Skills: a,f,g,h,j,k,l,m,n,o,p WHO KILLED SULLIVAN -Hypothetical mystery used to demonstrate "scientific

Topics to be Studied	Major Concepts	Activities
		method" in action. Skills: a,g,h,j,l, m,p Lab-investigation I Blue Version Measurement of Biological Materials Skills: a,d,e,f,g, h,i,j,k,l,p,o Lab-Use of the Microscope - printed sheet-focusing, wet mount Skills: a,c
2. Origin of life a. spontaneous generation b. biogenesis c. abiogenesis	Unity and Similarity in Life Theory Evidence Science as Inquiry	Discussion-Chapter 2 Student Debate (Biogenesis vs. Abiogenesis) Demonstration-Early Experiment in Spontaneous Generation. Exer. 2-1(Yellow Lab Manual) Skills: a,c, e,f,g,h,i,j,k,l,m, n,o,p
3. The Cell a. Cell Structure and Function 1. physical nature 2. chemical nature-organic molecules structure & function b. Cell Theory-History c. Cell Reproduction 1. mitosis 2. meiosis	Unity and Similarity of Life. Nature of Life Science as Inquiry	Discussion-Chap. 3,4,5,6,7 Analogy-analogy between the cell and a factory Transparencies-Comparison of mitosis vs. meiosis Film Loop- "How Cells Divide" Debate-vitalism vs. mechanism. Laboratory-Yellow Lab Manual. Ex. 3-4, 3-5, 3-6 "Comparison of living plant and animal cells"

Topics to be Studied	Major Concepts	Activities
4. Cyclic Nature of Life a. Carbon-hydrogen-oxygen cycle b. nitrogen cycle c. water cycle d. food cycles e. food web f. pyramid of numbers g. climax community	Unity and Similarity of Life Balance of Nature Interrelationships among living organisms and their environment	Yellow Lab Manual Ex. 7-1 "Mitosis in Plant and animal cells" Skills: a, b,e,f,g,h,j Discussion-Chap. 8 Exercise on Food Chains-problem solving exercise using a hypothetical situation

B. Skills Code

1. Basic Processes
   a. observing
   b. classifying
   c. measuring
   d. space-time relationships
   e. communicating
   f. predicting
   g. inferring

2. Integrated Processes
   h. formulating hypotheses
   i. controlling and manipulating variables
   j. interpreting data
   k. experimenting

3. Problem Solving Processes
   l. recognizing and stating problem
   m. collecting relevant data
   n. recognizing basic assumptions
   o. formulating hypotheses
   p. drawing valid conclusions

C. Laboratory Exercises:

1. Measurement of Biological Materials- Inquiry I Blue Version
2. Use of the microscope (printed material)
3. Comparison of living plant and animal cells- Yellow Manual ex. 3-4, 3-5, 3-6
4. Mitosis in plant and animal cells- Yellow Lab Manual ex. 7-1

D. Audio-visual materials

Filmstrips:
- Mitosis

Filmloops:
- Mitosis

Transparencies:
- Mitosis vs. Meiosis

E. Major Equipment:
1. compound microscope
2. meter stick

F. Living Things
1. onions
2. cheek cells
3. variety of plants and animals

G. Evaluation:
1. Quizzes
   a. Chapter 1 and 2 (graphs, hypothesis, control, theory) (10)
   b. Chapter 7 - Mitosis (10)
   c. Leaf Key (10)

2. Class participation: 5 points/progress report period

3. Informal Lab Reports
   a. Measurement (3)
   b. Microscope, use of (5)
   c. Plant and Animal Cells (5)
   d. Demonstration (spontaneous generation) (5)
   e. Mitosis (5)
   f. Enzymes (5)

4. Formal Lab Reports (10) Yeast and Elodea

5. BSCS Quarterly Exam #1 (Yellow) (45)

6. Teacher Constructed Test (45) Chapter 1, 2, 3, 5

TEACHER'S UNIT PLAN

Teacher: Mr. Grqurich - Mr. Miles Dates: Sept. 4 to Oct. 31

Subject: Biology Grade: 10 Section: C

Unit I - Introduction to Biology

Text: Living Things

I. Objectives:

A. Behavioral

1. The student when presented with a list of student definitions will be able to identify the common elements necessary in a working definition of Biology and Science.

2. The student when presented with three objects (Biological and non-Biological) will be able to describe these objects by listing their properties from empirical observation.

3. The student when presented with a list of properties will be able to identify the biological or non-biological objects to which they apply.

4. The student when presented with skill activities (Basic and integrated) to perform will be able to construct operational definitions of and identify their performance in class activities.

5. The student when presented with a set of statements about a biological specimen will be able to differentiate an observation from an inference.

6. The student when presented with a set of biological or non-biological objects will be able to order them based on student or teacher selected criteria.

7. The student when presented with a set of 10 leaves (different species) will be able to classify them based on student selected characteristics.

8. The student will demonstrate the ability to measure in selected units by collecting quantitative data from a teacher selected source.

9. The student when presented with a set of data or student collected data will be able to construct a valid graph of that information.

10. The student after collecting or being presented with data containing individual differences in results of measurement of a single object, will be able to identify sources of error in measurement when performing future quantitative measurements.

11. The student after exposure to graph extrapolation will be able, when presented with partial data, to identify or make predictions based on that data.

12. The student when presented with a hypothetical verbal or non-verbal problem situation (black box) will be able to identify and order the information into a logical sequence of steps involved in solving a scientific problem.

13. The student when presented with specimens (biological and non-biological) will be able to identify observational characteristics (criteria) of living, non-living and dead specimens.

14. The student will demonstrate the inadequacy of observational criteria by applying criteria established for living things to specimens for which they do not work.

15. The student after analysis of human needs for life will be able to construct an operational definition for and name the life characteristics (functions).

16. The student after exposure to selected laboratory equipment will be able to identify and properly use such equipment.

17. The student when presented with proper materials will be able to demonstrate the use of the microscope by locating and focusing on a designated specimen.

18. The student when presented with the proper materials will be able to construct a wet mount (letter e).

19. The student when presented with a variety of microscopes will be able to identify their different uses and properties.

B. Non-Behavioral

1. The student will develop greater confidence in his ability to analyze and question.

2. The student will develop a more inquiring mind.

3. The student will develop greater interest in biological problems.

II. Content

A. Topics	Major Concepts	Activities
1. Definitions Biology Science	Nature of Science (Biology)	<u>Discuss Unit I</u> <u>Develop operational definitions</u> of Biology Based on student past experience
2. Topics Studied in Biology		<u>Empirical Observation</u> Based on past experience
3. Skills a. Lab Techniques	Science as Inquiry (methods of inquiry)	<u>Inquiry Lesson</u> Identification of a simple microscope from its properties & function (elementary wooden microscope) <u>Exercise</u> - Demonstration comparative observation of microscopes <u>Exercise</u> - Demonstration microscope structure & function Printed Material 1. Diagram to be labeled 2. Directions for focusing microscope <u>Exercise</u> - Lab Use of Microscope (Printed Material) use of letter "e"
b. Observation		<u>Exercise - Lab.</u> Empirical observation lab equipment properties & uses

Topics	Major Concepts	Activities
		Exercise Observation Identify properties of Biological objects
e. Inferring		Exercise Inference development based on observation of biological and non-biological objects.
d. Ordering		Exercise Ordering - organize a set of objects in serial order based on a single property
e. Classifying		Exercise Classifying - grouping & sub-grouping objects (leaves) based on several properties
f. Measurement		Exercise - Measurement Student develops a standard of comparison (size) using a set of Biological objects (plants)
g. Prediction		Exercise - Developing a graph Exercise - Lab Graphing - Measurement - graphing data on sponge absorption rate (large vs small) Exercise - Extrapolation - Making predictions on plant growth rate based on limited data (graphed)
h. Communicating		Notebook Developing an outline Lab Report Develop formal report Content

Topics	Major Concepts	Activities
		<u>Drawings</u> (Printed Material) Directions for making lab drawings
i. Experimenting (problem solving) 1. define problem 2. collect data 3. develop hypothesis 4. test control experimental variables 5. results 6. conclusions		<u>Exercise</u> - Lab Observation & drawing cells (Printed Material) <u>Exercise</u> - Developing a hypothetical problem situation 1. Non Verbal "Black Box" 2. Verbal Bacterial Control discovery from contamination (graph interpretation)
4. Life a. differentiate (1) living (2) non-living (3) dead	Nature of "Life"	<u>Discussion</u>: Unit II, VII <u>Exercise</u> - definition Develop operational definitions of life, non-life, dead <u>Exercise</u> - Lab Observation - inferences. Develop criteria for grouping of 10 objects as living, non-living, dead <u>Exercise</u> Observation & inference Student develops criteria to determine how he is alive <u>Exercise</u> Test 10 objects against criteria
b. Properties of life (functions) (1) motion (2) respiration (3) ingestion (4) digestion (5) excretion		<u>Exercise</u> - life functions through observation & inference Identification of properties or function of an organism (student) necessary for maintaining

Topics	Major Concepts	Activities
(6) secretion (7) reproduction (8) irritability (9) assimilation (growth) (10) absorption		life. Exercise - Develop operational definitions for life functions.

B. Laboratory Exercises
1. Lab Procedure (Printed Material)
2. Identification of lab equipment
3. Use of microscope (letter "e")
4. Observation of cells
   Lab drawings (Printed Material)
5. Graphing - sponge absorption rate (measurement)

C. Audio-visual materials
Films:
The Scientific Method (Camden County)
Film loops:
Cytoplasmic Streaming
Algal Syngamy
How Animals Breathe
How Animals Move Under Water
How Spiders Capture Prey

D. Major Equipment
Elementary Wooden Microscope
Student Microscope
General Lab Equipment
Prepared slides (cells)
Synthetic Plant & Animal Materials (plastic flowers, etc.)

E. Living Things
Plants - variety
Animals - variety
Protista - variety

F. Evaluation
Quizzes and Exercises
1. Define Biology (1)
2. Observation & Inference exercise (4)
3. Leaf Collection (2)
4. Quiz - lecture notes (15)
5. Graph Construction
   student heights (5)
6. Movie observation (1)

7. Quiz - Reading and skills
   Unit I (15)
8. Define life (1)
9. Grouping exercise - criteria
   life, non-life, dead (5)

Lab exercises
1. Cell drawings (5)
2. Graphing - sponge absorption rate (5)

Notebook
   Outline & set up (15)

Class participation (15)

APPENDIX D

TEACHER CHARACTERISTICS

TEACHER CHARACTERISTICS FOR THE A, B, AND C ABILITY GROUPS

Characteristic	Ability Group A	B	C	Total
Number of Teachers	7	8	3	15
Marital Status				
Single	3	3	2	6
Married	4	5	1	9
Sex				
Male	4	6	3	12
Female	3	2	0	3
Age (years)				
Average	31.85	26.62	27.33	28.6
Range	23-37	23-34	24-33	23-37
Experience				
Average CHHS[a]	3.30	1.56	4.33	2.63
Average Other	3.40	1.31	.33	1.76
Average Total	6.85	2.87	4.66	4.40
Education--Course Work				
Biology Credits	46.71	46.37	48.05	47.06
Range	31-75	39-52	32-70	31-75
Chemistry Credits	18.57	16.75	10.33	17.03
Range	6-46	6-28	7-16	6-46
Physics Credits	4.57	5.76	11.66	7.00
Range	0-10	0-13	6-21	0-21
Math Credits	8.43	7.25	8.33	8.13
Range	3-18	6-12	6-13	3-18
BSCS Course--number of teachers	2	2	2	5
Education--Degrees				
Bachelors	7	8	3	15
Masters	5	4	1	8
Doctoral	1	0	0	1[b]
Type of College (undergraduate)				
University				
Public	2	3	0	4
Private	2	2	1	4
College	2	3	2	6
Teacher College	1	0	0	1

[a]CHHS is Cherry Hill High Schools.

[b]Two others completing Ph.D.'s.

APPENDIX E

STUDENT CHARACTERISTICS FOR A, B, AND C EXPERIMENTAL AND CONTROL SAMPLES

CHARACTERISTICS OF THE EXPERIMENTAL AND CONTROL A, B, AND C GROUPS

Ability Group	Treatment Group	No. Group	School[a]	No. School	Sex	No. Sex	Average Age (yrs.)	Age Range (years months)	Average IQ	IQ Range
A	Experimental	27	E	14	M	14	15.7	16,4-14,11	124.26	152-92
			W	13	F	13				
	Control	21	E	11	M	12	15.8	16,6-15,2	122.48	139-104
			W	10	F	9				
	Total	48	E	25	M	26	15.7	16,6-14,11	123.48	152-92
			W	23	F	22				
B	Experimental	33	E	16	M	17	15.9	16,7-15,4	102.36	130-87
			W	17	F	16				
	Control	37	E	20	M	18	15.8	17,2-14,11	108.75	133-91
			W	17	F	19				
	Total	70	E	36	M	35	15.9	17,2-14,11	105.74	133-87
			W	34	F	35				
C	Experimental	30	E	17	M	16	16.2	17,6-15,4	92.43	123-75
			W	13	F	14				
	Control	29	E	22	M	8	16.1	17,7-15,4	100.83	117-80
			W	7	F	21				
	Total	59	E	39	M	24	16.1	17,7-15,4	96.56	117-75
			W	20	F	35				
T	Experimental	90	E	47	M	47	15.9	17,6-14,11	105.62	152-75
			W	43	F	43				
	Control	87	E	53	M	38	15.9	17,7-14,11	109.43	139-80
			W	34	F	49				
	Total	177	E	100	M	85	15.9	17,7-14,11	107.53	152-75
			W	77	F	92				

[a]E is Cherry Hill High School East
W is Cherry Hill High School West

APPENDIX F

PERTINENT LETTERS AND FORMS

January 31, 1968

Dear Parent:

The Cherry Hill School System is presently carrying on a research study to determine the effectiveness of its present biology program. This study will provide information necessary for the future development of the biology curriculum and the improvement of Cherry Hill student education.

Your child has been selected to take part in this study. We hope that you and your child will accept this honor and will give your full support to this effort. As a participant it will be necessary for your child to delay taking biology for one year. Guidance will be provided in planning a schedule which will in no way deprive your child of any course normally taken. The only difference will be the sequence in which two courses will be taken. Your child will suffer no loss in educational quality or time. It is expected that he will gain in educational quality from the improvements to be made in the biology course which he will take as a junior. Those who do take part in the study are to be commended for their contribution to the improvement of education for all Cherry Hill students.

If you have any questions regarding this matter, contact the High School Guidance Department.

Upon giving permission for your child to take part in this study, please sign the enclosed form and return it to the High School Guidance Department.

Sincerely yours,

Principal

Permission Slip

I give my permission for ______________________________
(Student's Name)

to make the necessary schedule adjustment as a participant in the biology research study being conducted by the Cherry Hill School System.

____
(Parent's Signature)

____
(Student's Signature)

BIOLOGY SURVEY STUDY

__________group

__________section

__________number   ____________student number

____
(name)   Last   First   Initial

_____school_______teacher__________I.Q.______________sex

SCORES

BSCS FINAL . . . . total_____________

Nelson . . . . total_____________

TOUS . . . . total_____________

understand_________________

enterprise_________________

method-aims________________

POST . . . . total_____________

Critical Thinking. . . . . total_____________

inference__________________

assumption_________________

deduction__________________

interpretation_____________

argument___________________

Kuder. . . . . outdoor___________

scientific___________

Purdue Attitude. . . . . total___________

APPENDIX G

ABILITY GROUP MEANS AND STANDARD DEVIATIONS FOR SEVEN EVALUATION INSTRUMENTS

PRETEST MEANS FOR THE EXPERIMENTAL AND CONTROL A, B, AND C ABILITY GROUPS

Evaluation Instrument	A		B		C	
	E	C	E	C	E	C
Nelson	27.41	29.14	16.97	19.27	15.23	14.86
Comprehensive Final	21.78	21.33	18.21	19.97	15.37	15.41
TOUS	34.78	34.33	25.18	29.59	21.63	23.66
Enterprise	11.07	11.05	7.88	9.19	6.57	7.41
Scientists	11.59	11.05	8.55	10.24	7.23	7.72
Methods-Aims	12.11	12.24	8.76	10.16	8.00	8.52
POST	27.92	26.29	19.18	21.24	15.30	17.17
Critical Thinking	66.00	68.62	57.21	60.38	51.07	55.66
Inference	11.37	11.33	9.00	10.30	6.97	7.93
Assumption	9.07	10.10	8.97	10.35	9.17	8.72
Deduction	17.41	18.33	15.58	15.16	14.03	15.59
Interpretation	18.11	18.57	15.27	15.65	13.63	14.79
Argument	10.04	10.29	8.39	8.92	7.27	8.62
Outdoor	34.33	38.43	38.70	33.22	37.03	31.55
Scientific	35.33	39.24	34.91	38.54	35.17	30.00
Attitude	6.93	7.05	6.61	6.87	7.64	6.98

E is experimental group
C is control group

PRETEST STANDARD DEVIATIONS FOR THE EXPERIMENTAL AND CONTROL A, B, AND C ABILITY GROUPS

Evaluation Instrument	A		B		C	
	E	C	E	C	E	C
Nelson	9.06	10.49	6.62	7.75	3.45	5.82
Comprehensive Final	4.67	5.39	4.73	4.32	3.03	4.11
TOUS	6.41	6.81	6.11	6.49	6.46	6.22
Enterprise	2.43	2.31	2.62	2.81	2.47	2.56
Scientists	2.41	2.40	2.88	2.49	2.51	3.00
Methods-Aims	3.32	3.28	2.91	2.64	2.79	2.80
POST	4.16	4.93	4.99	4.13	4.06	4.77
Critical Thinking	8.57	9.11	8.11	8.69	6.95	6.85
Inference	3.59	2.97	2.66	2.76	2.03	2.49
Assumption	4.46	3.94	3.56	3.50	3.04	2.22
Deduction	2.80	3.25	2.82	3.49	2.37	2.82
Interpretation	2.94	2.66	2.84	2.69	3.63	2.96
Argument	1.32	2.22	2.01	2.05	2.63	2.23
Outdoor	14.49	16.02	12.30	13.07	13.51	8.29
Scientific	14.10	13.21	11.64	12.14	11.38	10.43
Attitude	1.48	1.35	1.70	1.44	1.04	1.71

E is experimental group
C is control group

POSTTEST MEANS FOR THE EXPERIMENTAL AND CONTROL
A, B, AND C ABILITY GROUPS

Evaluation Instrument	A		B		C	
	E	C	E	C	E	C
Nelson	47.59	33.47	31.12	21.59	18.87	15.21
Comprehensive Final	32.00	23.71	21.88	18.41	15.57	15.41
TOUS	37.56	35.19	27.61	28.24	21.63	22.10
Enterprise	11.96	11.24	9.00	8.68	6.67	6.58
Scientists	12.74	11.76	9.52	9.73	6.97	7.38
Methods-Aims	12.85	12.19	9.09	9.84	8.00	8.14
POST	31.44	30.00	24.45	23.73	15.70	18.07
Critical Thinking	73.59	74.14	62.76	64.73	52.97	59.83
Inference	12.33	12.19	9.45	10.51	7.27	9.72
Assumption	11.33	11.33	10.00	11.00	8.97	10.03
Deduction	19.67	19.76	17.09	17.35	14.53	16.00
Interpretation	19.48	20.00	17.00	16.68	14.83	15.62
Argument	10.52	10.86	9.21	9.19	7.43	8.45
Outdoor	37.96	38.29	39.00	33.30	38.10	32.28
Scientific	35.81	37.00	33.85	34.43	34.47	26.69
Attitude	6.91	7.05	6.57	6.34	6.75	5.40

E is experimental group
C is control group

POSTTEST STANDARD DEVIATIONS FOR THE EXPERIMENTAL AND CONTROL A, B, AND C ABILITY GROUPS

Evaluation Instrument	A		B		C	
	E	C	E	C	E	C
Nelson	7.38	11.72	8.82	8.78	5.85	5.72
Comprehensive Final	5.05	5.87	4.86	4.23	3.49	4.35
TOUS	5.65	5.57	5.97	6.82	6.26	5.14
Enterprise	2.67	3.06	2.85	2.61	3.01	2.44
Scientists	2.18	1.67	2.50	2.99	3.01	2.66
Methods-Aims	2.40	3.06	2.81	3.00	2.45	2.61
POST	3.78	4.24	4.72	4.99	5.38	6.40
Critical Thinking	9.19	7.25	7.80	8.80	8.78	8.57
Inference	2.94	2.20	3.24	2.39	2.95	2.53
Assumption	4.56	3.79	2.95	3.59	2.66	3.19
Deduction	2.50	2.88	2.81	2.94	3.05	2.62
Interpretation	2.79	2.19	2.93	3.45	3.68	3.21
Argument	2.08	1.74	1.71	1.75	2.45	2.01
Outdoor	13.12	16.33	12.01	14.27	13.42	9.73
Scientific	12.56	13.16	13.98	11.62	9.36	9.95
Attitude	1.84	1.26	2.01	1.77	1.94	2.03

E is experimental group
C is control group

APPENDIX H

PRETEST AND POSTTEST MEANS FOR MALE AND FEMALE GROUPS ON SEVEN EVALUATION INSTRUMENTS

PRETEST AND POSTTEST MEANS FOR MALE AND FEMALE EXPERIMENTAL AND CONTROL A GROUPED STUDENTS

Evaluation Instrument	Treatment Group	Male		Female	
		Pretest	Posttest	Pretest	Posttest
Nelson	E	25.64	46.50	29.30	48.77
	C	27.61	33.25	28.11	33.78
Comprehensive Final	E	21.35	31.92	22.23	32.08
	C	19.66	23.00	23.55	24.66
TOUS	E	34.57	36.42	35.00	38.77
	C	30.77	34.16	35.66	36.55
Enterprise	E	10.78	11.35	11.38	12.61
	C	10.91	11.25	11.22	11.22
Scientists	E	11.42	12.50	11.77	13.00
	C	10.58	11.16	11.66	12.55
Methods-Aims	E	12.35	12.57	11.84	13.15
	C	11.83	11.75	12.78	12.78
POST	E	27.42	30.35	28.46	32.61
	C	25.00	28.91	28.00	31.44
Critical Thinking	E	64.92	68.92	67.15	78.61
	C	66.41	72.08	71.55	76.89
Inference	E	10.64	11.28	12.15	13.46
	C	11.83	11.91	11.66	12.53
Assumption	E	9.85	9.21	8.23	13.61
	C	9.91	10.75	10.33	12.11
Deduction	E	17.21	18.85	17.61	20.53
	C	17.33	17.91	19.66	20.55
Interpretation	E	17.21	19.07	19.00	19.92
	C	18.33	19.75	18.89	20.33
Argument	E	9.92	10.00	10.15	11.07
	C	9.75	10.50	11.00	11.33
Outdoor	E	37.71	40.71	30.69	35.00
	C	36.58	35.33	41.44	42.22
Scientific	E	37.71	38.28	32.77	33.15
	C	45.08	41.75	31.44	30.66
Attitude	E	6.76	6.48	7.11	7.36
	C	6.88	6.86	7.28	7.30
IQ	E	119.00		129.92	
	C	120.00		125.77	

E is experimental group; C is control group

PRETEST AND POSTTEST MEANS FOR MALE AND FEMALE EXPERIMENTAL AND CONTROL B GROUPED STUDENTS

Evaluation Instrument	Treatment Group	Male		Female	
		Pretest	Posttest	Pretest	Posttest
Nelson	E	19.06	32.05	14.75	30.12
	C	19.94	21.22	18.63	21.94
Comprehensive Final	E	19.06	23.11	17.31	20.56
	C	20.83	18.00	19.16	18.79
TOUS	E	25.11	26.94	25.25	28.31
	C	29.55	27.94	29.63	28.52
Enterprise	E	7.70	8.52	8.06	9.50
	C	8.77	8.77	9.58	8.57
Scientists	E	8.47	9.41	8.62	9.62
	C	10.05	9.16	10.42	10.26
Methods-Aims	E	8.94	9.00	8.56	9.18
	C	10.72	10.00	9.63	9.68
POST	E	19.88	24.82	18.43	24.06
	C	21.94	23.72	20.58	23.73
Critical Thinking	E	58.06	62.00	56.31	63.56
	C	61.28	64.16	59.52	65.26
Inference	E	9.00	8.58	9.00	10.37
	C	10.83	10.50	9.79	10.52
Assumption	E	9.82	10.00	8.06	10.00
	C	9.83	10.16	10.84	11.78
Deduction	E	15.64	16.76	15.50	17.43
	C	16.28	18.16	14.10	16.57
Interpretation	E	15.29	17.29	15.25	16.68
	C	15.94	16.50	15.37	16.84
Argument	E	8.29	9.35	8.50	9.06
	C	8.39	8.83	9.42	9.52
Outdoor	E	40.05	41.29	37.25	36.56
	C	38.33	36.50	28.37	30.26
Scientific	E	42.70	42.64	26.62	24.50
	C	45.94	42.00	31.52	27.26
Attitude	E	7.11	6.98	6.05	6.12
	C	6.69	5.87	7.05	6.33
IQ	E	110.46		107.56	
	C	110.05		113.31	

E is experimental group; C is control group

PRETEST AND POSTTEST MEANS FOR MALE AND FEMALE EXPERIMENTAL AND CONTROL C GROUPED STUDENTS

Evaluation Instrument	Treat-ment Group	Male		Female	
		Pretest	Posttest	Pretest	Posttest
Nelson	E	15.81	20.56	14.57	16.92
	C	19.50	18.12	13.09	14.09
Comprehensive Final	E	15.37	15.56	15.35	15.57
	C	16.12	17.37	15.09	14.66
TOUS	E	21.44	21.00	21.85	22.35
	C	26.87	25.75	22.43	20.71
Enterprise	E	6.38	6.12	6.78	7.28
	C	8.00	7.25	7.19	6.33
Scientists	E	7.31	6.93	7.14	7.00
	C	9.50	8.62	7.05	6.90
Methods-Aims	E	8.06	7.93	7.93	8.07
	C	9.37	9.87	8.19	6.71
POST	E	14.94	15.06	15.71	16.42
	C	18.62	19.25	16.33	17.61
Critical Thinking	E	48.15	51.81	53.71	54.28
	C	61.75	63.37	53.33	58.23
Inference	E	6.75	6.56	7.21	8.07
	C	8.37	10.75	7.76	9.47
Assumption	E	9.50	9.00	8.78	8.92
	C	10.12	11.00	8.19	9.66
Deduction	E	13.00	14.18	15.12	14.92
	C	18.00	16.37	14.67	15.85
Interpretation	E	12.50	15.12	17.41	14.50
	C	16.50	17.12	14.10	15.04
Argument	E	6.94	6.93	7.64	8.00
	C	8.75	8.75	8.57	8.33
Outdoor	E	43.25	44.68	29.92	30.57
	C	33.25	36.00	30.85	30.85
Scientific	E	40.62	38.00	28.64	30.42
	C	39.37	36.87	26.43	22.80
Attitude	E	7.72	6.96	7.56	6.51
	C	7.79	5.13	6.62	5.50
IQ	E	94.43		97.07	
	C	103.62		99.76	

E is experimental group; C is control group

APPENDIX I

RELIABILITY COEFFICIENTS FOR ALL EVALUATION INSTRUMENTS FOR THE A, B, AND C ABILITY GROUPS

TEST-RETEST RELIABILITY COEFFICIENTS FOR THE A, B, AND C AND TOTAL OF ALL ABILITY GROUPS

Evaluation Instrument	Ability Group	r	F	Sig.
Nelson	Total	.69	156.68	.0005
	A	.53	18.24	.0005
	B	.52	25.35	.0005
	C	.22	2.95	.091
Comprehensive Final	Total	.55	75.69	.0005
	A	.52	17.30	.0005
	B	.27	5.24	.025
	C	.22	2.99	.089
TOUS	Total	.73	200.37	.0005
	A	.51	16.59	.0005
	B	.64	48.44	.0005
	C	.48	16.72	.0005
Enterprise	Total	.61	103.88	.0005
	A	.45	11.39	.002
	B	.55	29.98	.0005
	C	.30	5.62	.021
Scientists	Total	.61	105.89	.0005
	A	.51	16.66	.0005
	B	.49	21.15	.0005
	C	.39	10.12	.002
Methods-Aims	Total	.45	44.24	.0005
	A	.34	6.06	.018
	B	.29	6.46	.013
	C	.14	1.19	.280
POST	Total	.78	265.09	.0005
	A	.71	47.01	.0005
	B	.48	20.70	.0005
	C	.60	31.29	.0005
Critical Thinking	Total	.70	165.68	.0005
	A	.67	37.88	.0005
	B	.46	18.67	.0005
	C	.55	24.31	.0005

continued

Continued

Evaluation Instrument	Ability Group	r	F	Sig.
Inference	Total	.53	66.96	.0005
	A	.62	28.03	.0005
	B	.17	2.01	.161
	C	.50	19.48	.0005
Assumption	Total	.30	17.18	.0005
	A	.14	.95	.334
	B	.41	13.65	.0005
	C	.36	8.32	.006
Deduction	Total	.46	47.18	.0005
	A	.58	22.92	.0005
	B	.28	5.62	.021
	C	.25	3.66	.061
Interpretation	Total	.52	63.52	.0005
	A	.48	14.06	.0005
	B	.36	9.93	.002
	C	.32	6.60	.013
Argument	Total	.35	24.36	.0005
	A	.38	7.78	.008
	B	.25	4.43	.039
	C	.11	.66	.417
Outdoor	Total	.76	232.83	.0005
	A	.81	85.20	.0005
	B	.66	53.49	.0005
	C	.69	128.30	.0005
Scientific	Total	.76	242.19	.0005
	A	.83	104.65	.0005
	B	.72	73.42	.0005
	C	.73	63.20	.0005
Attitude	Total	.44	41.82	.0005
	A	.41	13.50	.001
	B	.56	30.37	.0005
	C	.37	8.82	.004

APPENDIX J

RESULTS OF KOLMOGOROV-SMIRNOV ONE-SAMPLE TEST OF NORMALITY

RESULTS OF THE KOLMOGOROV-SMIRNOV TEST OF NORMALITY FOR SIGNIGICANT RESULTS FOR THE A, B, AND C ABILITY GROUPS FOR HYPOTHESES ONE, TWO, AND THREE

Ability Group	H	H_o	Evaluation Instrument	Treatment Group	$F_o(X)$	$S_n(X)$	D	P	Rejection
A	1	a	Nelson	E	.36	.26	.10	> .20	nr
				C	.49	.38	.11	> .20	nr
		b	Comprehensive Final	E	.86	1.00	.14	> .20	nr
				C	.87	1.00	.13	> .20	nr
B	1	a	Nelson	E	.30	.12	.18	> .15	nr
				C	.82	.97	.15	> .20	nr
		b	Comprehensive Final	E	.28	.12	.16	> .20	nr
				C	.85	.97	.12	> .20	nr
		c	TOUS	E	.59	.70	.11	> .20	nr
				C	.85	1.00	.15	> .20	nr
		d	Enterprise	E	.82	1.00	.18	> .20	nr
				C	.86	1.00	.14	> .20	nr
	2	a	POST	E	.56	.67	.11	> .20	nr
				C	.82	1.00	.18	> .15	nr
C	1	a	Nelson	E	.70	.87	.17	> .20	nr
				C	.88	1.00	.12	> .20	nr
	3	b	Scientific	E	.82	.97	.15	> .20	nr
				C	.17	.03	.14	> .20	nr
		c	Attitude	E	.78	1.00	.22	> .10	nr
				C	.25	.07	.18	> .20	nr

$F_o(X)$ is a completely specified cumulative frequency distribution under H_o.

$S_n(X)$ is the observed cumulative frequency distribution of a sample of N observations.

D is the maximum deviation equal to $|F_o(X) - S_n(X)|$

APPENDIX K

RESULTS OF SNEDECOR TEST OF EQUAL VARIANCE

RESULTS OF THE SNEDECOR EQUAL VARIANCE TEST FOR THE POSTTESTS OF THE A ABILITY GROUP FOR HYPOTHESES ONE, TWO, AND THREE

Evaluation Instrument	Treatment Group	S^2	F	$F_{.05}$	Sig.	Rejection
Nelson	E C	54.46 137.36	2.52	2.28	> .05	r
Comprehensive Final	E C	25.50 34.46	1.35	2.28	< .05	nr
TOUS	E C	31.92 31.02	1.02	2.39	< .05	nr
Enterprise	E C	7.13 9.36	1.31	2.28	< .05	nr
Scientists	E C	4.75 2.79	1.70	2.39	< .05	nr
Methods-Aims	E C	5.76 9.36	1.62	2.28	< .05	nr
POST	E C	14.29 17.98	1.26	2.28	< .05	nr
Critical Thinking	E C	84.46 52.56	1.60	2.39	< .05	nr
Inference	E C	8.64 4.84	1.79	2.39	< .05	nr
Assumption	E C	20.79 14.36	1.45	2.39	< .05	nr
Deduction	E C	6.25 8.29	1.33	2.28	< .05	nr
Interpretation	E C	7.78 4.80	1.62	2.39	< .05	nr
Argument	E C	4.33 3.02	1.43	2.39	< .05	nr
Outdoor	E C	172.13 266.67	1.55	2.28	< .05	nr
Scientific	E C	157.75 173.19	1.10	2.39	< .05	nr
Attitude	E C	3.39 1.59	2.13	2.39	< .05	nr

S^2 is variance
E is experimental group
C is control group

RESULTS OF THE SNEDECOR EQUAL VARIANCE TEST FOR THE POSTTESTS OF THE B ABILITY GROUP FOR HYPOTHESES ONE, TWO, AND THREE

Evaluation Instrument	Treatment Group	S^2	F	$F_{.05}$	Sig.	Rejection
Nelson	E C	77.79 77.09	1.01	2.03	< .05	nr
Comprehensive Final	E C	23.62 17.89	1.32	2.03	< .05	nr
TOUS	E C	35.64 46.51	1.30	1.96	< .05	nr
Enterprise	E C	8.12 6.81	1.19	2.03	< .05	nr
Scientists	E C	6.25 8.94	1.43	1.96	< .05	nr
Methods-Aims	E C	7.90 9.00	1.14	1.96	< .05	nr
POST	E C	22.28 24.90	1.11	1.96	< .05	nr
Critical Thinking	E C	60.84 77.44	1.27	1.96	< .05	nr
Inference	E C	10.50 5.71	1.85	2.03	< .05	nr
Assumption	E C	8.70 12.89	1.48	1.96	< .05	nr
Deduction	E C	7.90 8.64	1.09	1.96	< .05	nr
Interpretation	E C	8.58 11.90	1.39	1.96	< .05	nr
Argument	E C	2.92 3.06	1.05	1.96	< .05	nr
Outdoor	E C	144.24 203.63	1.41	1.96	< .05	nr
Scientific	E C	195.44 135.02	2.45	2.03	< .05	nr
Attitude	E C	4.04 3.13	1.29	2.03	< .05	nr

S^2 is variance
E is experimental group
C is control group

RESULTS OF THE SNEDECOR EQUAL VARIANCE TEST FOR THE POSTTESTS OF THE C ABILITY GROUP FOR HYPOTHESES ONE, TWO, AND THREE

Evaluation Instrument	Treatment Group	S^2	F	$F_{.05}$	Sig.	Rejection
Nelson	E C	34.22 32.72	1.05	2.12	< .05	nr
Comprehensive Final	E C	12.18 18.92	1.55	2.11	< .05	nr
TOUS	E C	39.19 26.42	1.48	2.12	< .05	nr
Enterprise	E C	9.06 5.95	1.52	2.12	< .05	nr
Scientists	E C	9.06 7.08	1.28	2.12	< .05	nr
Methods-Aims	E C	6.00 6.81	1.14	2.11	< .05	nr
POST	E C	28.94 40.96	1.42	2.11	< .05	nr
Critical Thinking	E C	77.09 73.45	1.05	2.12	< .05	nr
Inference	E C	8.70 6.40	1.36	2.12	< .05	nr
Assumption	E C	7.08 10.17	1.44	2.11	< .05	nr
Deduction	E C	9.30 6.86	1.36	2.12	< .05	nr
Interpretation	E C	13.54 10.30	1.31	2.12	< .05	nr
Argument	E C	6.00 4.04	1.49	2.12	< .05	nr
Outdoor	E C	180.10 94.67	1.90	2.12	< .05	nr
Scientific	E C	87.61 99.00	1.13	2.11	< .05	nr
Attitude	E C	3.76 4.12	1.10	2.11	< .05	nr

S^2 is variance
E is experimental group
C is control group