TESTING AND EVALUATIONS

I. Tests to be used:

A. CHEM Study achievement tests.
B. PSSC achievement tests.
C. Teacher-made tests.
D. CHEM Study and PSSC comprehensive tests.

II. Laboratory reports:

Evaluation of specified lab. reports.

III. Special projects:

Credit given for special projects and reports.

IV. Total evaluation of achievement of students:

Total evaluation of items I, II, and III above.

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DOCUMENT RESUME

ED 024 605 SE 005 643

By- Lee, Addison E., Ed.

Research and Curriculum Development in Science Education.

Texas Univ., Austin. Science Education Center.

Report No- 6720

Pub Date 15 Oct 67

Note- 145p.

Available from- Science Education Center, Univ. of Texas, Austin 78712 ($2.50)

EDRS Price MF-$0.75 HC Not Available from EDRS.

Descriptors- Able Students, *Biology, *Curriculum Development, Instruction, Instructional Materials, *Research Reviews(Publications), Science Course Improvement Project, *Secondary School Science, Teacher Characteristics

Identifiers- Biological Sciences Curriculum Study

This publication presents fourteen research reports on new programs in high school biology and in particular the materials related to the Biological Sciences Curriculum Study. Teacher characteristics and behavior are reported in three of these papers. Three papers report on instructional materials, six on instructional procedures, and one deals with curricula for high ability biology classes. The final chapter discusses additional studies involving new high school biology programs. (BC)

THE UNIVERSITY OF TEXAS PUBLICATION
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1. THE NEW PROGRAMS IN HIGH SCHOOL BIOLOGY

EDITED BY
ADDISON E. LEE

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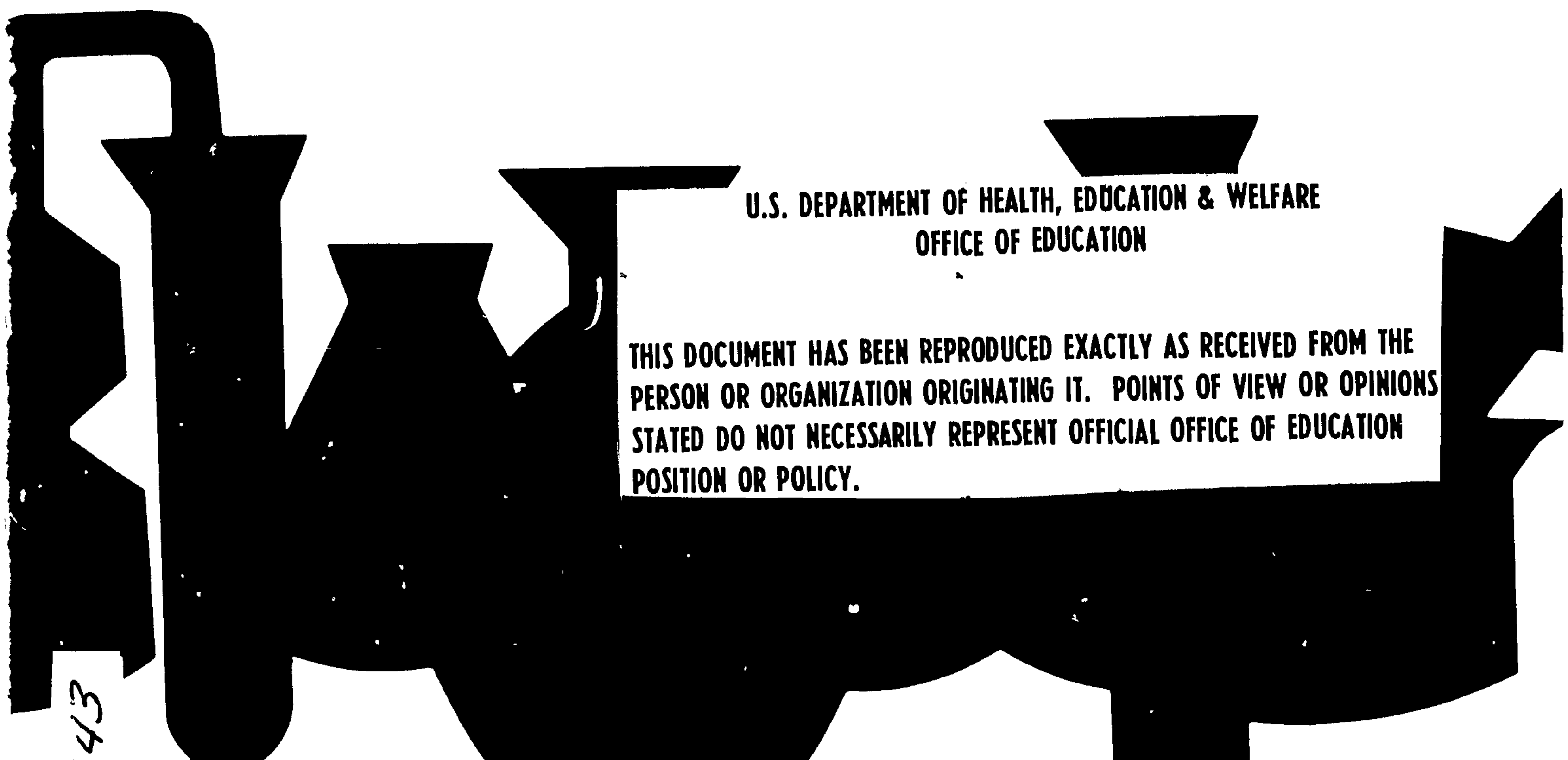

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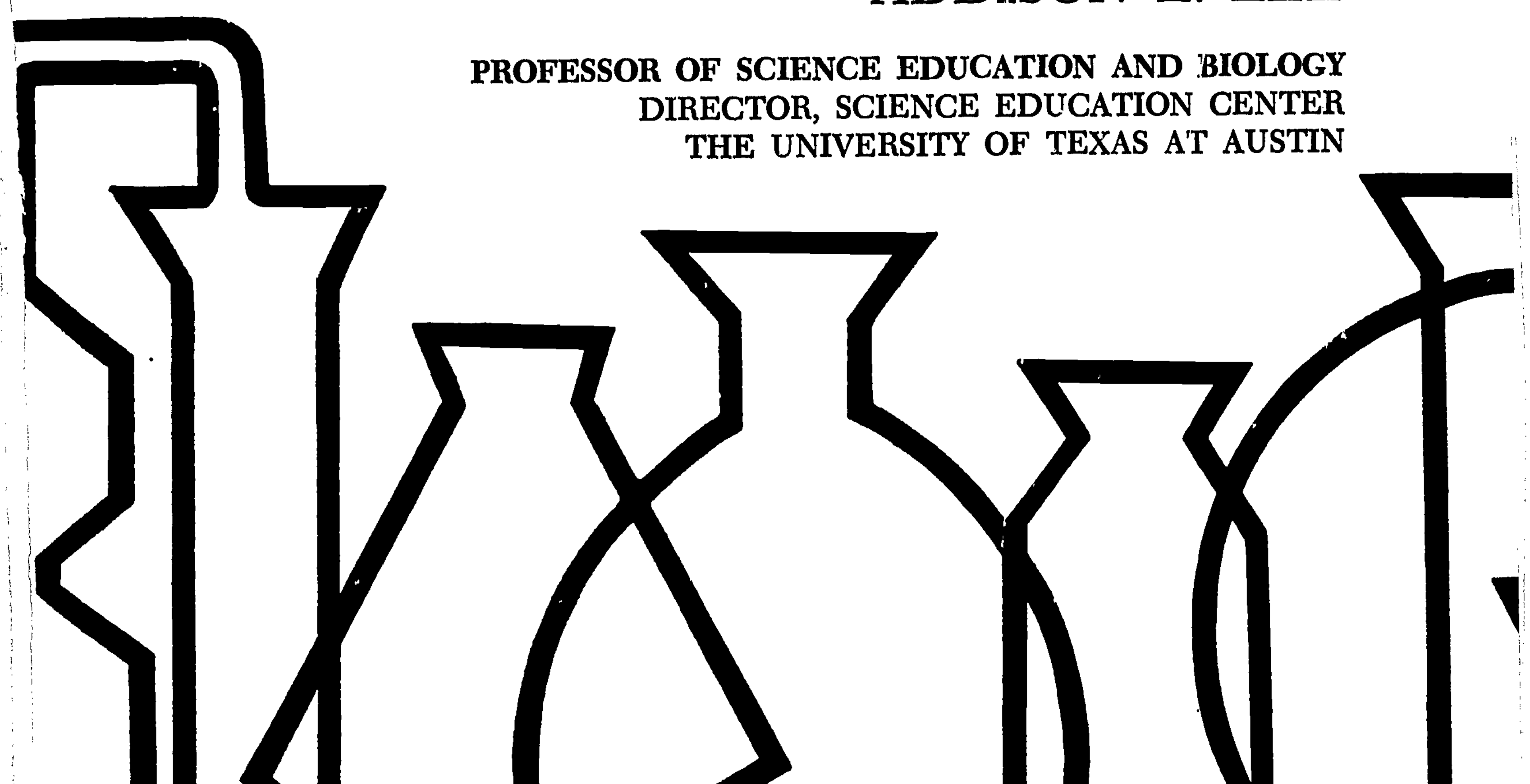

Copies of this publication may be procured for $2.50 from the
SCIENCE EDUCATION CENTER,
THE UNIVERSITY OF TEXAS AT AUSTIN,
AUSTIN, TEXAS 78712.

PUBLISHED BY THE UNIVERSITY TWICE A MONTH AND ENTERED AS SECOND-CLASS MATTER AT THE POST OFFICE AT AUSTIN, TEXAS UNDER THE ACT OF AUGUST 24, 1912

FOREWORD

Many of the new curriculum studies have now reached a stage of maturity where they are "on their own." The materials developed are being accepted and used now by many teachers not involved in their initial development, tryout, or evaluation. Although the materials have been described in detail in numerous publications and some analyses and evaluations of them reported, a great deal more needs to be done in terms of the current use of these materials by teachers and students.

It has often been stated that one anticipated function of new curriculum materials would be to serve as models or stimulants for the development of still other materials. It is pertinent, therefore, to analyze the situation and to determine if this impact has occurred.

In developing its program for graduate students, the faculty of the Science Education Center at The University of Texas at Austin has focused on a number of problems relating to the situation described above, and has planned a series of monographs to report the investigations carried out. This monograph is the first in the series and reports studies involving new programs in high school biology and, in particular, studies involving the use of materials developed in the Biological Sciences Curriculum Study. With the obvious exception of Chapters I and XVI, the chapters included in this monograph report work done by a number of graduate students in partial fulfillment of the requirements leading to the Ph.D. degree at The University of Texas at Austin.

A number of people associated with the Science Education Center have assisted in bringing this monograph to completion. Those who should have special mention are Dr. Earl J. Montague, who read several of the manuscripts and offered criticisms and suggestions; Miss Dale Ballard, graduate student, who assisted with editorial functions; Mrs. Mary Anne Hunter, who, with the help of Mrs. Evelyn Waugh, Miss Cheryl Harvey, and Mrs. Bonnie Worley, was responsible for most of the typing and preparation of the manuscripts for the press; and Mrs. Margaret Webb, who coordinated the project.

ADDISON E. LEE
Austin, Texas
October, 1967

The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

SAM HOUSTON

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

MIRABEAU B. LAMAR

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I. NEW CURRICULUM DEVELOPMENTS AS "WORKING PAPERS" FOR RESEARCH

Addison E. Lee

SCIENCE EDUCATION CENTER

THE UNIVERSITY OF TEXAS AT AUSTIN

It is commonly recognized that new knowledge obtained as a result of efforts of research scientists and mathematicians is important in our society. Not so well recognized but also important are recent efforts that deal not only with discovering new knowledge in science and mathematics but with discovering new ways of transmitting both old and new knowledge to students and to the public at large. These efforts involve initially identification of some of the most important information and ideals of science and mathematics and then the development of ways to communicate such information and ideas. Likewise, they involve, or should involve, the use and development of techniques for accurate surveying of actual teaching practices and the actual use of new curriculum materials and, perhaps more importantly, appropriate evaluations of these new techniques and materials.

It should be noted that much work is being done in the field of educational psychology on the one hand while on the other hand many new curriculum materials are being prepared, with little communication between workers in the two areas. Conceivably, research in science and mathematics education ought to bridge the gap between the two efforts. Research in science and mathematics education could involve the implications of educational psychology research for curriculum development and, likewise, new curriculum developments should be considered as "working papers" from which to identify and characterize materials and techniques that could be used to structure teaching programs for optimum effectiveness.

Yet, in spite of recognition that much work is being done in the field of educational psychology, it turns out that few instruments have been developed that will enable the curriculum maker to identify accurately the needs in a particular area or to provide the necessary basis for proper selection of curriculum materials. Furthermore, few instruments exist which provide for proper evaluation of actual classroom practices or teaching techniques in relation to the use of particular materials.

In the development of its graduate program the Science Education Center at The University of Texas at Austin undertook to design a program of graduate studies in research that included the use of existing curriculum materials and instruments for research as well as the development of new materials and instruments. The program has included the following areas:

1. Analysis of the nature and content of modern research in specific science and mathematics areas and the implications of this information for curricula at different levels.
2. Creation or development of new materials and approaches with promise of improvement for science and mathematics programs at various levels.
3. Analysis and evaluation of the use of new experimental materials developed for science and mathematics instruction.
4. Development of techniques distinct from current evaluation and examination

practices for exploring the effectiveness of specific science or mathematics teaching at various levels.

5. Development of new programs and procedures for the preparation of prospective science or mathematics teachers.

The program cited above involves both a creative and an experimental approach. It is really development and research and involves a triangle of people—the research scientist, the professional educator, and the teacher.

During the past several years, faculty and graduate students in the Science Education Center at The University of Texas at Austin have had the opportunity of participating in a number of the national curriculum studies. One result of this participation has been the availability of new and experimental materials that could be used in various research projects. One of the important developments has been the organization of a Research and Development Laboratory for the teaching of biology under the administration of and with support from the Biological Sciences Curriculum Study (BSCS). This laboratory is unique in a number of respects. The staff (project associates) for the laboratory is made up primarily of experienced high school teachers who contribute to the development of the program not only in their general knowledge of biology but also in their actual experience in teaching biology to high school students. The primary assignment of the project associates has been to work with the members of the BSCS Committee on Innovation in Laboratory Instruction and individual authors of the BSCS Laboratory Blocks.

It has turned out that members of the laboratory staff have not only been able to provide practical answers to the basic questions involved in their work with the committee and Laboratory Block authors but also have been able to provide many supplementary suggestions concerning the materials with which they worked. The staff has, in fact, conducted research in the identification and use of the most appropriate organisms to illustrate particular concepts and in the development of particular kinds of equipment and techniques best suited to carry out particular investigations. In actual practice then, this laboratory has turned out to be one of the most unusual, if not a unique one, in the history of biology teaching. One outgrowth of efforts in this laboratory has been a book, *Innovations in Equipment and Techniques for the Biology Teaching Laboratory*, by Richard E. Barthelemy, James R. Dawson, Jr., and Addison E. Lee (1), published in 1964 as a resource book for biology teachers. It includes various contributions of the laboratory staff, including reports of the development and descriptions of new techniques, the identification of different and perhaps better organisms for use in laboratory teaching, and the development of new or modified equipment for teaching specific techniques or concepts.

One example of the use of a different organism for the development of a laboratory investigation of mineral nutrition in plants is the use of Sorghum 610 rather than sunflower, corn, or beans, which are commonly used. Sorghum 610 is well known to agriculture researchers and is highly sensitive to iron or nitrogen deficiencies, but apparently has not been used to any appreciable extent in teaching elementary biology. Use of this plant in lieu of those commonly used reduces the time of the investigation from approximately a six-to-nine-week period to a

three-week period, and the results are very striking. In addition, the amount of culture medium, equipment, and storage space required for laboratory teaching is greatly reduced.

As previously indicated, the primary focus of the Research and Development Laboratory has been the development of the series of BSCS Laboratory Blocks. The objectives, history, and potential of this program have been described in BSCS *Special Publication No. 5*, "Laboratory Blocks in Teaching Biology" (2). This book also gives a complete listing of all BSCS publications, including course materials, Laboratory Blocks, pamphlets, bulletins, special publications, teachers' handbook, student investigations, tests, films, and newsletters. This list can serve as a useful reference source not only for biology teachers looking for teaching materials, but also for science educators looking for materials with research potential and models for curriculum development.

As indicated above, reports of the work of the BSCS Research and Development Laboratory have been disseminated through the publications of the BSCS program. However, parallel to this effort, a great deal of independent research has been carried out by staff and graduate students in the Science Education Center at The University of Texas at Austin and has involved use of these and similar new curriculum developments produced in the major national-level curriculum programs. In addition, attention has been paid to some programs which have been developed at a more local level. Insofar as possible, these studies have been based on the research and development rationale presented earlier in this chapter and represent examples of some of the areas listed. While some articles involving part of these studies have already been published in appropriate journals, it seems desirable to gather together a group of them with more complete details in one monograph to illustrate the continuity of this research at The University of Texas at Austin and to make available the results to other workers in the emerging field of Science Education.

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II. MATHEMATICS AND THE NEW SCIENCE CURRICULA

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BACKGROUND AND PURPOSE OF THE STUDY

An important phase of the development of new curriculum programs is their interaction with existing programs and among themselves. One problem encountered in curriculum developments in secondary school science and mathematics has been that of coordinating the mathematics program with the mathematical content of the science programs. This problem has become more important due to the nature of certain curriculum developments.

Two trends in the development of new high school science programs have been the updating of science content and increased emphasis upon understanding the content and processes of science. Each of these trends would seem to suggest that mathematical concepts and processes would become more and more involved in the science courses. The first, assuming that science is becoming more mathematical, implies a rather obvious need for the science courses to become more mathematical. The second implies further need for the science courses to become mathematical, if it is agreed that mathematics can aid the development of understanding through systematizing and symbolizing many scientific concepts. The purpose of this paper is to consider certain evidence of the possible increase in the utilization of mathematics in secondary school science courses, especially in biology, and to consider implications for the development of mathematics programs and the further development of high school science courses.

MATHEMATICS IN HIGH SCHOOL SCIENCE MATERIALS

One index of the degree of utilization of mathematics in high school science courses is the frequency of the appearance of mathematical concepts and processes in the textboks, laboratory manuals, and other written materials used in the courses. By examining sets of materials one would be able to ascertain any marked differences in their mathematical content. Further, if one would examine materials for a traditional science course and materials for a modern science course in the same area, he might determine trends on the increase or decrease in the use of mathematics as a result of a transition from the traditional to the modern course.

A study by Cain in 1962 included an analysis of selected high school science materials in physics, chemistry, and biology for their utilization of certain mathematical concepts and processes and the degree of such utilization (1). Table 1 is the tabulation of the analysis. The column headings in Table 1 are to be interpreted as noted following the table.

TABLE 1[a b]

THE RELATIVE DEGREE OF UTILIZATION OF SELECTED MATHEMATICAL CONCEPTS AND PROCESSES IN SELECTED COURSES IN HIGH SCHOOL BIOLOGY, CHEMISTRY, AND PHYSICS

Mathematical concepts and processes	Biology		Chemistry			Physics	
	Trad	BSCS-Y	Trad	CBA	CHEM	Trad	PSSC
Linear equations	0	2	4	4	4	4	4
Quadratic equations	0	2	3	2	3	4	4
Ratio, proportion, & variation	1	4	4	4	4	4	4
Conversion factors	0	2	3	3	4	4	2
Graphs	0	4	0	4	4	3	4
Probability	2	4	0	0	0	0	3
Tables	1	4	4	2	2	4	2
Statistics	1	3	0	0	1	0	2
Formulas	1	4	4	4	4	4	4
Trigonometric functions	0	0	0	0	0	1	3
Vectors	0	0	0	0	0	3	4
Intuitive plane geometry	0	0	0	2	3	4	4
Logarithms	0	2	0	2	0	1	0
Powers of ten	0	3	4	4	4	3	4
Nuclear or chemical equations	2	4	4	4	4	2	0
Intuitive solid geometry	0	1	2	4	4	3	3
Intuitive calculus	0	0	0	2	2	0	3
Measurement	0	4	3	4	4	3	4

[a] Number symbols in this table are to be interpreted as follows:
0—not included at all
1—used very few times; not important to development
2—used few times; of small importance to development
3—used several times; important to development
4—used numerous times; very important to development

[b] Quoted from Cain, Ralph W. and Lee, Eugene C. "An Analysis of the Relationship between Science and Mathematics at the Secondary School Level." *School Science and Mathematics,* LXIII (December 1963). P. 711.

Trad—traditional
biology—Moon, Truman J., Mann, Paul B., and Otto, James H. *Modern Biology.* Henry Holt and Co., New York. 1951.
chemistry—Dull, Charles E., Brooks, William O., and Metcalfe, H. Clark. *Modern Chemistry.* Henry Holt and Co., New York. 1954.

physics—Dull, Charles. *Modern Physics.*
Henry Holt and Co., New York. 1955.

BSCS—Y—Biological Sciences Curriculum Study. *High School Biology* (Yellow Version) Experimental edition.
Biological Sciences Curriculum Study, 1960.

CBA—Chemical Bond Approach Committee. *Chemistry* 2d ed. The Reed Institute, Portland, Ore. 1961.

CHEM—Chemical Education Material Study. *Chemistry: an Experimental Science.* 2d trial ed. The Regents of the University of California, 1960, 1961.

PSSC—Physical Science Study Committee. *Physics.*
D. C. Heath and Co., Boston. 1960.

The mathematical concepts and processes listed were selected, with some modification, from a list developed by Lockwood (2).

A comparison of the utilization of mathematics in the traditional and new science course materials, as shown in Table 1, reveals that there was only a slight increase in the chemistry and physics materials but a rather marked increase in the biology materials. This marked increase is indicated by the fact that the BSCS program uses fourteen of the eighteen concepts and processes listed, compared to only six for the traditional course, and by the fact that the BSCS program has nine of them rated important—as indicated by a rating of 4 or 3—while the traditional course has none rated so highly.

Following the revelation of the apparent increase in the utilization of mathematics in high school biology with the advent of BSCS materials, further investigation was undertaken to determine if the increase in mathematical content of the new biology materials would be reflected in the performance of students in biology classes in which the new materials were used. The purpose of this study was to investigate relationships between the achievement of students in selected high school biology programs, new and traditional, and their mathematical aptitude and achievement.

DESIGN OF THE STUDY

From its beginning the Biological Sciences Curriculum Study (BSCS) has engaged in evaluation of developed curriculum materials for high school biology. Beginning with the 1960–62 and 1962–63 Evaluation Programs, BSCS has collected and analyzed increasing quantities of data on students enrolled in their programs and in traditional biology programs (3). Among the data collected were scores on achievement tests in biology and on tests of mathematical aptitude. Since large numbers of subjects were included in the evaluation studies, these seemed a possible source of data for this study. Through the cooperation of BSCS and the Psychological Corporation, certain data were made available to the investigator.

Populations studies. All students included in this study were elements of samples used in the 1962–63 BSCS Evaluation Program. One group consisted of 517 students enrolled in a BSCS Yellow Version tenth-grade biology program in a large Texas city; the other consisted of 563 students enrolled in a traditional

tenth-grade biology program in another large Texas city. Members of the BSCS group were selected from classes taught by six teachers in three high schools. Members of the traditional group represented the classes of nine teachers in two high schools. Each group contained all students in the corresponding BSCS Evaluation Program center who met the following additional criteria: (1) enrollment in tenth grade; (2) enrollment in high school biology for the first time; (3) completion of first-year algebra prior to enrollment in biology, and no enrollment in second-year algebra concurrent with enrollment in biology; (4) availability of all desired data.

Data collected. The following data were collected for all students in each group:

(1) Measures of achievement in biology
  (a) Teacher-assigned grades, collected from school and teacher records
  (b) Scores on the *BSCS Comprehensive Test* (Revised)*
(2) Measure of mathematical achievement—teacher-assigned grades in first-year algebra, collected from school records
(3) Measure of mathematical aptitude—score on the *Differential Aptitude Test of Numerical Ability* (Form A)*
(4) Measure of verbal reasoning ability—scores on the *Differential Aptitude Test of Verbal Reasoning* (Form A)*

In addition to the above data, the following were collected for all students in the BSCS Group:

(5) Measures of achievement in portions of the BSCS Yellow Version program—scores on *BSCS Achievement Tests,* 1, 2, 3, and 4, collected from teacher records

Method of data analysis. Since relationships between pairs of variables were the focus of interest in this study, some form of correlation analysis was suggested.

Preliminary investigation of the data collected showed that all assumptions underlying the use of Pearson product-moment coefficients of correlation were satisfied. Further consideration of the problem led to the conclusion that, due to interrelationships among certain of the variables, partial correlation techniques would be used to minimize their effects. This decision to use partial correlation was based upon the nature of the variables involved and the information sought; such decisions must be made whenever correlation methods of data analysis are used (4, p. 343).

Coefficients of partial correlation were computed on a desk calculator from Pearson product-moment coefficients of correlation which were computed on a Control Data Corporation 1604 digital computer. In addition to the necessity of satisfying the assumptions underlying the use of the Pearson *r*, it was necessary that all coefficients of correlation utilized in computing others be significantly different from zero. All such requirements were checked at each step as computing progressed.

For each of the two groups the following coefficients of partial correlation were computed:

* Furnished to the investigator from the Psychological Corporation through the cooperation of BSCS from data collected for the 1962–63 BSCS Evaluation Program.

(1) between achievement in biology and mathematical achievement, with mathematical aptitude and verbal reasoning ability held constant;
(2) between achievement in biology and mathematical aptitude, with verbal reasoning ability held constant.

For the BSCS group the following additional coefficients of partial correlation were computed:

(3) between achievement in each of four portions of the BSCS biology program and mathematical achievement, with verbal reasoning ability held constant;
(4) between achievement in each of four portions of the BSCS biology program and mathematical achievement, with mathematical aptitude held constant;
(5) between achievement in each of four portions of the BSCS biology program and mathematical aptitude, with verbal reasoning ability held constant.

Differences between corresponding pairs of coefficients of correlations were computed, and the significance of each of the differences was determined by standard statistical techniques.

The following null hypotheses were tested:

(1) The coefficient of partial correlation between each of the measures of the achievement in biology and the measure of mathematical achievement, with verbal reasoning ability and mathematical aptitude held constant, for students in one biology program is not significantly different from the corresponding coefficient of partial correlation for students in the other program.
(2) The coefficient of partial correlation between each of the measures of achievement in biology and the measure of mathematical aptitude, with verbal reasoning ability held constant, for students in one biology program is not significantly different from the corresponding coefficient of partial correlation for students in the other program.
(3) The coefficient of partial correlation between the measure of achievement in any of the four portions of the BSCS biology program and the measure of mathematical achievement, with either verbal reasoning ability or mathematical aptitude held constant, is not significantly different from the coefficient of partial correlation between the measure of achievement in any other portion of the BSCS program and the measure of mathematical achievement, with the same variable held constant.
(4) The coefficient of partial correlation between the measure of achievement in any of the four portions of the BSCS biology program and the measure of mathematical aptitude, with verbal reasoning ability held constant, is not significantly different from the coefficient of partial correlation between the measure of achievement in any other portion of the BSCS program and the measure of mathematical aptitude, with the same variable held constant.

RESULTS OF THE STUDY

The results of the study are summarized in Tables 2–6. The z-transformation values and the z-values in Tables 2 and 3 were computed according to standard statistical tables and techniques, and the significance of the z-values determined by use of a table for the unit normal curve (4, pp. 255–256). The differences be-

tween coefficients of correlation in Tables 4, 5, and 6 include all possible pairs of coefficients taken such that the difference is positive in each case; the *t*-values were computed using a standard statistical formula, and the significance determined by referral to a standard *t*-table using N−4 degrees of freedom (N = 517 for the BSCS group) (4, pp. 256–257).

It should be noted that no differences are significant except for the coefficients of partial correlation between achievement in biology and mathematical aptitude, with verbal reasoning ability held constant (Table 3). The minimum value of *t* significant at the .05 level of confidence with 513 degrees of freedom is 1.965.

CONCLUSIONS AND LIMITATIONS OF THE STUDY

Based upon the results of this study, only the second of the null hypotheses set forth can be rejected. That is, there is a significant difference in the degree of relationship between achievement in biology and mathematical aptitude for students in the two different biology programs. The degree of relationship is greater for the BSCS group than for the traditional group, indicating that mathematical aptitude may be a more important factor to success in the BSCS biology program than it is in a traditional biology program.

The lack of any significant differences of relationship between achievement in biology and mathematical achievement when the two groups were compared

TABLE 2[a]

SECOND-ORDER COEFFICIENTS OF PARTIAL CORRELATION BETWEEN MATHEMATICAL ACHIEVEMENT AND ACHIEVEMENT IN BIOLOGY, Z-TRANSFORMATION VALUES, AND DIFFERENCES BETWEEN Z-TRANSFORMATION VALUES

Correlation Coefficient	BSCS Group	Traditional Group	Z_{BSCS}	Z_{TRAD}	Z_B-Z_T	Z-Value	Significance
$r_{18.23}$	.45	.49	.49	.54	−.05	−0.78	N.S.
$r_{19.23}$	.22	.14	.22	.15	.08	1.28	N.S.

BSCS Group: N = 517 V_1—Grade in alg. I V_8—Grade in biology
Traditional Group: N = 563 V_2—DAT Verb. Reasoning V_9—BSCS Comp. Final
V_3—DAT Num. Ability

[a] All values have been rounded to two decimal places from computations carried to four decimal places.

could have been influenced by two limitations of the study: (a) the use of only teacher-assigned grades as measures of mathematical achievement introduced many uncontrollable variables into the measure whose effects could well have hidden relationships; (b) no controls were used on possible differences between

TABLE 3[a]

FIRST-ORDER COEFFICIENTS OF PARTIAL CORRELATION BETWEEN MATHEMATICAL APTITUDE AND BIOLOGY ACHIEVEMENT, Z-TRANSFORMATION VALUES, AND DIFFERENCES BETWEEN Z-TRANSFORMATION VALUES

Correlation Coefficient	BSCS Group	Traditional Group	Z_{BSCS}	Z_{TRAD}	$Z_B - Z_T$	Z-Value	Significance
$r_{38.2}$	.34	.16	.36	.16	.20	3.28	p .01
$r_{39.2}$	.32	.05	.33	.05	.28	4.52	p .01

BSCS Group: N = 517 V_2—DAT Verb. Reasoning V_8—Grade in biology
Traditional Group: N = 563 V_3—DAT Num. Ability V_9—BSCS Comp. Final

[a] All values have been rounded to two decimal places from computations carried to four decimal places.

TABLE 4[a]

FIRST-ORDER COEFFICIENTS OF PARTIAL CORRELATION BETWEEN MATHEMATICAL ACHIEVEMENT AND BSCS ACHIEVEMENT TESTS, AND DIFFERENCES BETWEEN SELECTED PAIRS OF THE COEFFICIENTS (BSCS GROUP)

N = 517	$r_{14.2} = .32$ $r_{15.2} = .31$		$r_{16.2} = .37$ $r_{17.2} = .31$
Correlation Coefficients	**Difference**	**t-Value**	**Significance**
$r_{16.2} - r_{17.2}$	.06	1.39	N.S.
$r_{16.2} - r_{15.2}$	.06	1.37	N.S.
$r_{16.2} - r_{14.2}$	.05	1.14	N.S.
$r_{14.2} - r_{17.2}$	.01	0.27	N.S.
$r_{14.2} - r_{15.2}$	.01	0.21	N.S.
$r_{15.2} - r_{17.2}$	.00	0.08	N.S.

V_1—Grade in alg. 1 V_4—BSCS Ach. Test 1 V_6—BSCS Ach. Test 3
V_2—DAT Verb. Reasoning V_5—BSCS Ach. Test 2 V_7—BSCS Ach. Test 4

[a] All values have been rounded to two decimal places from computations carried to four decimal places.

mathematics programs of the two groups or within either group. In any case, the results of this study do not warrant any conclusions related to differences in relationships between achievement in biology and mathematical achievement for the two groups.

TABLE 5[a]

FIRST-ORDER COEFFICIENTS OF PARTIAL CORRELATION BETWEEN MATHEMATICAL ACHIEVEMENT AND BSCS ACHIEVEMENT TESTS, AND DIFFERENCES BETWEEN SELECTED PAIRS OF THE COEFFICIENTS (BSCS GROUP)

N = 517	$r_{14.3} = .24$ $r_{15.3} = .26$		$r_{16.3} = .31$ $r_{17.3} = .24$
Correlation Coefficients	Difference	*t*-Value	Significance
$r_{16.3} - r_{14.3}$	.07	1.89	N.S.
$r_{16.3} - r_{17.3}$	.07	1.78	N.S.
$r_{16.3} - r_{15.3}$	.05	1.38	N.S.
$r_{15.3} - r_{14.3}$	.02	0.51	N.S.
$r_{15.3} - r_{17.3}$	.02	0.51	N.S.
$r_{17.3} - r_{14.3}$	.00	0.02	N.S.

V_1—Grade in alg. 1 V_4—BSCS Ach. Test 1 V_6—BSCS Ach. Test 3
V_3—DAT Num. Ability V_5—BSCS Ach. Test 2 V_7—BSCS Ach. Test 4

[a] All values have been rounded to two decimal places from computations carried to four decimal places.

TABLE 6[a]

FIRST-ORDER COEFFICIENTS OF PARTIAL CORRELATION BETWEEN MATHEMATICAL APTITUDE AND BSCS ACHIEVEMENT TESTS, AND DIFFERENCES BETWEEN SELECTED PAIRS OF THE COEFFICIENTS (BSCS GROUP)

N = 517	$r_{34.2} = .31$ $r_{35.2} = .25$		$r_{36.2} = .27$ $r_{37.2} = .28$
Correlation Coefficients	Difference	*t*-Value	Significance
$r_{34.2} - r_{35.2}$	.06	1.31	N.S.
$r_{34.2} - r_{36.2}$	.04	1.03	N.S.
$r_{34.2} - r_{37.2}$	.03	0.67	N.S.
$r_{37.2} - r_{35.2}$	.03	0.62	N.S.
$r_{36.2} - r_{35.2}$	.01	0.33	N.S.
$r_{37.2} - r_{36.2}$	.01	0.28	N.S.

V_2—DAT Verb. Reasoning V_4—BSCS Ach. Test 1 V_6—BSCS Ach. Test 3
V_3—DAT Num. Ability V_5—BSCS Ach. Test 2 V_7—BSCS Ach. Test 4

[a] All values have been rounded to two decimal places from computations carried to four decimal places.

That no significant differences were found between achievement in the different portions of the BSCS program and either mathematical aptitude or mathematical achievement was not surprising in light of the fact that each of the tests used as measures was designed to cover a full quarter of the course. One might conjecture that tests designed to measure achievement in smaller segments of the course might uncover significant differences among them.

IMPLICATIONS OF THE STUDY

The primary implication of this study is that possible effects of high or low mathematical aptitude of students should be considered when they are considering enrolling in high school biology. It has long been accepted that students in physics and chemistry courses should have some facility in mathematics, but results of this study indicate that perhaps there should be concern for the mathematical ability of biology students.

Curriculum developers might consider the possibility of maintaining a more traditional biology course for students whose mathematical aptitude is low, or special remedial classes for students of low mathematical aptitude might be made a prerequisite to enrollment in a biology course of the BSCS type.

Further study of relationships between achievement in biology and mathematical achievement, using better measures of achievement and having better controls over concomitant variables, would perhaps reveal more clearly the true nature of such relationships. Likewise, further analysis of portions of the BSCS courses might be undertaken to determine if certain portions of the program are, in fact, more mathematical than others.

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III. THE DEVELOPMENT OF AN ATTITUDE INVENTORY DESIGNED TO DETERMINE REACTIONS OF BIOLOGY TEACHERS TO BSCS BIOLOGY

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INTRODUCTION

With the advent of new and up-to-date science curriculum materials has come an increasing realization that it is not enough to develop materials only, but that programs designed to provide the student with an understanding of the processes of science are also needed. In this connection the role of the teacher and the characteristics of the teacher become more important. The Biological Sciences Curriculum Study (BSCS) has recognized that the teacher is the key to the successful implementation of its Program (1). It follows that those involved in the design and development of curriculum materials should attempt to ascertain teachers' reactions to the materials developed. This is not to imply that quality in curriculum materials must be sacrificed in order to win favor with the teacher. The implication is that the teacher's attitudes concerning curricular materials must be considered if successful implementation of the materials is to be achieved.

Since the teaching techniques suggested in the BSCS biology program are in some instances quite different from the traditional approach to science teaching, and since the BSCS biology program is so devised that the newer techniques are essential to the success of the program, it seemed to the author that an attempt to assess biology teachers' reaction toward the program was needed.

In order to accurately identify the teachers' attitudes toward the BSCS biology program, the author designed and developed an Attitude Inventory. The purpose of this paper is to describe the design, development, and evaluation of this Attitude Inventory (2).

In designing and developing the Attitude Inventory, the investigator reviewed available literature relating to the BSCS biology program; he interviewed a number of scientists, high school teachers and others who were involved in the development of the BSCS materials and also a number of high school teachers who had not been involved in the development of that program. Included among the latter were individuals who had indicated unfavorable reactions to the new program. Written comments were also obtained from a group of high school science teachers who studied the BSCS materials in the spring semester of 1963 as a part of their course work in a seminar course for science teachers. These teachers' comments were related to the strengths and weaknesses of the BSCS program as each teacher interpreted its practicability for his own school situation. Following a careful study of the materials thus obtained, a large number of statements were prepared, reflecting specifically either a view favorable to the BSCS program or a view unfavorable to the program. Subsequently, 70 of the statements were selected by the in-

vestigator as being most likely to aid in the accurate identification of the genuine reactions of the teachers who would be involved in the investigation. These 70 statements were then compiled into a single instrument suitable for administering to a group of individuals. For each statement on the inventory, the respondent was asked for an indication of agreement or disagreement. Half of the statements reflected attitudes and opinions commonly held by those persons who designed the BSCS biology program; thus, agreement with those statements could be considered to represent attitudes favorable to the BSCS biology program. The other half of the statements reflected attitudes and opinions common to those persons who spoke or wrote in favor of the traditional biology program or in opposition to the BSCS biology program. This tentative draft of the attitude-measuring instrument was then administered to a selected group of individuals who had participated in the design and development of the BSCS biology program.

Through the use of an item analysis of the inventory and by incorporating suggestions from those who had responded to statements in the inventory, the inventory was reduced from 70 items to 50. The basic format of the inventory was retained with half of the statements reflecting favorable attitudes and opinions and the other half reflecting unfavorable attitudes and opinions. The order of the statements in the inventory was determined through the use of a table of random numbers. This 50-item inventory was resubmitted to the group of evaluators for suggestions, and following a second revision the inventory was reduced to 46 concise statements. An individual's score on the Attitude Inventory was determined by computing the number of items checked which indicated a favorable attitude toward the BSCS biology program, minus the number of items checked which indicated an unfavorable attitude toward the BSCS program. The maximum score possible on the inventory would, therefore, be a +23, indicating selection of all the statements compatible with the rationale of the BSCS biology program. The minimum score possible would be a —23, indicating selection of all the statements which were not compatible with the rationale of the BSCS program. Items judged to be in agreement with BSCS rationale and philosophy are indicated in the instrument below with an asterisk. Obviously, the asterisk was omitted in the instrument as reproduced and used in research studies.

It should be pointed out that the Attitude Inventory was designed and developed for use with teachers prior to the release of commercially prepared BSCS Biology materials. The final form of the Attitude Inventory follows:

STUDY OF TEACHER REACTIONS TO BSCS PROGRAM
ATTITUDE INVENTORY

Name____________________

INSTRUCTIONS

Attached are statements pertaining to the high school biology programs with which you are acquainted. These statements reflect a wide range of attitudes concerning these biology programs.

We would like for you to read each statement carefully and ask yourself whether you agree or disagree with the statement. We realize that in some cases the decision will be a difficult one. If you agree with the statement, place a check mark in the space provided by the statement. If you do not agree with the statement, leave the space provided blank.

Remember: Place a check mark only by those statements with which you definitely agree.

____ * 1. Laboratory work in high school biology should be more closely integrated with the text material.

____ 2. The high school biology program should be designed and controlled only by high school biology teachers.

____ * 3. The high school biology laboratory work would be more interesting if the nature of laboratory work were more investigative.

____ * 4. Demonstrations are not as effective as student participation type laboratory work.

____ * 5. Students gain more scientific knowledge by participation in BSCS-type laboratory work than they do in the conventionally patterned laboratory work.

____ 6. It would be difficult, if not impossible, to teach the BSCS biology course in its present form.

____ 7. It is not necessary that a student actually perform laboratory work in order to understand the principles of scientific investigation.

____ * 8. The BSCS biology program reflects the current trend in the biological sciences.

____ * 9. The situations which students are exposed to in BSCS biology are similar to those situations faced by a scientist in his every day work.

____ 10. The BSCS biology program has failed to provide for some of the most important aspects of the high school biology course.

____ 11. A practical biology course that has immediately usable information for the student is what is needed in the high school.

____ *12. BSCS biology adequately provides for differences in student ability.

____ 13. The major emphasis in high school biology should be the structure and functions of organs and tissues.

____ 14. Well-prepared motion pictures could be substituted for all high school biology laboratory work.

____ *15. Our knowledge in the life sciences has been derived from limited observations.

____ 16. A slight modification of the existing high school biology program is all that is needed to provide an effective high school biology program.

* Items judged to be in agreement with BSCS rationale and philosophy. Identification (*) not to be shown if instrument is reproduced and used.

____ *17. BSCS biology would enable the student to understand better the ways in which hypotheses are developed and tested.

____ *18. Students come to understand science through participating in laboratory work rather than by reading about science and watching demonstrations.

____ 19. Accurate evaluation of a student's achievement in a laboratory-oriented course, such as the BSCS course, would be impossible.

____ 20. At the present time, there is no need for a major revision of the high school biology program.

____ *21. The use of six weeks of concentrated laboratory work in one area of biology is justifiable.

____ 22. College-bound students would profit more from the conventional type of biology course than they would from the BSCS biology program.

____ *23. In high school biology, major emphasis should be placed on the molecular, cellular, and community aspects of biology.

____ 24. In considering the high school biology program as a whole, it appears that the existing program is adequate.

____ *25. Biological laws are only summations of experiences, consequently, in the future one may expect these laws to become modified or even discarded.

____ 26. The BSCS biology program seems designed exclusively for the above-average student.

____ *27. It is only by engaging in the steps of scientific inquiry that a student becomes able to discern the difference between experimentation and complex instrumentation.

____ 28. Actually, the so-called conventional high school biology course and the recommended BSCS biology course are quite similar.

____ 29. The biology textbooks and laboratory manuals currently in use in the high schools are adequate.

____ *30. The study of science as enquiry should be one of the major objectives of high school biology.

____ 31. The benefits that a student derives from actual first-hand laboratory experimentation cannot be justified in terms of the amount of teacher time and materials required.

____ *32. Laboratory investigations and open-ended experiments are excellent means for conveying an understanding of science.

____ 33. Demonstrations performed by the science teacher are just as effective as student-performed laboratory experiments.

____ *34. It is more important for the average student to understand the purpose

* Items judged to be in agreement with BSCS rationale and philosophy. Identification (*) not to be shown if instrument is reproduced and used.

and method of science than for him to be acquainted with the latest theory of the universe or the newest hormone.

—— 35. BSCS biology could be taught just as effectively without the extensive laboratory investigations suggested.

—— 36. Laboratory exercises should stress the names of structures and processes.

—— *37. The traditional biology course offered in the high school is no longer adequate.

—— 38. The need for the students to acquire factual information is greater than the need for them to understand the ways in which hypotheses are developed.

—— *39. Research biologists should be involved with others in designing the high school biology curriculum.

—— 40. Biology should be taught as a body of factual information.

—— *41. The BSCS biology program reflects careful planning of a practicable course.

—— *42. In high school biology, student work should be centered in the laboratory where real problems are explored.

—— 43. It is doubtful that the BSCS approach to teaching high school biology would result in the students' acquiring a better understanding of the true work of the scientist.

—— 44. The amount of time suggested for laboratory investigation in the BSCS biology program is excessive.

—— *45. A student comes to understand science through participating in science, rather than by serving as a bystander who only reads about science.

—— *46. Wholesale revision of the conventional high school biology course is imperative if a modern curriculum is to be developed.

THE EFFECTIVENESS OF THE ATTITUDE INVENTORY IN DETERMINING SCIENCE TEACHER ATTITUDES

The effectiveness of the Attitude Inventory in determining science teachers' attitudes toward the BSCS biology program was determined by comparing its identification of attitudes with the identification of the same attitudes as determined by a composite assessment based on three additional, different measures. The other measures comprised a Peer Rating (3), an Instructors' Rating, and a Follow-up Questionnaire designed to ascertain use, lack of use, and anticipated use of the BSCS program.

The data used in determining the science teachers' attitudes toward the BSCS program were all obtained following a training period in a Summer Institute for

* Items judged to be in agreement with BSCS rationale and philosophy. Identification (*) not to be shown if instrument is reproduced and used.

High School Science Teachers where 55 biology teachers were given the opportunity to become thoroughly acquainted with the content, philosophy, and methods of the BSCS biology program.

A brief description of the Peer Rating, the Instructors' Rating and the Follow-up Questionnaire is given below.

The Peer Rating: At the conclusion of the training period each biology teacher compared his own attitude toward the BSCS biology program with what he perceived as being the attitude of each of the other science teachers with whom he had worked and studied during the summer. The completed Peer Rating, when placed on a two-day grid and tabulated, yielded two evaluations: the relative position in the group of each individual as seen by himself and the relative position in the group of each individual as seen by all the other group members. Research studies (3) have revealed that after individuals had worked closely together in training situations similar to the BSCS Summer Institute Training Programs, the members of the group were able to evaluate rather accurately the attitudes of their peers. The Peer Rating score used in this study was obtained by determining the relative position of each individual in the group as seen by all the other group members.

The Instructors' Rating: At the conclusion of the summer training program, each instructor was asked to indicate what he perceived as being the reaction of each individual to the BSCS biology program. The instructors were asked to base this rating on any comments made by the individual which definitely, in the judgment of the instructor, placed the individual in the favorable-attitude or unfavorable-attitude category. If the instructor was unable to determine the proper category for a given student, this information was recorded.

The Follow-up Questionnaire: Following the return of the biology teachers to their respective schools and after a period of adjustment to the new school year, a Follow-up Questionnaire was mailed to each of them. The information sought by this questionnaire was related to the actual use, lack of use, and anticipated future use of the BSCS biology program. In addition, reasons for non-use of the materials were sought in those instances where the program was not being used.

The biology teacher sample was classified into three categories based upon their composite ratings in the four different attitude measures. The three categories were: (1) those science teachers who had clearly demonstrated a favorable attitude toward the BSCS biology program; (2) those science teachers who had clearly demonstrated an unfavorable attitude toward the BSCS biology program; and (3) those science teachers who had not clearly demonstrated either a favorable attitude or an unfavorable attitude toward the program.

The science teachers who satisfied one of the following three criteria were placed in the category of possessing a favorable attitude: (1) a score in the top quarter of the Attitude Inventory; (2) a rating in the top quarter of the Peer Rating; and (3) an indication that the science teacher was currently teaching BSCS biology, expressed satisfaction with the program, and anticipated its continued use. In addition to satisfying at least one of the above three criteria, the teacher must not have been given an unfavorable attitude rating by the instructors. The teacher was classified as possessing an unfavorable attitude if he satisfied any of the following cri-

teria: (1) scored in the bottom quarter of the Attitude Inventory; (2) a rating in the bottom quarter of the Peer Rating; (3) an indication on the questionnaire that he was not teaching BSCS biology, did not participate teaching the program, and did not prefer to teach the program even if conditions were such that he would be permitted to do so; and (4) received an "unfavorable attitude" rating from the instructor. Teachers not falling in either the "favorable attitude" category or the "unfavorable attitude" category were placed in an "indeterminate attitude" category.

The above listed criteria for classification of the sample into a favorable attitude group and an unfavorable attitude group resulted in the classification of 25 teachers as possessing favorable attitudes and 24 as possessing unfavorable attitudes; six were placed in an indeterminate attitude category. In the accompanying table there is shown a comparison of the effectiveness of the various measures used in determining the attitudes of the biology teacher sample. The number of teachers identified by the Attitude Inventory and the Peer Rating was limited to the top quarter in each case, and, therefore, the number of teachers selected was predetermined. Only two of the 14 teachers identified by the Attitude Inventory as possessing a favorable attitude were ruled out by the use of the other three measures. If the criteria for selection were modified to permit the top half of the group on the Attitude Inventory to be selected instead of the top quarter, the Attitude Inventory would have successfully identified approximately three-fourths of those teachers who were identified as possessing a favorable attitude when all four measures were used.

TABLE 1[a]

COMPARISON OF MEASURES USED IN THE DETERMINATION OF ATTITUDES

Measure	Number of Teachers Identified as Favorable to BSCS	Number of Teachers Identified as Unfavorable to BSCS	Number of Teachers Incorrectly Identified as Favorable to BSCS*
Attitude Inventory†	14	14	2
Peer Rating†	14	14	2
Instructors' Rating	34	6	11
Follow-up Questionnaire	24	4	9

* Based upon a composite assessment of attitudes using all four measures.

† Limited to top quarter; therefore, this number was predetermined.

[a] Blankenship, Jacob W., "Biology Teachers and Their Attitudes Concerning BSCS," *Journal of Research in Science Teaching*, III (March, 1965), pp. 54–60.

It should also be pointed out that while the Attitude Inventory and the Peer Rating were equally effective in correctly identifying attitudes, the Instructors' Rating was least accurate since it misidentified the attitude category of 11 members of the sample.

While the Attitude Inventory proved to be effective in correctly identifying attitudes, it may be noted that there is value in using multiple separate measures of attitude because of the protection offered against incorrectly identifying an individual's attitude as being favorable when in reality his attitude is unfavorable.

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IV. AN ANALYSIS OF CERTAIN CHARACTERISTICS OF BIOLOGY TEACHERS IN RELATION TO THEIR REACTIONS TO THE BSCS BIOLOGY PROGRAM

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INTRODUCTION

The appearance of new curricular materials in the secondary school sciences is, in part, a result of an increased interest on the part of educators and scientists. Their interest stems from a desire for a secondary school curriculum that is both interesting and consistent with current scientific knowledge.

The teaching emphasis suggested in these new curricular materials is in some cases quite different from that found in conventional science courses (1). Little information is available concerning the science teachers' reactions to these new curriculum programs which call for modification of, and in some instances radical changes in, the teaching techniques normally used by science teachers. Since the new science curricula are devised so that the suggested techniques of teaching are essential to the success of the program, the question logically arises as to how science teachers view these modifications and changes in teaching techniques and whether their attitudes regarding these changes affect their effectiveness in using these materials. It would seem that inquiry into teacher reactions toward a curriculum program, such as the Biological Sciences Curriculum Study (BSCS) biology program, might provide information that would be helpful to those individuals developing new curricular materials in that it would provide guidelines which would enable them to plan a science curriculum that is interesting and consistent with current scientific knowledge, *and* that can be used effectively by a majority of the secondary classroom teachers.

STATEMENT OF THE PROBLEM

This study was designed to permit the author to investigate the reactions of a selected group of science teachers to the BSCS biology program and relate these reactions to certain characteristics of this group of teachers.

The general null hypothesis developed and investigated was:

There are no differences in certain personal characteristics between teachers who demonstrate a favorable attitude (FA) toward BSCS biology and teachers who demonstrate an unfavorable attitude (UA) toward the BSCS biology.

Specific questions posed for answering were related to whether significant differences existed in the following areas between science teachers who demonstrated a favorable attitude toward the BSCS biology program and science teachers who demonstrated an unfavorable attitude toward the program: (1) the number of semester hours of academic course training in undergraduate biology; (2) mean grade point average in undergraduate biology; (3) age at the time of participation

in a special training program designed to acquaint teachers with the content, philosophy, and methods of the BSCS biology program; (4) number of years experience teaching high school biology; (5) mean score on the *Capacity for Status Scale* (*Cs*) of the *California Psychological Inventory* (*CPI*); (6) mean score on the *Social Presence Scale* (*Sp*) of the *CPI;* (7) mean score on the *Responsibility Scale* (*Re*) of the *CPI;* (8) mean score on the *Tolerance Scale* (*To*) of the *CPI;* (9) mean score on the *Achievement via Independence Scale* (*Ai*) of the *CPI;* (10) mean score on the *Intellectual Efficiency Scale* (*Ie*) of the *CPI;* (11) mean score on the *Flexibility Scale* (*Fx*) of the *CPI;* (12) mean score on the *Theoretical Values Scale* (*Th*) of the *Allport-Vernon-Lindzey Study of Values* (*AVL*); (13) mean score on the *Economic Value Scale* (*Ec*) of the *AVL.* The above-mentioned variables are those used in the study in an attempt to reduce the general hypothesis to manageable proportions. It is not the intention of the author to suggest that the variables being considersed are equal in value or importance.

PROCEDURE

The three conditions desirable for the study were: (1) a sufficiently large sample of science teachers; (2) a period of intensive training for these science teachers so that they might have the opportunity to become thoroughly familiar with the content, philosophy, and methods of the BSCS biology program; (3) a data-gathering period immediately prior to and immediately following this training period. These conditions were met in a Summer Institute for High School Science Teachers, sponsored by an institution of higher learning (with the financial assistance of the National Science Foundation).

Seven instruments were utilized in collecting necessary data for the study. Three instruments—a Background Questionnaire, the *California Psychological Inventory,* and the *Allport-Vernon-Lindzey Study of Values*—used to gather personal background information and responses to the selected psychological scales were administered to the science teachers at the beginning of the summer training program. The teachers' reactions to the BSCS biology program were evaluated in the study by the teachers' demonstrated behavior as observed through the use of four different measures: an Attitude Inventory (2) designed and developed by the investigator, a Peer Rating (3), an Instructors' Rating, and a Follow-up Questionnaire designed to ascertain use, lack of use, and anticipated use of the BSCS program. The data used in determining the science teachers' reactions to the BSCS program were all obtained following the training period.

The science teacher sample was classified into three categories based upon their composite ratings on the four attitude measures. The three categories were: (1) those science teachers who had clearly demonstrated a favorable attitude toward the BSCS biology program; (2) those science teachers who had clearly demonstrated an unfavorable attitude toward the BSCS biology program; (3) those science teachers who had not clearly demonstrated either a favorable or an unfavorable attitude.

The science teachers who satisfied one of the following three criteria were placed in the category of possessing a favorable attitude: (1) a score in the top quarter

of the Attitude Inventory; (2) a rating in the top quarter of the Peer Rating; (3) an indication that the science teacher was currently teaching BSCS biology, expressed satisfaction with the program, and anticipated its continued use. In addition to satisfying at least one of the above three criteria the teacher must not have been given an "unfavorable attitude" rating by the instructors. The teacher was classified as possessing an unfavorable attitude if he satisfied any of the following criteria: (1) a score in the bottom quarter of the Attitude Inventory; (2) a rating in the bottom quarter of the Peer Rating; (3) an indication on the questionnaire that he was not teaching the BSCS biology, did not anticipate teaching the program, and did not prefer to teach the program even if conditions were such that he would be permitted to do so; and (4) received an "unfavorable attitude" rating from the instructor. Teachers not falling in either the "favorable attitude" or the "unfavorable attitude" category were placed in an "indeterminate attitude" category. Application of the above-listed criteria for classification of the sample into a "favorable attitude" group and an "unfavorable attitude" group resulted in the classification of 25 science teachers as possessing favorable attitudes and 24 as possessing unfavorable attitudes. Six subjects were placed in an "indeterminate attitude" category.

FINDINGS OF THE STUDY

The test of significance used on the 13 personal characteristic variables were the *t*-test and the chi-square test. The *t*-test was used on Variable 2, grade point average, and on Variables 5 through 13, the psychological scale scores. Differences on Variables 1, 3, and 4 were tested by use of the chi-square test. In Table 1 there are shown the means, differences between the means, and the statistical significance of the differences for each of the 13 teacher characteristic variables. It is apparent that personality characteristics indicated by scores on the *Achievement via Independence Scale* and the *Intellectual Efficiency Scale* were significanlty higher for the favorable attitude group than for the unfavorable attitude group at the .01 level. Personality characteristics indicated by scores on the *Social Presence Scale, Responsibility Scale, Tolerance Scale,* and *Flexibility Scale* were significantly higher for the favorable attitude group than for the unfavorable attitude group at the .05 level. On the other hand, scores on the *Capacity for Status Scale, Theoretical Values Scale,* and *Economic Value Scale* were not significantly different when the two groups were compared.

It should also be noted that the unfavorable attitude group had more years experience than the favorable attitude group and that this difference was significant. There were no significant differences between the two groups when factors of age, grade point average, and semester hours of biology were compared.

In Table 2 are shown the number and percentage of the sample who taught BSCS biology during the 1963–1964 school year following their summer training program. A total of 27 of the 55-member sample, or 49 percent, taught the program Table 2 also shows the number of teachers who were planning to teach the program during the 1964–1965 school year: 44, or 80 percent of the sample, indicated intentions to teach BSCS biology.

TABLE 1[a]

THE MEANS, DIFFERENCE BETWEEN THE MEANS, AND SIGNIFICANCE OF THE DIFFERENCE FOR THE THIRTEEN VARIABLES

Variable	FA*	UA†	$\overline{X}_{FA} - \overline{X}_{UA}$	Significance
(1) Sem. hrs. biology	32.240	29.208	3.032	N.S.
(2) Grade point avg.	1.774	1.675	.099	N.S.
(3) Age	31.520	35.292	—3.772	N.S.
(4) Years experience	2.600	7.542	—4.942	.02
(5) CPI-Cs	21.280	19.708	1.572	N.S.
(6) CPI-Sp	37.240	33.208	4.032	.05
(7) CPI-Re	33.680	31.292	2.388	.05
(8) CPI-To	26.040	23.000	3.040	.05
(9) CPI-Ai	21.480	18.875	2.605	.01
(10) CPI-Ie	42.080	37.667	4.413	.01
(11) CPI-Fx	10.320	7.833	2.487	.05
(12) AVL-Th	50.680	48.792	1.888	N.S.
(13) AVL-Ec	38.520	40.958	—2.438	N.S.

* FA group: N = 25

† UA group: N = 24

[a] Blankenship, Jacob W., "Biology Teachers and Their Attitudes Concerning BSCS," *Journal of Research in Science Teaching, III* (March, 1965), pp. 54–60.

TABLE 2[a]

1963–1964 FOLLOW-UP RESULTS OF NUMBERS OF TEACHERS INVOLVED IN TEACHING BSCS BIOLOGY

	FA Group	UA Group	Indeterminate Group	Total	Percentage
Number Teaching BSCS	16	11	0	27	49%
Number Not Teaching BSCS	9	13	6	28	51%
Number Planning to Teach BSCS 1964–1965*	25	16	3	44	80%

TOTAL N = 55 Favorable Attitude Group N = 25 Unfavorable Attitude Group N = 24 Indeterminate Group N = 6

* This includes those currently teaching BSCS biology who plan to continue teaching the program.

[a] Blankenship, Jacob W., "Biology Teachers and Their Attitudes Concerning BSCS," *Journal of Research in Science Teaching, III* (March, 1965), pp. 54–60.

In Table 3 there are shown data obtained in a second year follow-up study. In comparing Table 2 with Table 3 it should be noted that 38 of the teachers in the study actually taught the course during the 1964–1965 school year (not 44 as indicated plans to do so in Table 2). Also, it should be noted that 35 of them planned to teach BSCS biology during the 1965–1966 school year. Of the 24 teachers who were initially identified as being unfavorable toward the program, 12, or 50 percent, were planning to teach the program during the 1965–1966 school year, while 21 of the 25, or 80 percent, identified as possessing favorable attitudes toward the program were planning to teach the program.

Table 4 comprises information relating to the reasons given for not teaching BSCS biology during the 1963–1964 school year. Although a number of reasons were given, lack of availability of textbooks, laboratory space, and equipment were the primary reasons given by all three groups for not teaching BSCS biology in 1963–1964. It should be noted, however, that the BSCS materials had just been made available by commercial publishers. During the 1964–1965 school year, however, only two teachers from all three groups listed lack of the textbooks and related materials as factors in their decisions not to teach BSCS biology (see Table 5). Three teachers from the unfavorable attitude group listed "local school administration does not favor use of the program" as their reason for not teaching BSCS biology. This reason was not given by any of the teachers in the other groups.

SUMMARY AND CONCLUSION

The purpose of this study was to investigate the reactions of a selected group of science teachers to a new science program (BSCS biology) and to relate these reactions to certain characteristics of this group of teachers. The sample consisted of 55 biology teachers who studied the content, philosophy, and methods of the

TABLE 3

1964–1965 FOLLOW-UP RESULTS OF NUMBERS OF TEACHERS INVOLVED IN TEACHING BSCS BIOLOGY

	FA Group	UA Group	Indeterminate Group	Total	Percentage
Number Teaching BSCS	20	16	2	38	69.1%
Number Not Teaching BSCS	5	8	4	17	30.9%
Number Planning to Teach BSCS 1965–1966*	21	12	2	35	63.6%
TOTAL N = 55 FA Group N = 25 UA Group N = 24 Indeterminate Group N = 6					

* This includes those currently teaching BSCS biology who plan to continue teaching the program.

TABLE 4[a]

REASONS GIVEN FOR NOT TEACHING BSCS BIOLOGY
1963-1964 SCHOOL YEAR

Reasons	FA Group	UA Group	Indeterminate Group	Total
1. Think conventional course better than BSCS	0	0	0	0
2. Do not think BSCS Program fulfills local needs	0	0	0	0
3. Textbooks and related materials not available	4	5	2	11
4. Adequate laboratory space not available	3	7	2	12
5. Adequate equipment and supplies not available	5	9	4	18
6. Feel personal preparation and training inadequate	0	4	2	6
7. Excessive additional work required of teacher	0	2	0	2
8. Local school administration does not favor use of Program	1	2	0	3
9. Fellow biology teachers do not favor use of Program	0	1	0	1
10. Not currently teaching biology in Senior High School	1	1	0	2
11. Lack of funds to buy equipment and supplies	2	2	1	5
12. Other reasons	0	1	2	3

[a] Blankenship, Jacob W., "Biology Teachers and Their Attitudes Concerning BSCS," *Journal of Research in Science Teaching, III* (March, 1965), pp. 54–60.

BSCS biology program in a summer training program. The data obtained and analyzed included: the number of semester hours of academic course credit in undergraduate biology; the earned grade-point average in undergraduate biology courses; the age of the teacher at the time of the teacher's attendance at the summer training program; the number of years of experience teaching high school biology; and nine scores, considered independently of one another, on selected psychological scales.

Based upon an analysis of four different measures used in determining the teachers' reactions to the BSCS program, the science teachers were classified as reacting either favorably or unfavorably to the program.

As a result of the data analysis, the null hypothesis that there are no differences between science teachers who react favorably to the BSCS biology program and science teachers who react unfavorably to the program was rejected. Analysis of the data revealed that, in general, science teachers who ranked higher on a group of scales measuring "capacity for independent thought and action" (4), and who had taught high school biology for three years or less reacted favorably to the

TABLE 5

REASONS GIVEN FOR NOT TEACHING BSCS BIOLOGY
1964–1965 SCHOOL YEAR

Reasons	FA Group	UA Group	Indeterminate Group	Total
1. Think conventional course better than BSCS	0	0	0	0
2. Do not think BSCS Program fulfills local needs	1	1	0	2
3. Textbooks and related materials not available	1	1	0	2
4. Adequate laboratory space not available	3	3	3	9
5. Adequate equipment and supplies not available	3	3	2	8
6. Feel personal preparation and training inadequate	0	0	0	0
7. Excessive additional work required of teacher	1	1	1	3
8. Local school administration does not favor use of Program	0	3	0	3
9. Fellow biology teachers do not favor use of Program	1	1	0	2
10. Not currently teaching biology in Senior High School	0	1	1	2
11. Lack of funds to buy equipment and supplies	0	0	2	2
12. Other reasons	0	0	0	0

BSCS biology program, while those teachers who ranked lower on measures of "capacity for independent thought and action" and who had been teaching high school biology for more than three years reacted unfavorably to the program.

Based upon an analysis of the reasons given for non-use of the BSCS biology program during both the 1963–1964 school year and the 1964–1965 school year, the author is of the opinion that the assumption made by the BSCS that, "The BSCS fully recognizes that merely providing new curricular materials, however good they may be, will not necessarily result in improved biology teaching in the secondary schools. It may facilitate improved teaching, but the teacher remains the key," (5) is supported by these findings. Thus, it would seem that additional studies relating to teacher reactions toward new curriculum programs would be appropriate.

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V. AN ANALYSIS OF CERTAIN ASPECTS OF THE VERBAL BEHAVIOR OF STUDENT TEACHERS OF EIGHTH-GRADE STUDENTS PARTICIPATING IN A BSCS LABORATORY BLOCK

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The Biological Sciences Curriculum Study (BSCS) undertakes to link the conceptual schemes of biology with the spirit and processes of scientific inquiry. One of the special features of the BSCS program is the use of Laboratory Blocks for instruction. Each Laboratory Block covers a series of experiences which permit the student to study a specific biological problem as a biologist might study it if he were starting with the same level of knowledge as the student (1).

The pioneering nature of the BSCS Laboratory Block materials points to the need for research concerning the challenging role of the science teacher. Among the many needs is that of determining some characteristics of effective teaching in the specific areas required for Laboratory Block instruction. One kind of attack on this problem is to delineate the basic relationship between verbal behavior of the teacher and subsequent achievement of the students in a class. One of the most important studies in this area was conducted by Flanders (2). In this study Flanders, utilizing the Flanders System of Interaction Analysis, categorized patterns of teacher influence observed in two groups of junior high school classes, mathematics and social studies. A pre- and post-test design was used to measure achievement. In addition, the students completed a student attitude inventory. The results of the study indicated that in classrooms in which the influence of the teacher was characterized as "indirect," both attitude and achievement scores of the students were superior to those in classrooms in which teacher influence was characterized as "direct."

The design of research that purports to link student achievement with specific behavior of a teacher faces some well-defined obstacles. Mitzel and Gross (3) conducted a survey of the methods by which pupil growth criteria were developed in 20 quantitative studies of teaching effectiveness. The critical evaluation of these studies placed emphasis on the multi-dimensional nature of teacher effectiveness with its accompanying variations from goal to goal.

The use of the Flanders System also has its limitations. Gage (4) pointed out that emphasis on the affective function of teaching ignores the cognitive aspects of classroom interaction. Yamamoto (5) noted the tendency to neglect the unique features of the individual student when one concentrates on the class as a group. In the Flanders System, for example, observers record the categories of student talk but fail to specify which student is doing the talking.

This brief review of classroom interaction is intended to convey some of the problems encountered in studies of teacher effectiveness. The remainder of the paper will be used to describe a study involving student teachers of biology at The University of Texas at Austin. This study was designed to extend the use of

the Flanders System to analyze the behavior of a group of student teachers and their eighth-grade science classes.

The study described here had two purposes: first, to determine the relationship between certain aspects of the verbal behavior of student teachers and the achievement and attitudes of eighth-grade students participating in a BSCS Laboratory Block entitled *Animal Behavior* (6); and second, to describe the differences, if any, in interaction patterns between two groups of student teachers when classified according to the Flanders System, one group characterized as indirect and the other as direct.

The observational system used in this study will be described in some detail because of its pertinence to researchers in other science curriculum areas as well as its importance in this study. One of the basic assumptions of the Flanders System of interaction analysis is that the verbal behavior of the teacher is an adequate sample of his total behavior. The observational procedure consists of a classroom observer classifying the statements in a classroom every three seconds and later tabulating the data in special matrices for analysis. The Flanders System employs a 10-category scheme with three broad divisions: (1) teacher talk, (2) student talk, and (3) silence or confusion. Teacher talk is further divided into two main types of influence, direct and indirect. Indirect influence is defined as actions taken by the teacher which encourage and support student participation. Direct influence refers to those acts that restrict student participation. The categories are outlined in Table 1.

After the observation is completed, the category numbers are entered in the form of tallies into a 10-row by 10-column matrix. Since the category numbers were initially written in columns, any two adjacent numbers can form a sequence pair. The first number in each sequence pair refers to the row category and the succeeding number refers to the column category. Each of the 100 cells of the matrix, then, represents a sequence of events. As an example, a tally in the row-four-column-eight cell would indicate that the teacher asked a question and received an answer.

The matrix enables one to analyze the amount of time certain patterns of teacher influence occur. The matrix also provides a statistical description called I/D Ratio. The I/D Ratio is the total number of indirect teacher statements divided by the total number of direct statements.

SUMMARY OF THE PROCEDURES

A 30-hour workshop was arranged for 10 student teachers at The University of Texas at Austin to provide them with an opportunity to perform the experiments outlined in the *Animal Behavior* Laboratory Block by Follansbee (6). The student teachers then taught this BSCS Laboratory Block to 239 eighth-grade students for a period of six weeks.

An achievement test for use with the *Animal Behavior* Laboratory Block entitled the "Animal Behavior Test" was constructed by the author using the BSCS grid for test analysis as a guide to the development of the test items (7). This test was used to measure the gain in pupil achievement with a six-weeks pre- and post-test

TABLE 1[a]

CATEGORIES FOR INTERACTION ANALYSIS

TEACHER TALK	INDIRECT INFLUENCE	1. ACCEPTS FEELING: accepts and clarifies the feeling tone of the students in a nonthreatening manner. Feelings may be positive or negative. Predicting or recalling feelings are included.
		2. PRAISES OR ENCOURAGES: praises or encourages student action or behavior. Jokes that release tension, not at the expense of another individual, nodding head or saying, "um hm?" or "go on" are included.
		3. ACCEPTS OR USES IDEAS OF STUDENT: clarifying, building, or developing ideas suggested by a student. As a teacher brings more of his own ideas into play, shift to category five.
		4. ASKS QUESTIONS: asking a question about content or procedure with the intent that a student answer.
	DIRECT INFLUENCE	5. LECTURING: giving facts or opinions about content or procedure; expressing his own ideas, asking rhetorical questions.
		6. GIVING DIRECTIONS: directions, commands, or orders to which a student is expected to comply.
		7. CRITICIZING OR JUSTIFYING AUTHORITY: statements intended to change student behavior from nonacceptable to acceptable pattern; bawling someone out; stating why the teacher is doing what he is doing; extreme self-reference.
STUDENT TALK		8. STUDENT TALK—RESPONSE: a student makes a predictable response to teacher. Teacher initiates the contact or solicits student statement and sets limits to what the student says.
		9. STUDENT TALK—INITIATION: talk by students which they initiate. Unpredictable statements in response to teacher. Shift from 8 to 9 as student introduces own ideas.
		10. SILENCE OR CONFUSION: pauses, short periods of silence and periods of confusion in which communication cannot be understood by the observer.

[a] Flanders, Ned A. *Interaction Analysis in the Classroom, A Manual for Observers.* The University of Michigan, 1964.

design. The reliability coefficient for the "Animal Behavior Test" was obtained from the post-test results of 53 students. The Kuder-Richardson Formula (8) was used to determine the test reliability since this method is independent of any particular split-up of items. The post-test reliability was found to be .521.

Additional information concerning the eighth-grade students was obtained from test results on the *California Achievement Tests in Reading* and the *California Mental Maturity Test.* The attitudes of the students toward their student teachers were sampled by means of the Michigan Student Questionnaire (9) after comple-

tion of the Laboratory Block. Each student teacher was observed once a week by one of three trained observers. The identification of relationships among student achievement, student attitude, and I/D ratio of the teacher was accomplished by the use of nonparametric statistical tests. In the tests used in this study, the data were changed from scores to ranks. The information gathered in this study was used to relate the independent variable of I/D Ratio to the dependent variables of student achievement and student attitude.

LIMITATIONS OF THE STUDY

This study was confined to a consideration of the verbal behavior of 10 student teachers and the achievement and attitudes of 239 students. The results of the study might have been different if a larger number of student teachers and students had been involved. However, the use of nonparametric statistics contributed to the values of the study because no assumptions concerning the distribution of the population of student teachers or students were required.

There were two limitations associated with the use of the BSCS Laboratory Block *Animal Behavior* in this study involving eighth-grade students. The first limitation was that the Laboratory Block had been written for tenth-grade students rather than eighth-grade students. The second limitation was the use of an experimental version of the laboratory manual.

Many of the problems associated with these two limitations were worked out by the student teachers during their workshop. During the workshop the student teachers had access to final revisions of both the student Laboratory Block and the teacher's supplement to the Laboratory Block. These two laboratory manuals included revisions not found in the earlier editions. Also, the student teachers had an opportunity to observe eighth-grade students prior to teaching them the Laboratory Block. This observation experience helped the student teachers, during the workshop, to modify sections of the material and procedures given in the student Laboratory Block.

Inability to control some variables was another limiting factor in the study. Differences in socio-economic bcakgrounds of students, school environments, and influences of the cooperating teacher were among the variables beyond the control of the investigator.

RESULTS OF THE STUDY

A significant relationship was found at the .05 level between the gains in median achievement on the "Animal Behavior Test" and the I/D Ratios of the corresponding student teachers. A Kendall rank correlation coefficient of .51 was obtained from the data given in Table 2. When the effects of initial ability were separated out, the correlation between achievement and I/D Ratio was reduced only slightly.

The significant relationship between achievement and verbal behavior of the teacher can also be illustrated by using the i/d Ratio (Revised I/D Ratio). This i/d Ratio is computed by dividing the summation of tallies in catgeories 1, 2, and 3 (Table 1) by the summation of tallies in categories 6 and 7 for any given teacher. A correlation of .60 was found between the gains in median achievement on the

"Animal Behavior Test" and the i/d or revised I/D Ratio. This correlation was significant at the .0083 level. When the effect due to the ability measured by the *California Achievement Tests* in reading was separated out, the correlation was reduced to .59. In other words, the students in the "indirect" classes appeared to achieve significantly more than students in the "direct" classes when the I/D or i/d Ratios were ranked.

A significant correlation was found at the .05 level between the gains in median achievement on the "Animal Behavior Test" and the class medians on the Michigan Student Questionnaire (9). The Kendall rank correlation was .51. The classes with higher achievement gains then tended to score higher on attitudes toward the teacher and the school work.

A significant relationship was also found at the .05 level between the I/D Ratios of the student teachers and the class medians on the Michigan Student Questionnaire. The Kendall rank correlation was .56. This relationship indicated that, operating independently, the observers and the students were able to identify the degree of indirect influence of the student teachers.

Several alternative reasons could be offered to explain the relationship between median gain in student achievement and teacher I/D Ratio ratings. The rejection of these alternative explanations would add support to the main findings of the study. One explanation could be that the five most indirect student teachers (high I/D Ratios) were assigned to the classes with the highest initial reading ability. This hypothesis was rejected as a result of a test of significance.

Another possibility might be that the five most indirect student teachers had been assigned to classes which were very low on the pre-test. It could be reasoned that these classes might achieve more gain on the achievement test because of the wider range available for improvement and not because of the influence of the teacher. This interpretation was rejected because of the lack of a significant relationship between the pre-test medians and gains in median achievement.

The results of giving the pre- and post-test design with a control group indicated that it was unlikely that the gains in median acheivement on the "Animal Behavior Test" were due to causes other than class instruction on the *Animal Behavior* Laboratory Block.

The results of this study of eighth-grade science students parallel some of the findings of Flanders (2), who used a pre- and post-test design to measure achievement in eighth-grade mathematics classes and seventh- and eighth-grade social studies classes. The findings of Flanders indicated that student achievement and attitude scores were significantly higher for those classes in which the teacher was more indirect.

DESCRIPTION OF INTERACTION PATTERNS

For the purpose of describing the differences in interaction patterns in this study, the composite matrix of the four most indirect student teachers (high I/D Ratios) was compared on a percentage basis with that of the three most direct teachers. These two matrices are shown in Tables 3 and 4. The analysis of the matrices indicated that:

TABLE 2

I/D RATIOS AND i/d RATIOS OF STUDENT TEACHERS AND MEDIAN CLASS SCORES

Class Code	Pre-Test Animal Behavior	Post-Test Animal Behavior	California Achievement Tests in Reading	Michigan Student Questionnaire	I/D Ratio of Teacher	i/d Ratio of Teacher
B	17.6	27.6	126.0	187.0	.903	2.40
E	16.5	24.8	128.0	181.0	.658	.907
F	15.0	23.0	117.0	177.5	.223	.409
C	13.5	22.2	112.5	170.5	.709	1.73
J	15.3	20.4	103.8	167.5	.519	.801
H	16.7	23.4	117.3	166.0	.298	.360
D	17.9	26.3	128.3	185.5	.552	1.06
A	15.0	25.2	116.5	178.0	.762	2.04
G	14.7	21.5	111.5	157.8	.288	.418
I	12.3	18.5	97.5	168.0	.542	.634

Acceptance of feeling was used over four times as much by the indirect group.

Statements of praise and encouragement were used twice as often by the indirect student teachers following student-initiated ideas.

Clarifying and making use of student ideas as a category was used over twice as often by the indirect group after student-initiated talk.

Lecture in a continuous fashion was used more by the direct group of student teachers. Total lecture time accounted for about 57 percent of teacher talk for the direct group as compared to 44 percent for the indirect group.

Direction-giving was used nearly twice as often by the direct group.

Criticism was sparingly used by both groups.

Student Patterns were different for the two groups. There were over twice as many student-initiated statements in the indirectly taught group.

Silence or confusion appeared more often in the classes taught by the direct group.

The relationships between the two groups described in this study are quite similar to the results reported by Amidon and Giammatteo (10) in their study of superior teachers.

CONCLUSIONS AND IMPLICATIONS OF THE STUDY

This study indicated significant relationships between the verbal influence of the student teachers on the freedom of participation of the pupils and the subsequent achievement and constructive attitudes of the students.

TABLE 3

COMPOSITE MATRIX FOR "INDIRECT" STUDENT TEACHERS, N = 4, ADJUSTED FOR 1,000 TALLIES*

Category	1	2	3	4	5	6	7	8	9	10	Total
1	4.0	.3	.2	.9	2.5	.1	.1	----	.5	.8	9.3
2	.4	2.5	5.6	5.2	3.9	1.0	.2	1.4	2.5	1.6	23.9
3	.4	1.2	36.4	13.4	15.8	1.9	.3	4.7	7.9	3.2	85.3
4	.9	.6	1.1	23.8	6.0	1.6	.4	53.1	7.4	18.5	113.5
5	1.9	1.5	1.6	23.7	176.7	8.6	.7	2.3	10.2	11.8	239.2
6	.4	.3	.2	2.9	6.0	33.8	.6	2.3	3.2	9.5	59.1
7	.1	.1	----	.5	1.2	.9	3.1	.5	1.2	.9	8.6
8	.3	12.3	22.8	18.6	7.6	2.1	1.0	75.5	2.6	9.3	152.0
9	.2	4.6	15.7	5.8	9.1	2.3	.7	.3	91.3	6.4	136.4
10	.7	.6	1.8	18.5	10.4	6.8	1.6	11.9	9.7	110.6	172.6
Total	9.3	23.9	85.3	113.5	239.2	59.1	8.6	152.0	136.4	172.6	1000.

* The adjusted figure in each cell of the 10 × 10 matrix is determined by multiplying by 1,000 the ratio between the tally in that cell and the total tally.

TABLE 4

COMPOSITE MATRIX FOR "DIRECT" STUDENT TEACHERS, N = 3, ADJUSTED FOR 1,000 TALLIES*

Category	1	2	3	4	5	6	7	8	9	10	Total
1	.4	----	----	.3	.7	.3	.1	.1	----	.3	2.1
2	----	1.7	3.6	4.1	4.2	.5	.1	.7	.7	2.5	18.1
3	----	.3	8.5	3.7	7.9	1.2	.3	2.1	2.1	3.9	30.0
4	----	.5	.1	15.3	5.4	1.2	1.0	37.1	3.1	12.3	76.1
5	1.1	1.1	.9	19.5	269.0	13.2	.9	.6	9.9	22.5	338.6
6	.3	.5	.1	4.1	8.3	75.6	1.1	1.0	6.5	20.2	117.7
7	----	.1	.1	.6	.4	.9	3.5	.5	.6	2.5	9.1
8	.1	11.2	9.1	11.6	7.5	2.7	.9	51.6	1.5	6.2	102.4
9	----	2.0	6.9	3.1	16.0	5.7	.1	----	25.0	5.2	64.0
10	.3	.7	.6	13.9	19.1	16.4	1.2	8.6	14.6	166.2	241.7
Total	2.1	18.1	30.0	76.1	338.6	117.7	9.1	102.4	64.0	241.7	1000.

* The adjusted figure in each cell of the 10 × 10 matrix is determined by multiplying by 1,000 the ratio between the tally in that cell and the total tally.

Comparison of the two composite matrices indicated that the verbal behavior patterns of the indirect group of student teachers differed substantially from those of the direct group. The indirect group was more receptive to student-initiated ideas, tended to encourage these ideas more, and also made more of an effort to build upon these ideas than did the direct group of student teachers. The indirect group also spent less time lecturing and giving directions.

This study, as well as other allied studies in interaction analysis, suggests implications for both implementors of new science curricula and educators concerned with teacher training. Two of these allied studies in the area of science education will be reviewed briefly. An observational system consisting of 45 categories was developed and tried out in 10 high school biology classes by Parakh (11). In this study of 10 teachers, the most conspicuous feature was the preponderance of teacher talk. The "average" or composite teacher talked about 75 percent of the total time in lecture-discussion classes and about 50 percent of the total time in laboratory classes. Taking into account that these are average figures and that wide variations existed among individuals, the point is made that we need additional quantitative information about the manner in which science materials are being implemented.

In a study of 17 physics teachers and their classes, Snider (12) noted that the verbal behavior of each of the teachers was quite consistent over a period of time provided that all observations were taken during a particular type of activity such as lecture, laboratory or recitation-discussion. This study by Snider emphasized the need for further investigation of teacher verbal behavior during such periods as laboratory investigations.

The continued alliance between educational researchers and curriculum developers should provide additional information concerning theories of classroom instruction. It is to be hoped that the teacher of the future will be more concerned with ways in which students learn and the most effective ways to assist in this learning process.

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VI. LIBRARY RESOURCE BOOKS FOR HIGH SCHOOL BIOLOGY

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In recent years, increased emphasis on many facilities and services of the public schools in Texas has followed the adoption of new curriculum programs. In particular, programs in the sciences have reflected a need for a reexamination of the teaching techniques and materials in the courses offered. Many of the new programs call for more attention to laboratory instruction and its requirement for equipment and facilities. A number of new textbooks are also available; among them are those developed in the major curriculum studies undertaken on a nationwide scale. The textbook and the laboratory are important common denominators in the high school science class. Both, however, require supplementation for the best instruction, and among the important supplements are library resources. Both the research scientist and the science teacher require good library resources.

In view of both the importance of textbooks and library resource materials in teaching high school biology and the recent publication of new textbooks, it appeared desirable to analyze the nature of the new textbooks and their recommendations for use of library resources and to compare the results with a similar analysis of older textbooks. This paper reports results of such a two-fold analysis.

Ten textbooks were selected for the study. Five of these had copyright dates ranging from 1951 to 1954 and five were copyrighted in 1963 or later. The textbooks analyzed were as follows:

Textbook No.

I. Baker, Arthur O., and Lewis H. Mills
Dynamic Biology Today
New York, Rand McNally and Company, 1953

II. Dodge, Ruth A., William M. Smallwood,
Ida Revely and Gus Bailey
Elements of Biology
Boston, Allyn and Bacon, 1952

III. Moon, Truman J., Paul B. Mann, and
James H. Otto
Modern Biology
New York, Henry Holt, 1951

IV. Smith, Ella Thea
Exploring Biology
New York, Harcourt, Brace and Company, 1951

V. Vance, B. B., and D. F. Miller
Biology for You
Chicago, J. G. Lippincott Company, 1954

VI. Biological Sciences Curriculum Study

Biological Science: Molecules to Man (Blue Version)
Boston, Houghton Mifflin Company, 1963

VII. Biological Sciences Curriculum Study
High School Biology (Green Version)
Chicago, Rand McNally and Company, 1963

VIII. Biological Sciences Curriculum Study
Biological Science, An Inquiry Into Life (Yellow Version)
New York, Harcourt, Brace and Company, 1963

IX. Otto, James H., and Albert Towle
Modern Biology
New York, Holt, Rinehart, and Winston, Inc., 1963

X. Gregory, William H., and Edward H. Goldman
Biological Science for High School
Dallas, Ginn and Company, 1965

The initial step in the study involved tabulating a list of all reference books (including pamphlets and bulletins) and periodicals cited and quoted in the several texts. All books and periodicals listed in bibliographies were included. The total list included 138 different titles; however, there were a total of 2,256 citations, including duplicates. The list included both the number of citations and quotations made and the number of different titles given. These data are given in Table 1. They indicate that the older textbooks used a few more references of different titles of books, but that the newer books used more quotations. On the other hand, more journals were cited and quoted in the newer books than in the older ones. It may also be noted that among the newer books the three BSCS textbooks used more quotations from books and a larger total number of journal citations and quotations than the other new books included in the study. The BSCS Blue Version was particularly conspicuous in this respect.

Publication dates of references (books and journals) were also determined and are given in Table 2. Obviously one could not expect listing of references published after 1954 in the older textbooks studied and, in general, one would expect a larger number of references with older publication dates in the older textbooks than in the newer ones. Virtually no journal references with publication dates prior to 1945 are listed in either the older or newer textbooks studied. The number of references to books published later than 1950 was somewhat similar except that the text by Otto and Towle had considerably more published in 1960 or later than any of the other newer books.

Book references were classified in the following categories: College Textbooks; High School Textbooks; Books on Special Topics; and Miscellaneous (including encyclopedias). The data reveal little difference among the ten textbooks studied concerning the nature of the references. In all of the texts the largest number of references were books on special subjects and, as might be expected, very few high school texts were cited in any of the texts studied. Two of the older texts did make some noticeable use of encyclopedias but only one of the newer textbooks mentioned an encyclopedia. Journal references were classified as professional journals

or popular reading journals. In general more professional journals were used than popular reading journals. The BSCS Blue Version included the largest number of professional journals.

TABLE 1

THE NUMBER OF BOOKS AND PERIODICALS CITED AND QUOTED IN THE TEXTBOOKS STUDIED

Textbooks Number	Books			Journals		
	Total No. Cited and Quoted	No. Different Titles Cited	No. Different Titles Quoted	Total No. Cited and Quoted	No. Different Titles Cited	No. Different Titles Quoted
		Copyright 1951–1954				
I	140	95	4	0	0	0
II	481	365	3	1	1	1
III	190	180	0	0	0	0
IV	233	189	11	30	12	4
V	157	151	5	4	4	1
		Copyright 1963–1965				
VI	246	149	74	235	23	23
VII	224	114	10	126	10	5
VIII	213	125	11	170	4	3
IX	234	229	3	52	6	4
X	138	120	5	88	3	1

The list of book references cited and quoted in the ten textbooks was compared with the *AAAS Book List for Young Adults* (1). The AAAS Book List contains over 1,000 science and mathematics books selected and recommended by scientists in many fields. The results of this comparison are given in Table 3 and reveal, as might be expected, that the newer texts contain more references listed in the AAAS Biology list than do the older texts. Of the five new texts studied, the one by Otto and Towle has the highest number of references cited in the AAAS Book List.

Although reference to individual scientists and their research, strictly speaking, is not necessarily a library resource, such citations or quotations often lead the student to the library if made in such a way as to motivate the student to learn more about the individual scientist or the research he has pursued. For this reason, the textbooks studied were analyzed in terms of references made to individual scientists and their work. Table 4 summarizes the results and indicates that the newer textbooks have made much greater use of references to scientists and their work. Fairly similar numbers of scientists were introduced in all of the newer books with the text by Otto and Towle having the smallest number.

TABLE 2

PUBLICATION DATES OF BOOKS AND JOURNALS CITED AND QUOTED IN THE TEXTBOOKS STUDIED

	DATES OF PUBLICATION								
Textbook Number	1929 and Earlier	1930 to 1934	1935 to 1939	1940 to 1944	1945 to 1949	1950 to 1954	1955 to 1959	1960 and Later	Date not Known
				BOOKS					
				Copyright 1951–1954					
I	7	19	32	34	2	0	--	--	1
II	116	50	84	59	28	4	--	--	24
III	1	4	23	23	103	25	--	--	1
IV	19	5	21	27	48	56	--	--	13
V	10	11	31	43	32	20	--	--	10
				Copyright 1963–1965					
VI	6	1	2	7	3	21	49	56	4
VII	7	1	2	0	3	13	36	48	4
VIII	4	1	2	1	5	14	51	44	3
IX	2	1	3	1	4	13	43	140	22
X	4	1	2	0	9	16	44	27	17
				JOURNALS					
				Copyright 1951–1954					
I	0	0	0	0	0	0	--	--	0
II	0	0	0	0	0	0	--	--	1
III	0	0	0	0	0	0	--	--	0
IV	3	1	0	1	5	16	--	--	4
V	0	0	0	0	0	3	--	--	1
				Copyright 1963–1965					
VI	1	1	0	0	16	69	81	56	11
VII	2	0	0	0	1	11	48	57	7
VIII	1	0	0	0	12	64	59	28	6
IX	1	0	0	0	4	13	9	21	4
X	0	0	0	0	0	6	36	45	1

The nature of reference use was studied for each of the ten textbooks analyzed. Data concerning citations varied considerably from one text to another and no conspicuous pattern differences were observed when the older books were compared with newer ones. In most instances the citations were in the form of a bibliography at the end of a chapter or unit. Some of the references were annotated, while others were not. The nature of the annotations varied considerably. In some instances the annotations pointed up specific uses; certain sections were singled

TABLE 3

REFERENCES IN TEXTBOOKS STUDIED RECOMMENDED IN THE AAAS BOOK LIST

	Texts 1951–1954					Texts 1963–1965				
	I	II	III	IV	V	VI	VII	VIII	IX	X
Total Number of Titles from Texts in AAAS Book List	4	22	17	29	9	50	38	45	72	43
Number of Titles from Texts that Appear Among First Priority Titles in AAAS Book List	1	12	4	10	3	20	13	20	25	15

TABLE 4

REFERENCE TO SCIENTISTS AND THEIR WORK IN THE TEXTBOOKS STUDIED

		Dates of Contributions of these Scientists				
Textbook Number	Total No. of Scientists Introduced	Before 1850	1850 to 1925	1925 to 1940	1940 to 1960	Dates Not Established
		Copyright 1951–1954				
I	41	16	21	1	2	1
II	70	18	27	4	9	12
III	43	10	21	1	1	10
IV	78	27	17	4	23	8
V	32	9	13	0	3	7
		Copyright 1963–1965				
VI	146	46	43	10	33	14
VII	103	29	23	11	37	3
VIII	146	48	49	11	36	2
IX	69	19	27	5	17	1
X	135	36	36	11	33	19

out; and the degree of difficulty was indicated. In a number of instances complete information (complete name of author or title, name and address of publisher, publication date) for each reference was not given.

The approach made by the different authors in listing references varied considerably. Some were listed simply as "References" or "Bibliography." Others appear

under such headings as "Increasing Your Knowledge of This Unit" or as "Applying Your Knowledge" for library research. Some were listed as "Further Reading" or "Interesting Reading." Suggestions to note advertisements in "reliable books and magazines"; "look up definitions," etc.; "find out all you can"; "consult reference books" were found. In one instance the suggestion is made that the students collect twigs from trees and with a "tree book" identify them. There were a number of suggestions to write reports on subjects not covered in the textbook. In another instance it is suggested that the students find out what new elements have been discovered and what vitamins are prepared commercially in capsule or tablet form. Suggestions that students study the lives of early scientists occur often. In one book the question was asked, why the library, as well as the laboratory, is important to scientific research.

Contributions from the study reported here are perhaps as important for things found lacking as for the specific data collected and the trends observed. Although various suggestions were made for use of library resources, there were few, if any, really imaginative procedures that would appear to lead the student directly into the need for, and techniques of, library study. In general, it can be surmised that too many references were listed carelessly with incomplete data and insufficient annotations and perhaps with little good reason for inclusion.

There is little evidence of research on the extent or nature of student use of library resources. Likewise, there is little evidence that most high school libraries are adequately stocked with appropriate references. On the positive side, however, the trend toward increased use of quotations (often in the context of providing evidence) and an increased use of journal references, as well as more use of up-to-date materials, may be considered as progress in more effective use of library resources. In the final analysis, textbook authors, teachers, and students need to recognize and accept what every scientist knows—that the library is an indispensable tool for effective work.

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VII. THE DEVELOPMENT OF SOME SUPPLEMENTARY TEACHING MATERIALS AND EVALUATION OF THEIR USE IN THE HIGH SCHOOL BIOLOGY PROGRAM*

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INTRODUCTION

New curriculum programs in biology are well known and have been widely disseminated. They include a number of new textbooks, some of which were developed in the large national-level curriculum studies and others prepared in the traditional way. Many of these programs, particularly those developed by the Biological Sciences Curriculum Study, have included the development of certain ancillary materials that can be used in conjunction with the textbooks to develop the total program in high school biology. In many of the programs that have been developed, a great deal of emphasis has been placed on teaching inquiry as one of the important features of the course. In particular, the Laboratory Blocks (1), "Invitations to Inquiry" (2), and the Single Topic Films (3) have been developed in the BSCS program to aid in meeting this objective. The techniques involved in teaching these materials vary from a completely "dry-lab" situation at one extreme to a "wet-lab" situation on the other. Relatively little attention has been given to the development of intermediate type materials.

The project reported in this paper describes the design and evaluation of some new supplementary teaching materials that illustrate an intermediate position between the two extremes mentioned above.

DEVELOPMENT OF MATERIALS

The project involved the development of a series of materials that we have chosen to call "Springboards for Discussion." They are designed for use with the overhead projector and audio-tape player. Each Springboard, with one or two exceptions, involves either singly or in combination some visual or audio presentation of a classical or current experiment in biology. In certain instances selected scientists were asked questions and their answers were recorded; in other instances they were asked to give a more formal presentation. The visuals developed for each Springboard for Discussion included pictorial and diagrammatic materials with certain questions asked at various times within the presentation. The pattern-of-use design was such as to require interruption at many places in the presentation to allow interaction among members of the class and the teacher. Each Springboard included a Teacher's Guide that gave directions for the presentation, and Student Notebook Sheets for student responses.

In this project, the Springboards for Discussion were designed to fit a particular

* This project was supported in part by a grant from the United States Office of Education.

textbook, BSCS Blue Version, *Molecules to Man* (4); however, they could be used with other texts and could serve as models for the development of other Springboards for Discussion.

Twelve Springboards for Discussion were developed for the first semester of high school biology. These were:

1. Why Study Biology?
2. Why Are There No Bluebonnets on Serpentine Soils?
3. Is This a Living Fluid Infectant?
4. What Causes This Selective Advantage?
5. Is This a Case of Spontaneous Generation?
6. What Controls Cell Development?
7. What Is a Source of Carbon in Plants?
8. Listen to Leaders in Science: Microbiology.
9. What Are Some Techniques of Studying Cell Components?
10. Does the Nucleus Change During Differentiation?
11. Can Resting Cells be Forced to Grow?
12. Can Tumor Cells Produce Normal Cells?

In each of the above cases the presentation was structured to elicit class discussion and to give the students vicarious experiences in the methods used by scientists. Students were asked to anticipate certain results, to interpret data, to plan experiments to test hypotheses, or to criticize certain procedures. Their responses formed the basis of class discussions and allowed the students opportunities to become acquainted with methods of scientists and with evidence upon which present-day understandings are based.

An illustration of the Teacher's Guide and a facsimile copy of the transparencies of one of the Springboards, "Why Are There No Bluebonnets on Serpentine Soil?", is found at the end of this chapter. It should be remembered that appropriate use of any of the Springboards requires considerable emphasis on teacher-student interactions and on student-student interactions. Therefore, in actual use it is very important not to unmask the various parts of each transparency until they are needed for the next step in the discussion. In the following facsimile copy, the effect of transparent covers is used to facilitate reading here, but obviously covers on the transparencies used in the classroom were opaque.

EVALUATION OF THE SPRINGBOARDS

These Springboards were evaluated following their use in two schools in a large metropolitan school system. Preliminary test data gathered from both schools included pre-test scores on the *Processes of Science Test* and the Verbal Reasoning and Numerical Ability portions of the *Differential Aptitude Test*. Selected items on the BSCS *Comprehensive Final Examination* and a post-test of the *Processes of Science Test* were administered to the first-semester biology classes in both schools at the end of the semester. Teacher feedback was obtained on each Springboard and on the project as a whole.

The test data were analyzed by means of an analysis of variance, with scores on the *Differential Aptitude Test* serving as a concomitant variable and scores on

selected items of the BSCS *Comprehensive Final Examination* and gains between pre- and post-tests of the *Processes of Science Test* serving as criterion variables. Table 1 shows the necessary statistics about both groups needed for analysis of variance. Since the groups were considerably different on the concomitant variable of the *Differential Aptitude Test* scores, an adjusted mean ($\overline{X}$) was computed for each group on the criterion variables. This held the *Differential Aptitude Test* scores constant for each comparison. Tables 2 and 3 are summary tables for the analysis of covariance that were computed for each of the criterion variables.

The adjusted means for gains on the post-pre scores of *Processes of Science Test* are .1323 and .0244 for the experimental group and the control group, respectively. In order to test the significance of this difference an F ratio was computed for the two groups. This difference is shown in Table 2 to equal 17.4734. Referring to an F table, the probability was found to be $<.01$. The difference was significant; therefore, the experimental group showed a higher mean gain or gains of post-pre scores on the *Processes of Science Test* compared to the control group when the *Differential Aptitude Test* scores were held constant.

TABLE 1

MEANS, ADJUSTED MEANS, AND STANDARD DEVIATIONS FOR THE *PROCESSES OF SCIENCE TEST* AND SELECTED ITEMS FROM THE BSCS *COMPREHENSIVE FINAL EXAMINATION* AND MEANS AND STANDARD DEVIATIONS FOR THE *DIFFERENTIAL APTITUDE TEST*

School 1 (Control group) N = 558	$\overline{X}$ gain	Adjusted $\overline{X}$*	Standard Deviation
Processes of Science Test	2.3469	.0244	5.6648
Selected Items from the BSCS *Comprehensive Final*	13.8548	4.8113	5.1645
Differential Aptitude Test	54.7760	---------	15.2667
School 2 (Experimental group) N = 416	**$\overline{X}$ gain**	**Adjusted $\overline{X}$**	**Standard Deviation**
Processes of Science Test	2.0432	.1323	4.4805
Selected Items from the BSCS *Comprehensive Final*	11.7188	4.2782	3.8161
Differential Aptitude Test	45.0673	---------	15.7820

* Adjusted $\overline{X} = \overline{Y}$ dependent variable—b $\overline{X}$ D.A. T.
b = slope of the regression line of the dependent variable on *Differential Aptitude Test* scores.

TABLE 2

SUMMARY TABLE OF THE ANALYSIS OF COVARIANCE FOR GAINS ON THE SCORES BETWEEN PRE- AND POST-TESTS OF THE *PROCESSES OF SCIENCE TEST*

Source of Variation	Sum of Squares	df*	Mean Square	F†	P‡
Between groups	463.2249	1	463.2249	17.4734	<.01
Within groups	25768.0186	972	26.5103		
Total	26231.2435	973			

* df = degrees of freedom
† F = Mean square between groups / Mean square within groups
‡ P = Probability

TABLE 3

SUMMARY TABLE OF THE ANALYSIS OF COVARIANCE FOR SCORES ON SELECTED ITEMS OF THE BSCS *COMPREHENSIVE FINAL EXAMINATION*

Source of Variation	Sum of Squares	df*	Mean Square	F†	P‡
Between groups	74.3439	1	74.3439	4.8261	<.05
Within groups	14973.2355	972	15.4045		
Total	15047.5794	973			

df = degrees of freedom
† F = Mean square between groups / Mean square within groups
‡ P = Probability

The adjusted means for scores on selected items on the BSCS *Comprehensive Final Examination* are 4.2782 and 4.8113 for the experimental group and the control group, respectively. In order to test the significance of this difference an F ratio was computed for the two groups. This is shown in Table 3 to equal 4.8261. Referring to an F table, the probability is found to be <.05. The difference was significant; therefore, the control group showed a higher mean score on selected items of the BSCS *Comprehensive Final Examination* when the *Differential Aptitude Test* scores were held constant.

A significant difference was found between the control group and the experimental group on gains of the *Processes of Science Test.* Regression lines of the

Processes of Science Test scores on *Differential Aptitude Test* scores for both groups were parallel over the observed range of the *Differential Aptitude Test* scores.

A significant difference was found between the experimental group and the control group on scores of selected items of the BSCS *Comprehensive Final Examination* when the *Differential Aptitude Test* scores were held constant. Preliminary statistics showed scores on selected items of the BSCS *Comprehensive Final Examination* per unit of the *Differential Aptitude Test* scores were the same for both the control group and the experimental group over the observed range of the *Differential Aptitude Test* scores.

SUMMARY OF FINDINGS

The experimental group scored significantly higher on the *Processes of Science Test* ($P<.01$) when scores on the *Differential Aptitude Test* were held constant.

The control group scored significantly higher on the selected items of the BSCS *Comprehensive Final Examination* ($P<.05$) when scores on the *Differential Aptitude Test* were held constant.

Teacher feedback generally agreed with the analysis of the test data as reported above.

CONCLUSIONS

The Springboards for Discussion are effective devices for teaching the processes and procedures of scientific inquiry. Both the control and experimental groups made gains as measured by pre- and post-tests of the *Processes of Science Test*. The relatively higher gains of the experimental group when scores on the concomitant variable were held constant probably reflect positive effects of the Springboards for Discussion in terms of the objectives of this test. However, the higher gains made by the control group on selected items of the BSCS *Comprehensive Final Examination* suggest that gains of the experimental group in learning scientific inquiry may have been made at the expense of some teaching of content. The findings indicate, therefore, that future research is needed to compare the teaching of content *per se* and scientific inquiry *per se*. They also point up the need for creating new materials in which a stronger attempt to do both jobs is made.

Although the Springboards for Discussion may be considered effective teaching devices to emphasize processes and procedures of scientific inquiry, their use must be judiciously fitted in with other materials of the biology program. Less material on other topics can be covered with the Springboards for Discussion format than with conventional classroom procedures. This situation may also account in part for the relatively higher score of the control group on selected items of the BSCS *Comprehensive Final Examination.*

The preparation and use of materials such as the Springboards for Discussion appear to provide one potentially effective way of implementing changes in teaching patterns, particularly as they involve teaching the processes of science. The response by teachers, and the relative ease with which the materials were used

in the project reported here, indicate the practicality of this approach and support the suggestion that other new materials of this type should be developed.

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SPRINGBOARD
FOR
DISCUSSION

WHY ARE THERE NO BLUEBONNETS
ON SERPENTINE SOIL?

TEACHER'S GUIDE

W H Y A R E T H E R E N O B L U E B O N N E T S O N S E R P E N T I N E S O I L ?

This Springboard for Discussion is designed for use after Chapter 1 of the BSCS Blue Version Textbook. During the discussion of topics 1-8 and 1-9 in Chapter 1, the role of investigation in science is emphasized. This Springboard is based upon an actual study and emphasizes the symbiotic relationship of a legume and the nitrogen-fixing bacteria. It illustrates one experimental approach and poses some interesting unanswered problems that might be tested by a similar approach.

Students may be aware of the symbiotic relationship of the nitrogen-fixing bacteria and legumes; if not, the teacher may provide this information at the appropriate time in this discussion.

P R O C E D U R E:

BEFORE SHOWING THE FIRST TRANSPARENCY, HAND OUT PAGES FOR STUDENT NOTEBOOKS. THEN GIVE THE STUDENTS THE FOLLOWING INFORMATION:

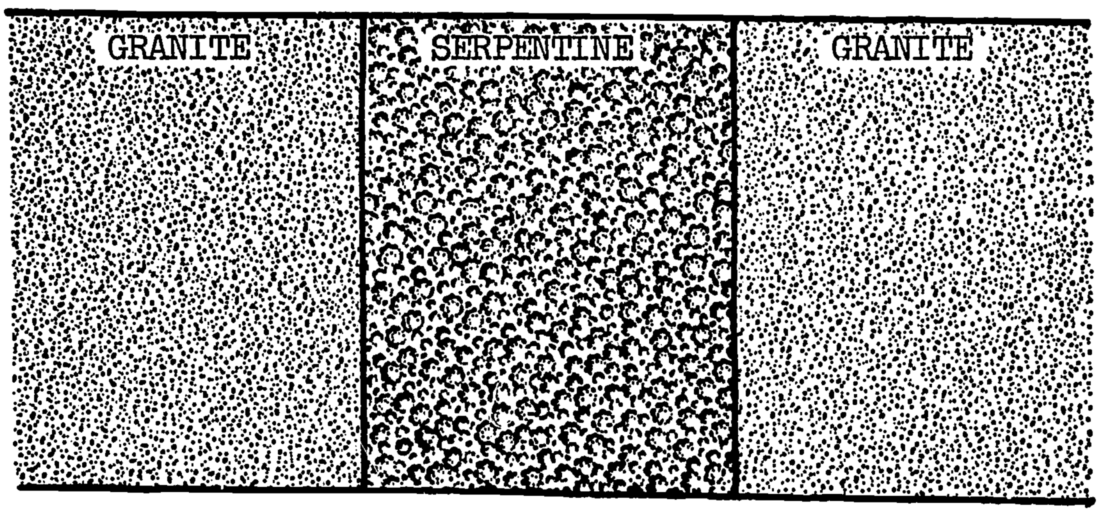
Not all questions encountered in biology can be answered easily by experimental studies. In many cases the scientist merely gets some "clues" that enable him to suggest possible explanations of the phenomena observed. Living organisms are affected by many things in their environments that the scientist may not be able to control precisely. On the other hand, careful observation of critical factors may provide information useful for designing experiments to test possible explanations of the phenomena observed.

PROJECT TRANSPARENCY # I AND READ ALOUD COPY ON TRANSPARENCY

WHY ARE THERE NO BLUEBONNETS ON SERPENTINE SOIL?

TRANSPARENCY # I

IN CENTRAL TEXAS THERE IS A REGION OF LAND WHERE SEVERAL TYPES OF IGNEOUS ROCK HAVE INTRUDED. THESE INTRUSIONS HAVE FORMED SMALL AREAS OF LAND. EACH AREA CONTAINS SOIL DERIVED FROM ONE TYPE OF ROCK. SEVERAL OF THESE SMALL AREAS ARE MADE UP OF SOILS FROM A PARTICULAR TYPE OF IGNEOUS ROCK CALLED SERPENTINE. SURROUNDING THE SERPENTINE AREA ARE AREAS DERIVED FROM GRANITE, ANOTHER IGNEOUS ROCK.



PROJECT TRANSPARENCY # II, PART 1 AND READ ALOUD COPY ON TRANSPARENCY
(DO NOT UNMASK PART 2 AT THIS TIME.)

Allow the students time to write on their notebook pages suggestions to answer the question on the transparency. Then discuss the ideas they have written and write them on the chalk board. Then:

"Let's see what possibilities the botanist considered."

UNMASK PART 2 AND READ ALOUD COPY ON TRANSPARENCY.

Compare the four possibilities suggested by the botanist with those the students have suggested. Discuss the advantages and disadvantages as well as the practicalities of each.

Instruct the students to write in their notebook suggestions as to how each of the possibilities suggested by the botanist might be tested. Then:

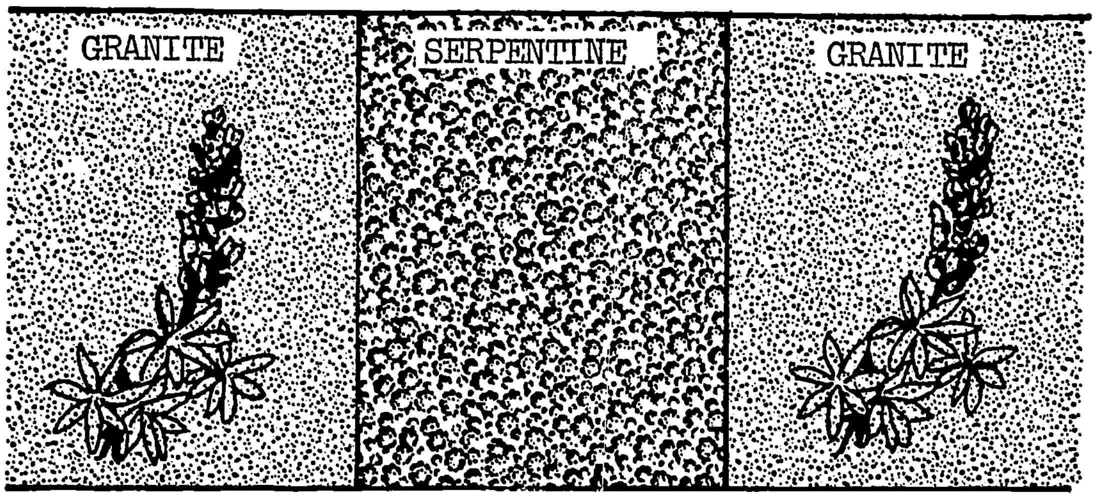
"Let's see how the botanist tested Possibility # 1."

WHY ARE THERE NO BLUEBONNETS ON SERPENTINE SOIL?

TRANSPARENCY # II

PART 1

A BOTANIST WHO WAS OBSERVING PLANTS IN THIS REGION OF TEXAS NOTICED THAT BLUEBONNETS GREW ON THE GRANITE SOILS ADJACENT TO THE SERPENTINE SOILS, BUT DID NOT GROW ON THE SERPENTINE SOILS. HE WONDERED WHY BLUEBONNETS WERE DISTRIBUTED IN THIS PATTERN.



QUESTION: WHAT DO YOU THINK ARE SOME POSSIBLE REASONS THIS PATTERN OCCURED?

PART 2

POSSIBILITY # 1 - ANIMALS OR OTHER AGENTS THAT COULD DISTRIBUTE THE BLUEBONNET SEEDS MIGHT NOT BE ABLE TO GET TO THE SERPENTINE SOILS DUE TO NATURAL OR MAN-MADE BARRIERS.

POSSIBILITY # 2 - THE SERPENTINE SOIL MAY CONTAIN SOME SUBSTANCE THAT KEEPS BLUEBONNET SEEDS FROM GERMINATING.

POSSIBILITY # 3 - THE SERPENTINE SOIL MAY LACK SOMETHING WHICH THE BLUEBONNET PLANTS REQUIRE FOR GROWTH.

POSSIBILITY # 4 - THE SERPENTINE SOIL MAY CONTAIN SOME SUBSTANCE WHICH IS POISONOUS TO THE BLUEBONNET PLANTS AFTER THEY HAVE GERMINATED.

PROJECT TRANSPARENCY # III, PART 1 AND READ ALOUD COPY ON TRANSPARENCY
(DO NOT UNMASK PART 2 AT THIS TIME.)

Compare what the botanist did with the suggestions students have made in their notebooks. Then:

"Let's see what the botanist did next."

UNMASK PART 2 AND READ ALOUD COPY ON TRANSPARENCY

Review orally with the students the events thus far--the original observation that bluebonnets did not grow on serpentine soil while they did grow on adjacent granite soil; the botanist asked why; he then suggested some possibilities for testing; he eliminated the first possibility on the basis of certain specific observations; he then designed an experiment as illustrated here to get information that might enable him to choose among the other possibilities. Leave Part 2 on the screen and at this point introduce the following questions:

Why did the botanist use a number of soil samples?

Why did he use a number of seeds in each pot?

Discuss answers to these questions. Emphasize the need for replication in research. Then:

"Let's look at the results the Botanist obtained."

WHY ARE THER NO BLUEBONNETS ON SERPENTINE SOIL?

TRANSPARENCY # III

PART 1

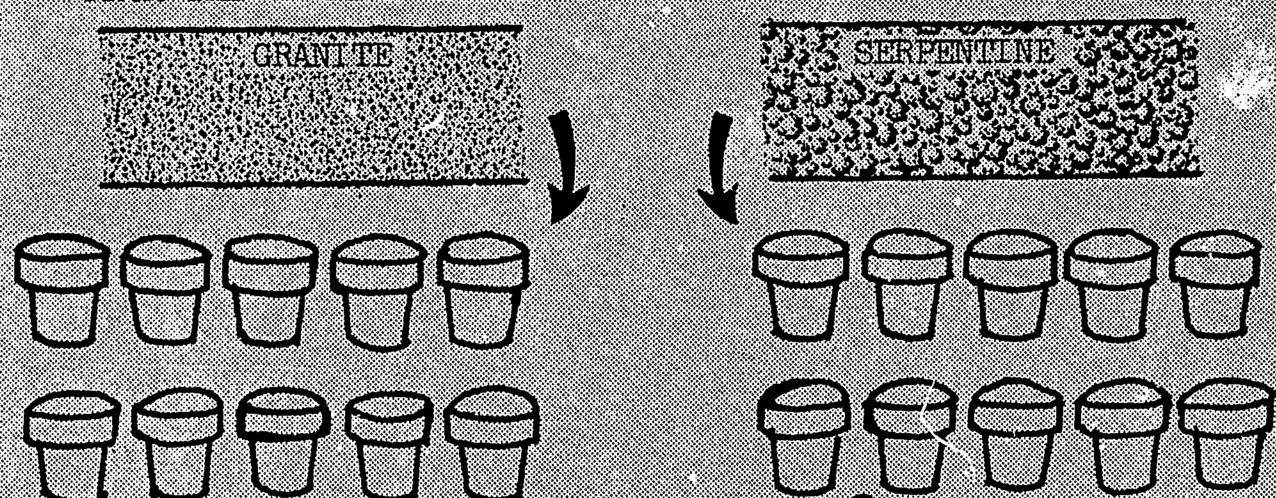
POSSIBILITY # 1 - ANIMALS OR OTHER AGENTS THAT COULD DISTRIBUTE THE BLUEBONNET SEEDS MIGHT NOT BE ABLE TO GET TO THE SERPENTINE SOILS DUE TO NATURAL OR MAN-MADE BARRIERS.

THE BOTANIST OBSERVED THAT ANIMALS AND OTHER AGENTS THAT MIGHT DISTRIBUTE THE SEEDS WERE ON BOTH THE GRANITE AND THE SERPENTINE SOILS: THEREFORE, HE CONSIDERED THIS AS EVIDENCE TO ELIMINATE POSSIBILITY # 1.

PART 2

POSSIBILITY # 2 - THE SERPENTINE SOIL MAY CONTAIN SOME SUBSTANCE THAT KEEPS BLUEBONNET SEEDS FROM GERMINATING.

THE BOTANIST GATHERED SOME BLUEBONNET SEEDS AND COLLECTED SOIL FROM THE SERPENTINE AREAS AND FROM THE GRANITE AREAS. HE FILLED 10 FLOWER POTS WITH SOIL FROM THE SERPENTINE AREA AND 10 FLOWER POTS WITH SOIL FROM THE GRANITE AREA.



HE THEN PLANTED 10 BLUEBONNET SEEDS IN EACH OF THE 20 FLOWER POTS.

PROJECT TRANSPARENCY # IV, PART 1 AND READ ALOUD COPY ON TRANSPARENCY.
(DO NOT UNMASK PARTS 2, 3, AND 4 AT THIS TIME.)

Be sure the students understand why this decision was made. Then:

"Let's see what the botanist observed next."

UNMASK PART 2 AND READ ALOUD COPY ON TRANSPARENCY

Then: "What do you suppose the botanist did next?"

Allow the students to make suggestions to answer this question.

UNMASK PART 3 AND READ ALOUD COPY ON TRANSPARENCY

Allow time for discussion of these results. The students should develop from the observation the idea that although bluebonnet seeds germinate in both granite and serpentine soil, they will continue to grow and develop root nodules only in the granite soil. The students should raise several questions at this point.

What are root nodules?
What is their structure and composition?
Are root nodules necessary for bluebonnets to grow?
If so, why are they necessary?

At this point it may be necessary to introduce information to help the students answer these questions. (This step in the teaching process is somewhat analogous to "prior knowledge" the working scientist uses.) From a discussion of these questions, students should understand the following idea:

Since the nodules contain bacteria that fix atomspheric nitrogen, plants lacking nodules may lack sufficient nitrogen to grow. Thus the germinating bluebonnets in the serpentine soil may not have had enough nitrogen for continued growth because they had no root nodules to fix atmospheric nitrogen.

UNMASK PART 4 AND READ ALOUD COPY ON TRANSPARENCY

Instruct the students to write suggestions in notebooks.

WHY ARE THERE NO BLUEBONNETS ON SERPENTINE SOIL?

TRANSPARENCY # IV

PART 1

AFTER THE BLUEBONNET SEEDS HAD BEEN PLANTED SEVERAL WEEKS, THE BOTANIST OBSERVED THAT APPROXIMATELY 95% OF THE SEEDS SPROUTED IN BOTH TYPES OF SOIL. ON THE BASIS OF THIS EVIDENCE HE ELIMINATED POSSIBILITY # 2.

POSSIBILITY # 2 -- THE SOILS MAY CONTAIN SOME SUBSTANCE WHICH KEEPS THE BLUEBONNET SEEDS FROM GERMINATING.

PART 2

THE BOTANIST CONTINUED TO OBSERVE THE GROWTH OF THE BLUEBONNET PLANTS IN THE WEEKS THAT FOLLOWED AND DISCOVERED THAT EVEN THOUGH THE SEEDS GERMINATED IN BOTH TYPES OF SOIL, THE SEEDS IN THE GRANITE SOILS THRIVED AND FLOWERED BUT THE SEEDS IN THE SERPENTINE SOIL WERE STUNTED AND DIED WITHOUT FLOWERING.

PART 3

THE BOTANIST EXAMINED THE ROOTS OF PLANTS FROM BOTH TYPES OF SOIL AND FOUND NODULES ON THE PLANTS GROWN IN THE GRANITE SOIL. NO NODULES WERE FOUND ON THE PLANTS FROM THE SERPENTINE SOIL.

QUESTION: WHAT DO THE OBSERVATIONS RECORDED ABOVE SUGGEST?

PART 4

QUESTION: HOW MIGHT YOU TEST THE ASSUMPTION THAT BLUEBONNETS IN THE SERPENTINE SOIL LACK NITROGEN?

PROJECT TRANSPARENCY # V, PART 1 AND READ ALOUD COPY ON TRANSPARENCY.
(DO NOT UNMASK PARTS 2, 3, 4 AND 5 AT THIS TIME.).

Ask the students to compare the suggestions they wrote in their notebooks with what the botanist acutally did. Then:

"Let's see what results he obtained."

UNMASK PART 2 AND READ ALOUD COPY ON TRANSPARENCY

On the basis of evidence now at hand, ask the students to chose between these two remaining possibilities. Then:

"Let's see what the botanist decided."

UNMASK PART 3 AND READ ALOUD COPY ON TRANSPARENCY

Note that the botanist did indeed select # 3 as the most probale explanation as to why bluebonnets fail to grow on serpentine soil. Compare this decision with those made by students. Then:

"While this decision appears to be an answer to the original question that started this Springboard for Discussion, have new questions been raised?"

Allow students time to write suggestions in their notebooks and then report them orally to the class.

UNMASK PART 4 AND READ ALOUD COPY ON TRANSPARENCY

The discussion should bring out that this question is unanswered at present. However, one interesting clue may be suggested. It is known that serpentine soils often lack molybdenum. It has also been shown that this element is required for growth by the nitrogen-fixing bacteria. Now:

"What new problem does this clue suggest?"

Discuss possibilities.

UNMASK PART 5 AND READ ALOUD COPY ON TRANSPARENCY

Ask students to write in their notebooks suggestions as to how to answer the question on the transparency. Conclude this Springboard for Discussion with a listing and discussion of the appropriateness of the suggestions recorded and include a final reminder that as we answer one question in science, new ones are sure to emerge.

WHY ARE THERE NO BLUEBONNETS ON SERPENTINE SOIL?

TRANSPARENCY # V

PART 1

TO TEST THE ASSUMPTION THAT BLUEBONNETS IN THE SERPENTINE SOIL LACK NITROGEN, THE BOTANIST SET UP AN EXPERIMENT SIMILAR TO THE EARLIER ONE. HE AGAIN COLLECTED SERPENTINE SOIL AND DIVIDED IT INTO TWO GROUPS OF POTS. TO ONE GROUP HE ADDED NITROGEN. THE OTHER GROUP SERVED AS A CONTROL.

PART 2

HE FOUND THAT THE BLUEBONNETS IN SERPENTINE SOIL WITH ADDED NITROGEN FLOUISHED AND WOULD FLOWER.

THE BOTANIST REFERRED TO THE LAST TWO POSSIBILITIES HE HAD ORIGINALLY SET OUT TO INVESTIGATE:

POSSIBILITY # 3 - THE SOILS MAY LACK SOMETHING WHICH THE BLUEBONNET PLANTS REQUIRE FOR GROWTH.

POSSIBILITY # 4 - THE SOILS MAY CONTAIN SOME SUBSTANCE WHICH IS POISONOUS TO THE BLUEBONNET PLANTS AFTER THEY HAVE GERMINATED.

PART 3

CONSIDERING THE RESULTS OF HIS OBSERVATIONS AND EXPERIMENTS, THE BOTANIST CONCLUDED THAT POSSIBILITY # 3 SEEMED THE MOST LOGICAL EXPLANATION FOR THE GROWTH DISTRIBUTION PATTERN OF THE BLUEBONNETS HE OBSERVED. THEREFORE, HE ELIMINATED POSSIBILITY # 4 AND ACCEPTED # 3 AS THE BEST OF THOSE SUGGESTED.

PART 4

EVEN THOUGH THE BOTANIST DISCOVERED THE ELEMENT NEEDED FOR BLUEBONNETS TO GROW ON THE SERPENTINE SOIL, THERE ARE STILL NEW UNANSWERED QUESTIONS.

ONE QUESTION IS: WHY DO THE NODULE BACTERIA THAT FIX ATMOSPHERIC NITROGEN FAIL TO GROW IN THE SERPENTINE SOIL?

PART 5

NEW PROBLEM: SUGGEST A METHOD OF TESTING TO SEE IF MOLYBDENUM IS THE MISSING ESSENTIAL ELEMENT FOR NODULES TO FORM ON BLUEBONNET ROOTS IN SERPENTINE SOIL.

VIII. THE DEVELOPMENT OF A STUDENT CHECKLIST TO DETERMINE CLASSROOM TEACHING PRACTICES IN HIGH SCHOOL BIOLOGY

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INTRODUCTION

The ultimate test of the effectiveness of any new curriculum is the extent to which it contributes to its desired outcomes. Curriculum makers in recent years have seriously attempted to identify the philosophy, rationale, and objectives that underlie the materials they have developed. For example, Glass (1), Schwab (2), and Kolb (3), as well as a number of other sources, give the philosophy and rationale for the development of the Biological Sciences Curriculum Study (BSCS) materials. A substantial number of materials from this study have now been produced and are now in use. Thus at least two tasks may be identified and should be carried out with some success before one can assess the effectiveness of programs in which these materials are used. One of these tasks involves an analysis of the relationship between the actual classroom practice where these materials are used and the philosophy and rationale of the program and a comparison of this relationship with that found in classes not using the new materials. The importance of classroom practice to the successful use of curriculum materials has been recognized by Tyler (4), Hurd (5), Grobman (6), Flanders (7), and others. In fact Hurd (8) has suggested that the limited influence of the efforts of biology curriculum committees in the past has been due to their "consistent failure to directly recognize that the measure of course improvement is to be found more in improved methods of teaching than in the reassortment and realignment of subject content."

An instrument and technique were developed to try to accomplish the task of identifying actual classroom practices as they relate to the philosophy and rationale of the BSCS program. It is the purpose of this paper to describe the development and evaluation of an instrument that we have called the *Biology Classroom Activity Checklist (BCAC)*. This instrument was designed to help accomplish the first task identified above.

A second task is also important in the ultimate test of the effectiveness of any new curriculum. It would require an evaluation of the changes in behavior of students in the new programs and would also require the development of new instruments to determine this change. We have not attempted to deal with this second task in the work reported here.

DESCRIPTION OF TEACHER PRACTICES

The problem of determining the nature of the classroom practices advocated by BSCS was given some direction by Belanger (9) when he stated that "Embedded in the documents of contemporary science curricula are a variety of teaching be-

havioral factors which are valued as important dimensions of science teaching." The problem became one of reading the various materials written by persons associated with BSCS and itemizing the teaching practices that were contained in these materials. Fifty-three specific classroom practices based on these statements of BSCS rationale were formulated. These practices, written in terms of the student's viewpoint, were organized into seven sections, as follows:

Section A—Role of the Teacher in the Classroom
Section B—Student Classroom Participation
Section C—Use of Textbook and Reference Materials
Section D—Design and Use of Tests
Section E—Laboratory Preparation
Section F—Type of Laboratory Activities
Section G—Laboratory Follow-up Activities

JUDGMENT OF TEACHER PRACTICES

Although these classroom practices were based on published statements of BSCS rationale, it was still necessary to receive a subjective judgment of these practices to determine whether or not they manifest teacher effectiveness. This judgment was obtained by submitting the list of classroom activities to five individuals selected for their knowledge of BSCS philosophy. Each individual was either a member of the BSCS writing team, a member of a BSCS committee, or a BSCS staff consultant. This panel included both scientists and classroom teachers. These persons were asked to decide whether each of these classroom practices would contribute positively, negatively, or not at all toward BSCS objectives. Ratings of the judges and other comments they made were considered in rewriting the instrument. Guilford's (10) method of computing the reliability of judgmental ratings was used. The judgment reliability coefficients are recorded in Table 1. These coefficients indicate a high degree of agreement among the judges and between the judges and the authors of the instrument concerning the way in which each of these items contributes toward teacher effectiveness.

TABLE 1

JUDGMENTAL RELIABILITY COEFFICIENTS OF THE *BIOLOGY CLASSROOM ACTIVITY CHECKLIST* ITEMS

	Intraclass Correlation
Among judges	.84
Between Judge A and authors	.95
Between Judge B and authors	.93
Between Judge C and authors	.90
Between Judge D and authors	.89
Between Judge E and authors	.88

DEVELOPMENT OF THE *BIOLOGY CLASSROOM ACTIVITY CHECKLIST (BCAC)*

The formulation of a list of teaching practices that were judged to be those that contribute positively toward the attainment of BSCS objectives was the first step in this study. The next step involved the development of a technique for determining the extent to which each of these practices occurred in a particular classroom. After a critical review of the methods used in previous studies, the technique selected was that of having students report on the practices that took place in their classroom. This approach was chosen because it was felt that students were in an advantageous position to know what took place in the classroom. Investigators such as Cornell (11), Reed (12), Cogan (13), and Lewin (14) believe that students can accurately report what they have observed. It should be noted that the author of this study received no objections from any of the 75 teachers whose students completed the checklist subsequently developed and used.

Initially two forms of the instrument were written. Form A consisted of 53 statements such as: "Our tests often ask us to write out definitions of terms." The student was instructed to indicate TRUE if the statement described what occurs in his classroom and FALSE if it did not.

For Form B the same item was written as follows: "Our tests ask us to write out definitions of terms." The student was to indicate NEVER, SELDOM, OFTEN, or ALWAYS. Both forms were administered to several local biology classes. Form B required about 50% more time to complete than Form A, and the variance of scores was slightly less on Form A than on Form B. Because of these two factors it was decided to write items in the style of Form A.

Of the 53 items on the *BCAC*, 26 were judged as describing practices that contributed positively toward the attainment of BSCS objectives and 27 were judged as describing negative practices. In the instrument as it appears in this paper the positive BSCS practices are indicated by an asterisk. Obviously the asterisks were omitted in the instrument as published and used in several research studies. The first step in the scoring procedure involved counting the "correct" responses of each student. A positive item that was marked TRUE or a negative item that was marked FALSE was classified as a correct response. The percentage of correct responses was computed as the student's score. Thus the test scores had a potential range of 0 to 100 with the highest scores indicating a greater degree of agreement with biology classroom practices recommended by individuals associated with BSCS.

The *BCAC* instrument as finally developed and used for studies to be reported subsequently is given below:

BIOLOGY CLASSROOM ACTIVITY CHECKLIST[a]

The purpose of this checklist is to determine how well you know what is going on

[a] This checklist has been developed by Addison E. Lee and Leonard H. Kochendorfer for investigative purposes only. No right to reproduction is granted or implied without written permission of the authors.

in your biology class. Each statement describes some classroom activity. The activities are not judged as either good or bad. Therefore, this checklist is not a test and is not designed to grade either you or your teacher. You are to read each statement and decide if it describes the activities in your class. All answers should be recorded on the answer sheet. NO MARKS should be made in this booklet.

SAMPLE QUESTION

Checklist	Answer Sheet T	F
1. My teacher often takes class attendance.	1. [ ]	[ ]

If the statement describes what occurs in your classroom, blacken the space under the letter T (TRUE) on answer sheet; if it does not, blacken in the space under the letter F (FALSE).

REMEMBER:

1. The purpose of the checklist is to determine how well you know what is going on in your classroom.
2. Make no marks in this booklet.
3. All statements should be answered on the answer sheet by blackening in the space under the chosen response in pencil or ink.
4. Please do not write your name on this booklet or answer sheet.

SECTION A

1. Much of our class time is spent listening to our teacher tell us about biology.
2. My teacher doesn't like to admit his mistakes.
3. If there is a discussion among students, the teacher usually tells us who is right.
4. My teacher often repeats almost exactly what the textbook says.

*5. My teacher often asks us to explain the meaning of certain things in the text.

6. My teacher shows us that biology has almost all of the answers to questions about living things.

*7. My teacher asks questions that cause us to think about things that we have learned in other chapters.

*8. My teacher often asks questions that cause us to think about the evidence that is behind statements that are made in the textbook.

SECTIONS B

1. My job is to copy down and memorize what the teacher tells us.

*2. We students are often allowed time in class to talk among ourselves about ideas in biology.

3. Much of our class time is spent in answering orally or in writing questions that are written in the textbook or on study guides.

*4. Classroom demonstrations are usually done by students rather than by the teacher.

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

5. We seldom or never discuss the problems faced by scientists in the discovery of a scientific principle.
*6. If I don't agree with what my teacher says, he wants me to say so.
7. Most of the questions that we ask in class are to clear up what the teacher or text has told us.
*8. We often talk about the kind of evidence that is behind a scientist's conclusion.

SECTION C

1. When reading the text, we are expected to learn most of the details that are stated there.
2. We frequently are required to write out definitions to word lists.
*3. When reading the textbook, we are always expected to look for the main problems and for the evidence that supports them.
*4. Our teacher has tried to teach us how to ask questions of the text.
5. The textbook and the teacher's notes are about the only sources of biological knowledge that are discussed in class.
*6. We sometimes read the original writings of scientists.
*7. We are seldom or never required to outline sections of the textbook.

SECTION D

*1. Our tests include many questions based on things that we have learned in the laboratory.
2. Our tests often ask us to write out definitions of terms.
*3. Our tests often ask us to relate things that we have learned at different times.
*4. Our tests often ask us to figure out answers to new problems.
*5. Our tests often give us new data and ask us to draw conclusions from these data.
6. Our tests often ask us to put labels on drawings.

SECTION E

1. My teacher usually tells us step-by-step what we are to do in the laboratory.
*2. We spend some time before every laboratory in determining the purpose of the experiment.
3. We often cannot finish our experiments because it takes so long to gather equipment and prepare solutions.
4. The laboratory meets on a regularly scheduled basis (such as every Friday).
*5. We often use the laboratory to investigate a problem that comes up in class.
*6. The laboratory usually comes before we talk about the specific topic in class.
7. Often our laboratory work is not related to the topic that we are studying in class.
8. We usually know the answer to a laboratory problem that we are investigating before we begin the experiment.

SECTION F

1. Many of the experiments that are in the laboratory manual are done by the teacher or other students while the class watches.

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

*2. The data that I collect are often different from data that are collected by the other students.
3. Our teacher is often busy grading papers or doing some other personal work while we are working in the laboratory.
*4. During an experiment we record our data at the time we make our observations.
*5. We are sometimes asked to design our own experiment to answer a question that puzzles us.
6. We often ask the teacher if we are doing the right thing in our experiments.
*7. The teacher answers most of our questions about the laboratory work by asking us questions.
8. We spend less than one-fourth of our time in biology doing laboratory work.
9. We never have the chance to try our own ways of doing the laboratory work.

SECTION G

*1. We talk about what we have observed in the laboratory within a day or two after every session.
*2. After every laboratory session, we compare the data that we have collected with the data of other individuals or groups.
3. Our teacher often grades our data books for neatness.
4. We are required to copy the purpose, materials, and procedure used in our experiments from the laboratory manual.
*5. We are allowed to go beyond the regular laboratory exercise and do some experimenting on our own.
*6. We have a chance to analyze the conclusions that we have drawn in the laboratory.
7. The class is able to explain all unusual data that are collected in the laboratory.

ESTABLISHMENT OF RELIABILITY AND VALIDITY

The final form of the *Biology Classroom Activity Checklist* was administered to 1,261 tenth-grade biology students in 64 classrooms. These classrooms were located in eleven states and the teachers involved were using a variety of curriculum materials.

The method used to establish the reliability of the instrument was based on the assumption that all variance in the intraclass scores represented error variance and the interclass variance expressed true variance. If the instrument is a reliable measure of classroom activity, one would expect greater variance in the indices assigned to the total population of classrooms than in the indices assigned to individual classroms. Horst (15) developed a reliability measure based upon the comparison of these variances. The reliability coefficient obtained with this formula was .96.

There were several indications of the validity of the *BCAC*. The correlation of .84 among the judgmental evaluations of the instrument items is indicative of a

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

high degree of agreement concerning the content validity of these items.

One would expect that the nature of the activities which occur in the classroom portion of a biology class would be highly correlated with the type of activities that take place in the laboratory portion. For example, it would be incongruous for a teacher to stress the investigatory nature of biology in the classroom and then conduct a strictly illustrative laboratory. If the *BCAC* is a valid means of determining what takes place in a biology class, the scores which the pupils assign to the classroom portion of the course, represented in sections A through D, should be highly correlated with the scores assigned to the laboratory portion, represented in sections E through G. The correlation coefficient between the class mean scores on the laboratory portion and the classroom portion of the *BCAC* was .84.

POTENTIAL USES OF THE *BIOLOGY CLASSROOM ACTIVITY CHECKLIST*

It is possible to conceive of several applications for an instrument such as the *Biology Classroom Activity Checklist.* Many curriculum projects emphasize that the method by which the materials are taught is important to their successful use; yet this aspect is often virtually ignored when curriculum evaluation is undertaken. Usually the assumption is made that the appropriate teaching practices are being used as long as teachers who are reputed to be successful claim to be using them. Curriculum research may be made more valid if the appropriate teaching practices are identified and an instrument such as *BCAC* is used to determine whether or not these specific practices actually take place in the classroom.

This type of instrument may also have a use in the pre-service and in-service training of teachers. Since the *BCAC* itemizes specific teacher practices, these items can serve as a basis for discussion among teacher and students. The instrument could also be used by teachers for self-evaluation.

SUMMARY

The purpose of this project was to develop a valid, yet easy to administer, technique of determining the extent to which the classroom practices of teachers are in agreement with the practices advocated by a particular curriculum project. A list of classroom activities, based upon the published statements of individuals associated with BSCS and verified by a panel of judges, was formulated. This checklist was administered to over 1,200 students of 64 teachers and reliability and validity data were gathered. A reliability coefficient of .96 was obtained. Two methods of computing validity each yielded a coefficient of .84.

An instrument such as this should be useful in the evaluation of new curricula and in the training of teachers.

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

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IX. CLASSROOM PRACTICES OF HIGH SCHOOL BIOLOGY TEACHERS USING DIFFERENT CURRICULUM MATERIALS

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STATEMENT OF THE PROBLEM

Schwab (1), Hurd (2), Grobman (3), and others have stated that the way in which a teacher uses the Biological Sciences Curriculum Study (BSCS) materials is important for successful outcomes. This statement raises a number of questions. To what extent do teachers using BSCS materials follow classroom practices that are in harmony with the BSCS philosophy and rationale? How do the practices of first-year BSCS teachers compare with those used by more experienced BSCS teachers? To what degree are these same practices being utilized by teachers using curriculum materials other than BSCS? What is the relationship between a teacher's expressed acceptance of BSCS philosophy and rationale and the nature of his classroom practices? What is the relationship between a teacher's classroom practices and the gain in his students' understanding of the nature of science? Studies conducted at the Science Education Center of The University of Texas at Austin have provided some data concerning these questions.

It is recognized that the student-teacher relationship is complex and is influenced by a variety of factors. Because of this complexity, it is not practical to designate a single group of classroom practices as being the most effective approach to teaching a subject. The purpose of this study was primarily that of ascertaining the extent to which the teaching approach and techniques advocated by BSCS are currently being used by a selected sample of both BSCS and non-BSCS teachers. No attempt has been made to place a value judgment on the various teaching practices analyzed or various curriculum materials used in the study.

INSTRUMENTS USED TO GATHER DATA

Since no suitable instrument was available to determine actual classroom practices of teachers using curriculum materials, the first task in this study was to develop one for this purpose. Descriptions of the development and evaluation of the instrument, *Biology Classroom Activity Checklist (BCAC)* as well as a copy of the instrument itself are found elsewhere in this monograph (4). The instrument is composed of 53 specific classroom activities based upon published statements of BSCS philosophy rationale and verified by a panel of judges thoroughly familiar with this program. The students in one class of each teacher who participated in the study completed the *BCAC*. A single mean score was computed for each classroom and adjusted to a 0-to-100 range, with the highest scores indicating a greater degree of agreement with practices recommended by BSCS. Reliability and validity coefficients of .96 and .84, respectively, were obtained for the instrument.

Other instruments used in the study were:

(a) *The Processes of Science Test (POST)* developed in the BSCS program and

designed to measure the student's understanding of the process of science and the scientific enterprise. This test is reported to measure a student's ability to interpret data and deal with hypotheses (5). The test contains 40 items and was administered to students participating in this study as a pre-test in the fall of 1965 and as a post-test in the spring of 1966.

(b) An Attitude Inventory, developed by Blankenship (6, 7) as a means to determine the reactions of science teachers to the BSCS program. A 30-item slightly modified form of this instrument was used in this study.

ADMINISTRATION OF INSTRUMENTS

September, 1965—*Processes of Science Test*. Administered to 1,484 tenth-grade students in 64 classrooms.

April, 1966—*Processes of Science Test*. Readministered to 1,210 tenth-grade students in 64 classrooms.

April, 1966—*Biology Classroom Activity Checklist*. Completed by 1,231 tenth-grade students in 64 classrooms.

April, 1966—*Attitude Inventory*. Completed by 64 teachers in the sample selected for the study.

SELECTION OF THE SAMPLE OF CLASSES USED IN STUDY

In order to obtain a sample that could be expected to represent a variety of teaching practices, three distinct groups of classes were selected. Each of these groups was composed of tenth-grade biology classes as follows:

(a) Group EB: This group consisted of one class of students from each of 22 teachers who were identified from published BSCS teacher lists and had considerable training and experience in the BSCS program. The mean number of years of experience in teaching BSCS by these teachers was 5.0. This group was composed of classes from 12 states. Fourteen classes used BSCS Blue Version, six used the Yellow Version, and two used the Green Version (8).

(b) Group BB: This group consisted of one class of students from each of 21 teachers who were identified as not having had previous experience and training in the BSCS program, but who were using the materials for the first time. The teachers in this group were identified by their respective science supervisors and were located in seven cities in one state. Nineteen classes used the Yellow Version and two used the Green Version.

(c) Group NB: This group consisted of one class of students of each of 21 teachers from schools which were given an option to use BSCS materials but which were identified as using curriculum materials other than BSCS. The teachers in this group were identified by their respective science supervisors and were located in three cities in a single state.

It should be emphasized that these groups were deliberately selected to provide populations that might be expected to exhibit a variety of teaching approaches and methods. It is not suggested that these groups are representative of the larger populations from which they were drawn.

RESULTS AND CONCLUSIONS

The data recorded in Table 1 indicate that, when the groups described above are considered as entities, statistically significant differences exist among them in regard to the classroom practices of experienced BSCS teachers, first-year BSCS teachers, and teachers using curriculum materials other than BSCS. The data show that the practices of the experienced BSCS teachers more closely conform to those advocated by BSCS, with beginning BSCS teachers showing the next highest degree of conformity and the non-BSCS showing the least degree of conformity.

TABLE 1

COMPARISON OF THE *BIOLOGY CLASSROOM ACTIVITY CHECKLIST* MEAN SCORES OF THE THREE EXPERIMENTAL GROUPS

	Mean Score	σ	σ_M
Group EB	65.70	8.14	1.78
Group BB	57.34	6.37	1.43
Group NB	50.04	5.90	1.32

	Difference of the Means	Z $\frac{(M_1 - M_2)}{\sigma \, dM}$	Level of Significance
Group EB Group BB	8.36	3.67	$<.01$
Group BB Group NB	7.30	3.76	$<.01$
Group EB Group NB	15.66	8.07	$<.01$

Table 2 shows that although there were definite differences among these three groups, there was considerable overlap in the degree of conformity to the BSCS philosophy and rationale. It should be noted that out of a possible score of 100, only one of the EB group classes scored in as high as the 80–84 range (actual score 83). Likewise one of the NB group classes scored in the 65–69 range (actual score 67). The number and percent of classes of each group in the middle group of ranges—45–64—is as follows:

GROUP EB	13 classes 59% of total group
GROUP BB	18 classes 86% of total group
GROUP NB	18 classes 86% of total group

Thus it seems reasonable to conclude that the BSCS program has made a definite impact on biology classroom teaching practices. However, as suggested recently by Mayer (9) it is also apparent that some teachers have been using the practices in agreement with BSCS philosophy and rationale for many years. These examples

illustrate the importance of considering actual classroom practices in the evaluation of new curriculum materials. They also illustrate the importance of in-service training for use and evaluation of new curriculum materials.

One purpose of this study was to determine the relationship between the use of the classroom approach advocated by BSCS and the gain in pupil understanding of the nature of science and scientific inquiry. Table 3 indicates the relationship between gains on the *POST* expressed in $\bar{z}$ scores, and class means on the *BCAC*. A first-order partial correlation coefficient of .32 indicates that a teacher's classroom practices are a significant factor in effecting changes in students' understanding of the nature of science as measured by the *POST*. This study has shown that within the three groups examined, those classes using BSCS materials and employing

TABLE 2

DISTRIBUTION OF *BIOLOGY CLASSROOM ACTIVITY CHECKLIST* MEAN SCORES FROM DIFFERENT CLASS GROUPS

Score Range	Group EB Experienced BSCS	Group BB First-Year BSCS	Group NB Others
0–29	0	0	0
30–34	0	0	1
35–39	0	0	1
40–44	0	0	0
45–49	0	2	7
50–54	1	7	10
55–59	5	6	1
60–64	7	3	0
65–69	1	2	1
70–74	4	1	0
75–79	3	0	0
80–84	1	0	0
85–100	0	0	0
Total	22	21	21

practices advocated by BSCS had significantly greater gains in pupil understanding of the nature of science as measured by *POST* than those classes using other materials and employing other classroom practices.

Another purpose of this study was to determine the relationship between teachers' acceptance of statements of BSCS philosophy and rationale and the nature of their classroom practices. The *Attitude Inventory* identified earlier in this paper was administered as a means of determining a teacher's acceptance of BSCS rationale. A Pearson product-moment correlation coefficient of .73 between *Attitude Inventory* scores and *BCAC* scores is indicative of a high degree of relationship

TABLE 3

CORRELATIONS BETWEEN GAIN IN CLASS MEANS ON THE *PROCESSES OF SCIENCE TEST, BIOLOGY CLASSROOM ACTIVITY CHECKLIST* SCORES, AND *PROCESSES OF SCIENCE TEST* PRE-TEST SCORES

r_{12}	r_{23}	r_{13}	$r_{12.3}$	t	Level of Significance of $r_{12.3}$
.38	.20	.49	.32	2.64	$< .02$

r_{12} —correlation between *BCAC* scores and *POST* $\bar{z}$ scores

r_{23} —correlation between *POST* $\bar{z}$ scores and *POST* pre-test scores

r_{13} —correlation between *BCAC* scores and *POST* pre-test scores

$r_{12.3}$—first-order partial correlation

between what a teacher expresses as the philosophy and rationale behind his teaching and what he actually practices. Yet the *Attitude Inventory* scores of a few individuals indicated a high degree of agreement with BSCS philosophy and rationale while their *BCAC* scores showed that their classroom practices did not reflect this attitude. Likewise, some cases of relatively high *BCAC* scores and low *Attitude Inventory* scores were also found. From these data it can be concluded that for some individuals there is either inability or unwillingness to have their practices conform to their professed attitudes or there is incongruity between their professed attitudes and those which actually guide their practice.

SUMMARY

The classroom practices of 64 teachers who were using different curriculum materials were studied. These practices were determined by use of a *Biology Classroom Activity Checklist* completed by students in one of each teacher's classes. This instrument was developed by the authors to determine the extent to which BSCS and non-BSCS teachers were using classroom practices recommended by BSCS. The *Processes of Science Test* was given to detect changes in student understanding of science. The teachers completed an *Attitude Inventory* as a measure of their acceptance of the published BSCS philosophy and rationale.

Significant differences were found in the classroom practices of experienced BSCS, first-year BSCS, and non-BSCS teachers.

A significant relationship between the nature of the classroom practices and gains of the *Processes of Science Test* was found.

A significant correlation was also found between the teacher's attitude concerning the BSCS philosophy and rationale and the degree to which his classroom practices agreed with those advocated by BSCS.

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X. USE OF THE BIOLOGY CLASSROOM ACTIVITY CHECKLIST IN IDENTIFYING SPECIFIC CLASSROOM PRACTICES OF INDIVIDUAL TEACHERS AND STUDENTS

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INTRODUCTION

The development and characteristics and certain uses of the *Biology Classroom Activities Checklist* have been reported in previous chapters (1, 2). In these reports use of the instrument was limited to studies of the relationships among classroom practices of groups of teachers using different curriculum materials. However, this instrument, or similar ones that could be developed, has potential use also for identifying specific classroom practices of individual teachers. In this connection, it should be emphasized again that selection of items (classroom practices) listed in *BCAC* did not imply any value judgment of "good" or "bad." Each teacher obviously must decide for himself what practices can best produce the desired results in his own classroom. Therefore, the instrument can be used in this context only to identify or bring more sharply into focus activities of individual teachers and their students that constitute classroom practice in order that the information so gained may be used in subsequent planning.

GROUP CLASSROOM PRACTICES ON DIFFERENT SECTIONS OF *BCAC*

As previously reported (1) the *BCAC* was composed of seven sections as follows:

Section A—Role of the Teacher in Classroom
Section B—Student Participation in Classroom
Section C—Use of Textbook and Reference Materials
Section D—Design and Use of Tests
Section E—Preparation for Laboratory
Section F—Type of Activities
Section G—Laboratory Follow-up Activities

Figure 1 illustrates the profile of the three groups of teachers reported in the previous studies. The greatest variation among these groups was in the design and use of tests, in the use of textbooks and reference materials, and in student participation in class. The least variation among the groups was in the preparation for laboratory, in the laboratory activities carried out, and in the role of the teacher in the class. It should be noted that group EB and group BB had almost identical scores on preparation for the laboratory—but even so the scores were only 58 and 59 respectively out of a possible 108 on the instrument. It should also be mentioned that within each group the highest scores were obtained in the sections dealing with the role of the teacher and with the laboratory, with the exception that group EB also scored high on the design and use of tests.

THE IDENTIFICATION OF SPECIFIC CLASSROOM PRACTICES OF INDIVIDUAL TEACHERS

Certain data obtained in the studies previously reported (1, 2) have been analyzed to provide a profile of specific classroom practices of individual teachers and students. Specific items on this instrument have been selected for study, and positive responses on these items are given in Table 1.

Figure 1
Biology Classroom Activity Checklist Scores of Three Groups of Teachers

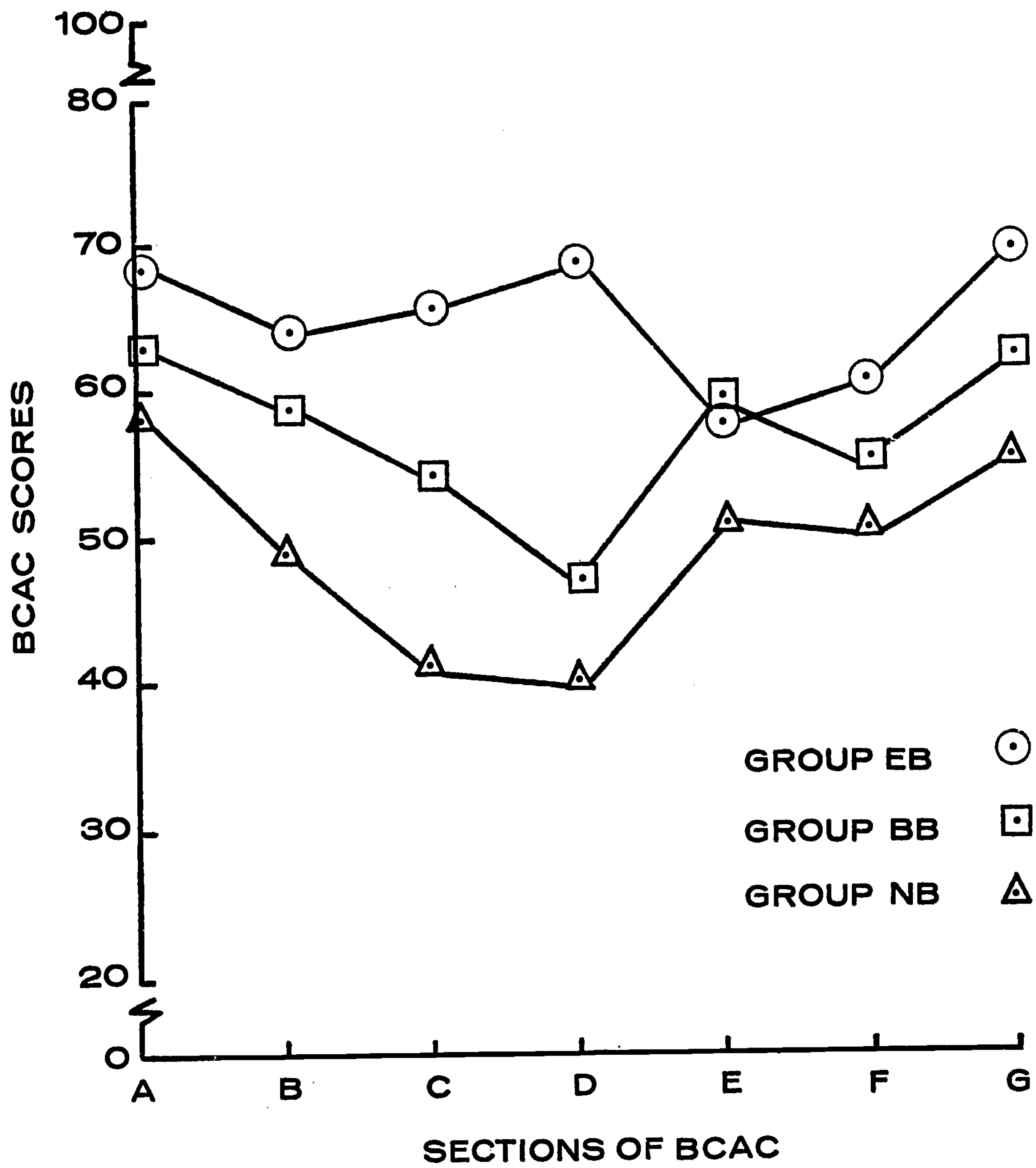


TABLE 1

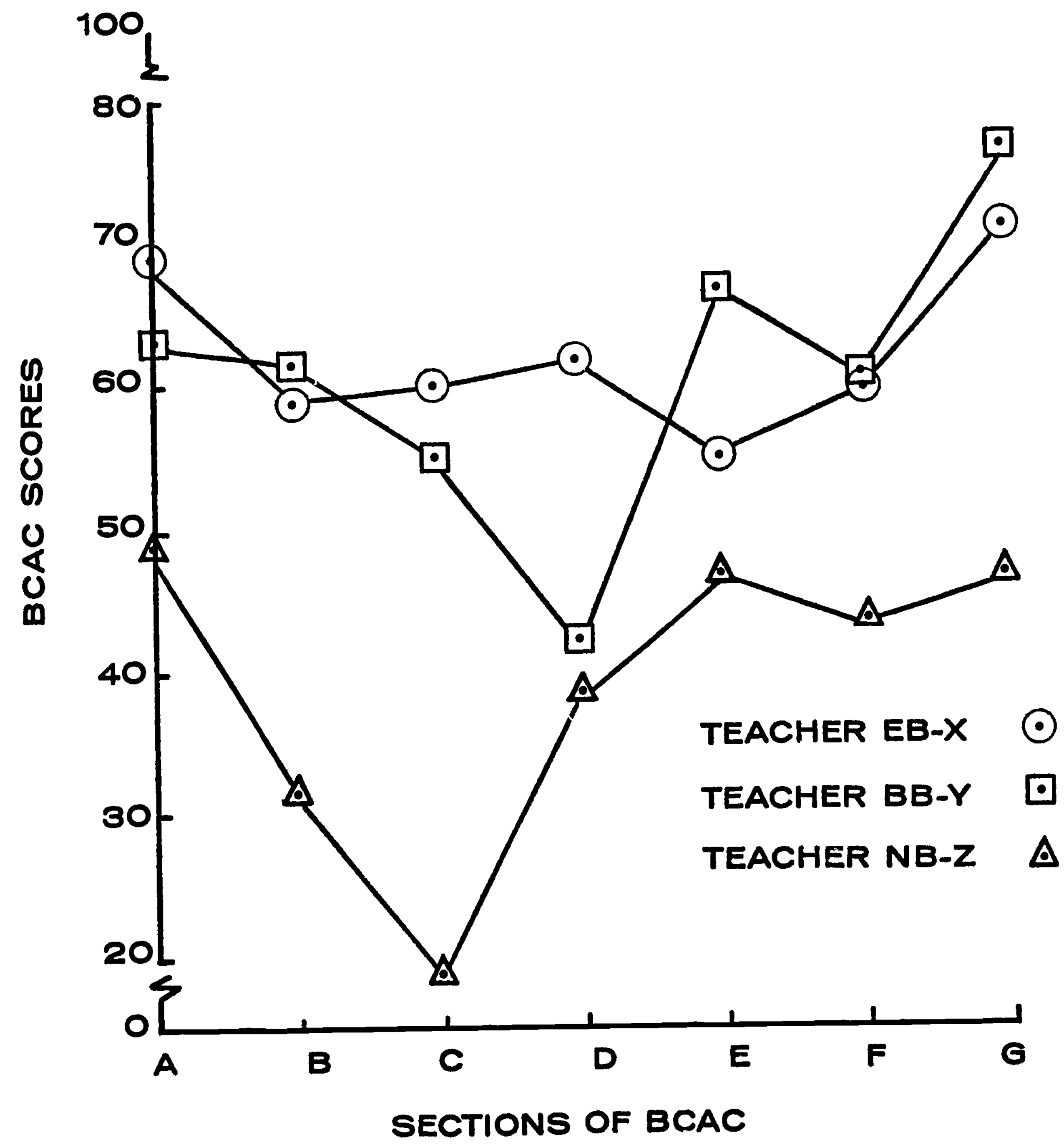
STUDENT RESPONSES TO SELECTED ITEMS ON THE *BIOLOGY CLASSROOM ACTIVITY CHECKLIST* IN THREE CLASSROOMS

SECTION AND ITEM	Percent of Positive Responses Teacher X GROUP EB	Teacher Y GROUP BB	Teacher Z GROUP NB
A6 My teacher shows us that biology has almost all of the answers to questions about living things.	12	60	29
B3 Much of our class time is spent in answering orally or in writing questions that are written in the textbook or on study guides.	12	90	33
B4 Classroom demonstrations are usually done by students rather than by the teacher.	31	75	14
B5 We seldom or never discuss the problems faced faced by scientists in the discovery of a scientific principle.	25	20	81
C2 We frequently are required to write out definitions to words lists.	6	35	81
C4 Our teachers has tried to teach us how to ask questions of the text.	56	70	0
C5 The textbook and the teacher's notes are about the only sources of biological knowledge that are discussed in class.	38	55	95
D1 Our tests include many questions based on things that we have learned in the laboratory.	88	75	29
D5 Our tests often give us new data and ask us to draw conclusions from these data.	75	50	0
D6 Our tests often ask us to put labels on drawings.	12	70	95
E8 We usually know the answer to a laboratory problem that we are investigating before we begin the experiment.	19	10	71
F7 The teacher answers most of our questions about the laboratory work by asking us questions.	38	80	33
G5 We are allowed to go beyond the regular laboratory exercise and so some experimenting on our own.	69	75	19

It should be recalled that teachers in group EB were experienced in the use of the BSCS materials, teachers in group BB were experienced teachers using BSCS materials for the first time, and teachers in group NB were experienced teachers not using BSCS materials. Teachers EB-X and BB-Y were selected for this example because mean scores for their classes on the entire *BCAC* were similar (61.56 and 62.55, respectively). The class for Teacher NB-Z had a *BCAC* mean score of 37.48. Although Teachers EB-X and BB-Y had similar mean scores, the scores on some individual items differed considerably. Thus analysis of these items can result in

Figure 2

Biology Classroom Activity Checklist Scores of Three Selected Classes



the formulation of some statements concerning the differences in the practices employed by these two teachers. For example the responses recorded in Table 1 indicate that teacher BB-Y conveys the impression that biology is complete (item A6). This teacher expects the students to do more learning on their own (items B3 and B4) and his classroom tests place more emphasis on recall than those of Teacher EB-X (D5 and D6). In comparing Teacher EB-X with Teacher NB-Z, we may conclude that the students of Teacher NB-Z are expected to learn more details (C2); there is less class discussion (B5, C4, and C5); and more emphasis is placed on writing out answers to questions (B3). His tests are more textbook-content orientated (D1, D5, and D6). His labs are more illustrative than investigative (E8) and more rigid than those of Teacher EB-X (G5). Such descriptions of a teacher's classroom practices and student responses could be expanded by considering all 53 items of the *BCAC*.

Another way to illustrate the classroom practices of individual teachers and students is shown in Figure 2. The graph in Figure 2 is made from scores on all items in each section of *BCAC* for the same three classes just described. In general the profiles shown in Figure 1 for the entire group and Figure 2 for three selected classes are similar, except that classes of Teacher EB-X and BB-Y were somewhat closer in section scores than the groups they represented. This relationship is to be expected since these two classes were selected because they had similar *BCAC* mean scores. Even so, the two differed considerably in section D—the design and use of tests. It may also be noted that the profile for the class of Teacher NB-Z was similar (proportionately lower in section C—use of curriculum materials) to the entire group NB but with lower scores, again reflecting a fairly low *BCAC* mean score for this class (37.48).

SUMMARY

The *Biology Classroom Activity Checklist (BCAC)* was used to help identify specific classroom practices of individual and group secondary school biology teachers and students using different curriculum materials. The instrument was administered to the students in a number of classes and responses were tabulated to provide data to make a profile in terms of specific classroom activities of teachers and students individually and in groups. Comparison of these profiles revealed specific differences among individual teachers and groups of teachers.

This technique is of possible use in self-evaluation and planning by teachers and in developing in-service or workshop training programs for groups of teachers.

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XI. THE DEVELOPMENT OF A STUDENT CHECKLIST TO DETERMINE LABORATORY PRACTICES IN HIGH SCHOOL BIOLOGY

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INTRODUCTION

The curriculum movement in American secondary school science education during the past decade has been characterized by important developments and shifts in emphasis in the approach to science instruction. One of these trends, important especially in terms of its potential impact on secondary laboratory science instruction, is the move toward seeking methods of instruction whereby the student can be thoroughly exposed to the nature of science and scientific inquiry. Hurd (1), Brandwein, Watson and Blackwood (2), and Martin (3), as well as a number of other sources, stress the importance of creating opportunities for the investigation and development of ideas in the secondary school science laboratory. However, the understanding of the rationale and philosophy of this "new" approach presents many problems. Among these problems, according to Tyler (4), are the extent to which the rationale and philosophy of the new curricular materials are followed and also the degree to which the teacher's understanding of the materials and his actual teaching performance complement each other.

The first step in studying these problems involved the development of techniques to determine actual classroom practices, particularly as they relate to laboratory experience. The simplest technique was to develop an evaluation instrument based on a description of laboratory instruction in terms of activities carried on by the students in the laboratory. The new curriculum materials developed by the Biological Sciences Curriculum Study (BSCS) emphasize the new approach with extensive student laboratory activities. Thus, it appeared desirable to use the rationale and objectives of these materials as a basis for the instrument. A careful analysis was required to translate these into specific laboratory activities. Once this was accomplished, a checklist instrument of these activities—called the *Biology Laboratory Activity Checklist (BLAC)*—was developed and used to determine the nature and extent of laboratory instruction in selected high school biology classes using both the BSCS and the non-BSCS approaches. In addition, the instrument was used in determining the relationship of the nature and extent of laboratory activities in these classes to: (1) laboratory facilities available; (2) teacher acceptance of BSCS objectives; and (3) student gain in understanding the processes of science. The *BLAC* was further used to determine the degree to which laboratory activities in selected high school biology classes conformed to the activities judged to be those which contributed toward the attainment of BSCS objectives. A comparable instrument, the *Biology Classroom Activities Checklist*, has been developed by Lee and Kochendorfer (5) to investigate classroom prac-

tices. It is the purpose of this paper to describe the development and evaluation of the *Biology Laboratory Activity Checklist.*

DESCRIPTION OF LABORATORY ACTIVITIES

Compilation of the list of laboratory activities was based on statements in the BSCS literature and was so constructed as to include both laboratory activities that were recommended by the BSCS and judged to contribute positively to BSCS objectives and laboratory activities that were discouraged by BSCS or that were judged as practices negative to BSCS objectives. Sixty such items, 30 of which were considered to contribute positively to BSCS objectives and 30 of a negative character, were identified. The items were grouped into four categories:

1. Pre-laboratory activities;
2. Laboratory activities;
3. Post-Laboratory activities; and
4. General reaction to the laboratory.

JUDGMENT OF LABORATORY ACTIVITIES

Although the laboratory activities were identified from the BSCS literature, it was necessary to submit the checklist of laboratory activities to a panel of judges who were thoroughly familiar with BSCS laboratory objectives and rationale. These included BSCS consultants, college biologists, high school biology teachers, and a science supervisor. The judges rated each item as to whether it contributed positively, negatively, or had no value in contributing to BSCS laboratory objectives and rationale. The *BLAC* was revised accordingly. If new items were added, each one was re-evaluated in terms of the BSCS literature to assure that the particular items conformed to BSCS objectives.

DEVELOPMENT OF THE *BIOLOGY LABORATORY ACTIVITY CHECKLIST (BLAC)*

Each items was designed so that a student could react to it by a simple TRUE or FALSE response. Once judgment validity had been established, a pilot study was understaken by administering the *BLAC* to 10 high school biology classes. These 10 classes did not participate in the major study. It should be noted that investigators such as Leeds and Cook (6), Reed (7) and Cogan (8) have emphasized the importance of having students report on classroom practices and on the behavior of their teachers. Based upon these findings, the decision was made to use the "Student Report" approach to determine the nature and extent of biology laboratory instruction. In summary, the pilot study served two functions: (1) the development and tryout of procedures for administering the *BLAC*, and (2) the provision of data which could be used in obtaining an indication of the reliability of the *BLAC*.

In the instrument as it appears in this paper the positive BSCS practices are indicated by an asterisk. Obviously the asterisks were omitted in the instrument as published and used in several research studies.

ESTABLISHMENT OF RELIABILITY AND VALIDITY

The validity of the *BLAC* is based on two points: (1) that each item was based upon statements by individuals who participated in the development of the BSCS program, and (2) that each item was verified by a panel of judges who were thoroughly familiar with the BSCS program.

The 10 biology classes in the pilot study, representing two classes for each of five high school biology teachers, were used to establish the reliability of the *BLAC*. For the two classes of each teacher, a *t* test was computed in order to compare *BLAC* data. In each of the five cases, the *t* was not significant, indicating that the two separate groups of students did not disagree about the nature and extent of laboratory activities. The pertinent data and summary of this analysis are presented in Table 1.

TABLE 1

ANALYSIS OF PILOT STUDY DATA: COMPARISON OF *BLAC* CLASS MEANS FOR THE TWO CLASSES OF EACH TEACHER

Teacher	Class A Mean	Class B Mean	Differences Between Means	*t* Value*
1	26.24	27.50	1.26	0.95
2	26.80	25.30	1.50	1.00
3	30.71	31.56	0.85	0.77
4	28.92	28.52	0.40	0.29
5	27.30	26.39	0.91	0.68

* *t* value of 2.01 is required for rejection of a null hypothesis stated for these comparisons (0.05 level of confidence)

The *BLAC* Instrument as finally developed and used for subsequent studies is presented below:

BIOLOGY LABORATORY ACTIVITY CHECKLIST[a]

[a] This checklist has been developed by Addison E. Lee and Lehman W. Barnes, Jr. for investigative purposes only. No right to reproduction is granted or implied without the written permission of the authors.

The purpose of this checklist is to determine how well you know what is going on in your biology class. Each statement describes some laboratory activity. The activities are not judged as either good or bad. Therefore, this checklist is not a test and is not designed to grade either you or your teacher. You are to read each statement and decide if it describes the activities in your class. All answers should be recorded on the answer sheet. NO MARKS should be made in this booklet.

SAMPLE QUESTION
Checklist

Answer Sheet

	T	F
1.	( )	( )

1. My teacher often takes class attendance.

If the statement describes what occurs in your classroom, blacken the space under the letter T (TRUE) on the answer sheet; if it does not, blacken in the space under the letter F (FALSE).

REMEMBER:

1. The purpose of the checklist is to determine how well you know what is going on in your classroom.
2. Make no marks in this blooklet.
3. All statements should be answered on the answer sheet by blackening in the space under the chosen response in pencil or ink.
4. Please do not write ycur name on this booklet or answer sheet.

SECTION A

1. My teacher usually tells us step-by-step what we are to do in the laboratory.

*2. We spend some time before every laboratory in determining the purpose of the experiment.

3. We often cannot finish our experiments because it takes so long to gather equipment and prepare solutions.

4. The laboratory meets on a regularly scheduled basis (such as every Friday).

*5. We often use the laboratory to investigate a problem that comes up in class.

*6. The laboratory usually comes before we talk about the specific topic in class.

7. Often our laboratory work is not releated to the topic that we are studying in class.

8. We usually know the answer to a laboratory problem that we are investigating before we begin the experiment.

*9. Members of our class are able to help in the preparation of upcoming laboratory exercises.

10. Our teacher usually explains exactly what results we should expect from an investigation.

11. We are encouraged to read up on an experiment before we do it with hope of finding the answer.

SECTION B

1. Many of the experiments that are in the laboratory manual are done by the teacher or other students while the class watches.

*2. The data that I collect are often different from data that are collected by the other students.

3. Our teacher is often busy grading papers or doing some other personal work while we are working in the laboratory.

*4. During an experiment we record our data at the time we make our observations.

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

*5. We are sometimes asked to design our own experiment to answer a question that puzzles us.
6. We often ask the teacher if we are doing the right thing in our experiments.
*7. The teacher answers most of our questions about the laboratory work by asking us questions.
8. We spend less than one-fourth of our time in biology doing laboratory work.
*9. We spend at least half of our time in biology doing laboratory work.
10. We never have the chance to try our own ways of doing the laboratory work.
*11. Very little of our laboratory time is spent in the classification of specimens.
*12. We work with a variety of equipment and materials in our laboratory activities.
13. Plastic (plaster, wood, etc.) models and wall charts are often used in our laboratory exercises.
*14. We work with a variety of living plants, animals, and microbes.
15. We can usually answer most of our laboratory work questions by finding the answers in the textbook.
16. Our laboratory work consists primarily of the identification of the structures of various organisms.
*17. The laboratory provides many opportunities in identifying and defining problems to be investigated.
18. Our experiments can almost always be completed in a single laboratory period.
*19. The laboratory includes many activities that make it possible for us to discover things for ourselves.
20. Our laboratory often consists of thoroughly learning the names of structures and their parts.
21. We work a great deal with a variety of preserved specimens and prepared slides.
*22. We are able to set our own pace when doing a laboratory investigation.
*23. We construct many tables, charts, and graphs in our laboratory notebooks.
*24. We spend practically no laboratory time on definitions of biological terms and the learning of these definitions.
25. We spend more laboratory time making dissections of preserved organisms than studying live ones.
26. Our laboratory work consists primarily of making drawings of specimens and labeling them.
27. The equipment that we use is often too complex for most high school students to work with.

SECTION C

*1. We talk about what we have observed in the laboratory within a day or two after every session.
*2. After every laboratory session we compare the data that we have collected with the data of other individuals or groups.

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

3. Our teacher often grades our data books for neatness.
4. We are required to copy the purpose, materials, and procedures used in our experiments from the laboratory manual.
*5. We are allowed to go beyond the regular laboratory exercise and do some experimenting on our own.
*6. We have a chance to analyze the conclusions that we have drawn in the laboratory.
7. The class is able to explain all unusual data that are collected in the laboratory.
*8. When analyzing data from one of our experiments, we are usually asked to make predictions about what might happen in related experiments.
9. We spend very little time in the interpretation of graphs and tables of the data that we collect.
10. We do not usually get the chance to repeat an experiment even when our first attempts were careless and sloppy.
*11. We often make tables and draw graphs of data that we collect in our investigations.
12. We sometimes have to repeat an experiment in order to get the expected results.
*13. We often present to the class our results and conclusions from an investigation.
*14. We sometimes do an additional experiment because the data previously collected suggest a new question to us.
*15. Our tests include many questions based on things that we have learned in the laboratory.

SECTION D

1. I feel that I gain a better understanding of the nature of scientific investigation as a result of the teacher's lectures than when I do experiments.
2. In many of our laboratory activities I do not actually feel that I am participating in real scientific investigations.
*3. Our teacher feels that the laboratory is the most important part of our biology course.
*4. I feel that I gain a better understanding of the nature of scientific investigation as a result of class discussions.
*5. The students in our class feel that the laboratory is the most important part of our biology course.
*6. I feel that I gain a better understanding of the nature of science because of my own investigations.
7. I feel that I gain a better understanding of the nature of science primarily as a result of classroom demonstrations by the teacher.

POTENTIAL USES OF *BLAC*

There is a need in educational research for instruments that can be used for

* Items considered as those which contribute positively toward the attainment of BSCS objectives. Identification (*) not to be included if instrument is reproduced and used.

identifying actual practices occurring in various kinds of classes. This would enable investigators to properly describe the experimental classes with which they are working. The *BLAC* approach is an example of one kind of approach that might be used in the effort to refine educational research techniques.

The *BLAC* may be of use in assisting teachers in identifying their own approach to laboratory instruction—not by the *BLAC* score itself but by the student responses to particular items. The various items should provide some sort of profile as to what goes on in a particular class. In this respect the *BLAC* might be of use in teacher training; *e.g.* in feedback for the student teacher. The *BLAC* could also serve as a springboard for discussion and training in academic, summer, and in-service institutes.

SUMMARY

The purpose of this project was to develop a feasible and practical technique of determining the extent to which high school biology laboratory activities of teachers are in agreement with the activities advocated for a given curriculum. A list of biology laboratory activities was compiled from BSCS literature and verified by an appropriate panel of judges. The checklist was administered in a pilot study to two classes for each of five high school biology teachers. A t test in each of the five cases was not significant indicating that the two separate groups of students for each teacher did not disagree about the nature and extent of laboratory activities.

This instrument, in addition to providing a useful research tool, has the potential of contributing to the evaluation of student laboratory activities by all teachers engaged in teaching high school biology.

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XII. LABORATORY INSTRUCTION IN HIGH SCHOOL BIOLOGY CLASSES USING DIFFERENT CURRICULUM MATERIALS

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INTRODUCTION

There is general agreement that one of the primary emphases of the Biological Sciences Curriculum Study (BSCS) is the importance of a laboratory experience that involves actual student investigations. Much of the success in the teaching of BSCS materials is predicated on the students' involvement in these activities. Hurd and Palmer (1), Klinckman (2), Cox (3), and Grobman (4) have supported the belief that the laboratory should be the very center of learning activities in a modern biology course. The BSCS Laboratory Block Program exemplifies the BSCS approach to the laboratory. Lee (5) has emphasized that the biology student may become involved in the study of topics in a Laboratory Block in such a manner that he follows the pattern a scientist might employ.

Although there has been emphasis on laboratory activity since the beginning of the BSCS program, and the present literature continues to emphasize the necessity of investigations, little is actually known about the nature and extent of laboratory instruction that is being carried on in high school biology courses currently, whether using BSCS materials or not. The questions that should be asked are: To what extent do BSCS teachers follow the BSCS laboratory approach? How do the nature and extent of laboratory activities in classes of experienced BSCS teachers compare with those activities in classes of first-year BSCS teachers? What are the nature and extent of laboratory activities in classes where materials other than BSCS materials are used? The study reported here was concerned with the problem of determining the nature and extent of laboratory instruction in selected high school biology classes which were using different curriculum materials.

THE INSTRUMENT USED IN THIS STUDY

A checklist instrument, the *Biology Laboratory Activity Checklist (BLAC)* was developed for use in this study. A description of this instrument as well as a copy of *BLAC* is found elsewhere in this monograph (6). *BLAC* is composed of 60 items which describe the potential laboratory activities of a high school biology class. It was used to determine the degree to which laboratory activities in selected high school biology classes conform to the activities judged to be those which contribute toward the attainment of BSCS objectives. Half of the *BLAC* statements represented activities which were judged to contribute positively toward BSCS objectives and half represented activities which were considered not to support BSCS objectives.

In the present study the *BLAC* was administered to the students in each of 63 participating classes. A single mean score on the *BLAC* was computed for each

class. The possible range of these scores was from zero to 60, the higher scores indicating a greater degree of conformity with laboratory activities judged to contribute positively toward BSCS objectives.

A DESCRIPTION OF THE GROUPS PARTICIPATING IN THIS STUDY

Three groups were selected for this study. Selection was made so as to provide a wide range of participating classes in terms of curriculum materials that were being used and the length of time the teacher had been using them. Those selected included a group of teachers who had taught BSCS biology for several years, a group of teachers who were teaching BSCS materials for the first time, and a group of teachers who were not using BSCS materials. A description of each group is as follows:

Group EB consisted of one class of students under each of 21 teachers who were identified as having had considerable training and experience in the BSCS program. These teachers were recommended by BSCS officials on the basis of their work in BSCS. The mean number of years of experience in teaching BSCS by the group was five. Because of the limited number of teachers who had had several years of experience with BSCS, this group was spread over 11 states.

Group BB consisted of one class of students under each of 21 teachers who were identified as not having had previous experience and training in the BSCS program, but who were using the BSCS materials for the first time. A state education agency official assisted in the identification of those school districts that were using BSCS materials for the first time. The teachers in this group were chosen by their science supervisors and were located in seven cities in one state.

Group NB consisted of one class of students under each of 21 teachers who were identified as using curriculum materials other than BSCS. A state education agency official assisted in the identification of those school districts that were not using BSCS materials. The teachers in this group were chosen by their science supervisors and were located in three cities in one state.

It should be emphasized that these three groups were selected for the purpose of providing populations that would be expected to exhibit a variety of types of laboratory instructional practices.

The samples are non-random, and thus generalizations about the populations from which these samples were drawn must be made with some caution. However, no effort was made by the investigator to choose particular teachers or classes for the experimental groups other than to apply the criteria of materials used and the length of time the teachers had been using them. The selection of teachers was made by supervisors and BSCS officials and the selection of classes was made by the individual teachers. Any variables that may have been operating to affect the selection procedures should not, in general, have had more effect on the selection of the teachers and/or classes in one group than in another group. The primary interest of this study was to detect the type of laboratory practices that occurred in a variety of classes and to determine whether or not they followed practices recommended by BSCS.

RESULTS AND CONCLUSION

The means of the scores of the three experimental groups on the *BLAC* were as follows:

Group EB 39.25
Group BB 33.46
Group NB 28.87

As was previously stated, the possible range of scores was from zero to 60, the higher scores indicating a greater degree of conformity with laboratory activities judged to contribute positively toward BSCS objectives.

The primary purpose of the study was to analyze the degree to which selected high school biology classes using different curriculum materials participate in laboratory activities that conform to laboratory practices recommended by BSCS. Table 1 presents a distribution of *BLAC* class means of the three experimental groups. There was a rather large range of class means in each group with some degree of overlap among the three groups. For example, although the overall mean (33.46) for Group BB was lower than the overall mean (39.25) for Group EB, one of the classes in Group BB scored higher on the *BLAC* than 16 of the classes in Group EB.

TABLE 1

DISTRIBUTION OF *BLAC* CLASS MEANS FOR THE THREE EXPERIMENTAL GROUPS

Range of *BLAC* Class Means	Number of Classes		
	Group EB	Group BB	Group NB
56–60	--	--	--
51–55	--	--	--
46–50	3	--	--
41–45	4	1	--
36–40	9	5	--
31–35	5	10	4
26–30	--	5	15
21–25	--	--	2
16–20	--	--	--
11–15	--	--	--
6–10	--	--	--
0–5	--	--	--
Totals	21	21	21

To study the original problem, the question of whether or not the three groups

differed significantly in terms of *BLAC* class mean scores was stated in the form of an hypothesis:

> There are no significant differences among *BLAC* class mean scores among the three experimental groups.

An analysis of variance was applied to the *BLAC* class mean scores of the three groups. This analysis served as a test of the hypothesis.

Table 2 presents the results of the analysis. The resulting F value of 33.76 was significant at the .01 level of confidence. A test of the significance of the difference between each pair of means, *i.e.*, Group EB with BB, BB with NB, and EB with NB, was made by use of a technique involving the standard error of any difference between pairs of group means. Guilford (7) shows that the value required for significance is the product of the standard error and the *t* value based on the proper number of degrees of freedom. The standard error is estimated from the mean square within groups. In the present analysis the required value is the product of 1.27 (the standard error) and 2.66 (the *t* value at the .01 level of confidence with 62 degrees of freedom), or 3.38. The computed difference in all three comparisons of group means exceeds this value (EB-BB, 5.79; BB-NB, 4.59; EB-NB, 10.38).

TABLE 2

RESULTS OF AN ANALYSIS OF VARIANCE OF *BLAC* CLASS MEAN SCORES OF THE THREE EXPERIMENTAL GROUPS

Components	Sum of Squares	Degrees of Freedom	Mean Square	
Between Groups	1138.00	2	569.50	
Within Groups	*1011.94*	*60*	16.87	F = 33.76†
Total	1149.94	62		

† Significant at .01 level

The decision was to reject the null hypothesis. Based on *BLAC* mean scores, there is a significant difference among the three experimental groups in the degree of conformity of laboratory activities to those laboratory activities recommended by BSCS. Group EB exhibited the highest degree of conformity, Group BB next, and Group NB the least.

Previous reference has been made to the degree of overlap in *BLAC* scores among the classes in the three groups. Although the scores for the three groups are significantly different, the identification of a class as to group membership does not necessarily indicate the nature of the laboratory approach used in that class. An extreme example would be the case of the lowest scoring class in Group EB. The *BLAC* mean score of this class is lower than the mean scores of 14 of the 21 Group BB classes. Similarly, the highest scoring class in Group NB has a mean score higher than the scores of 15 of the 21 Group BB classes. Thus to make a judgment as to the laboratory approach of a particular class based on curriculum

materials used or the number of years in which the teacher has used these materials may be unwarranted.

On the basis of the above discussion, certain conclusions can be made:

1. The *BLAC* is capable of identifying the degree to which laboratory activities conform to BSCS recommended laboratoıy activities.
2. Significant differences do exist among the high school biology classes in the three experimental groups of this study in the approach to laboratory instruction.
3. It is not necessarily warranted to make a judgment about the laboratory instruction in a particular biology class solely on the basis of the curriculum materials used or the length of time that the materials have been used by the teacher.

CONCLUSIONS BASED ON AN ANALYSIS OF SELECTED *BLAC* ITEMS

An analysis of selected *BLAC* items can provide some indication of trends in the experimental groups and suggest some differences that may exist between BSCS and non-BSCS classes as to laboratory activities.

The following 11 items (see Table 3) provide a comparison of experienced BSCS classes (Group EB) and non-BSCS classes (Group NB). These data include the item number, the BSCS recommended answer, the percentage of classes agreeing that the activity occurred, the percentage of classes unable to agree on whether or not the activity occurred, and the percentage of classes agreeing that the activity did not occur. Percentages are provided for Group EB and Group NB. The criterion for selecting these 11 items was that there was at least a 50 percent difference in responses (YES or NO) in the particular category that was recommended by the BSCS. Selected percentages are emphasized by italicizing the percent (*e.g.*, *62*) to amplify differences between Group EB and Group NB on the eleven items.

The items included in Table 3 are:

- B- 8. We spend less than one-fourth of our time in biology doing laboratory work.
- B-11. Very little of our laboratory time is spent in the classification of specimens.
- B-15. We can usually answer most of our laboratory work questions by finding the answers in the textbook.
- B-16. Our laboratory work consists primarily of the identification of the structures of various organisms.
- B-20. Our laboratory work often consists of thoroughly learning the names of structures and their parts.
- B-21. We work a great deal with a variety of preserved specimens and prepared slides.
- B-25. We spend more laboratory time making dissections of preserved organisms than studying live ones.
- C- 6. We have a chance to analyze the conclusions that we have drawn in the laboratory.

C- 8. When analyzing data from one of our experiments, we are usually asked to make predictions about what might happen in related experiments.

C- 9. We spend very little time in the interpretation of graphs and tables of the data that we collect.

C-11. We often make tables and draw graphs of data that we collect in our investigations.

TABLE 3

COMPARISON OF THE CLASS RESPONSES OF TWO OF THE EXPERIMENTAL GROUPS TO SELECTED *BLAC* ITEMS

BLAC Item	Recommended by BSCS Panel	Percent of Group EB Classes Yes	?	No	Percent of Group NB Classes Yes	?	No
B- 8	No	14	24	62	43	48	10
B-11	Yes	95	5	0	24	67	10
B-15	No	0	43	57	71	24	5
B-16	No	5	24	71	71	29	0
B-20	No	5	29	67	76	24	0
B-21	No	14	19	67	62	24	14
B-25	No	5	0	95	62	10	29
C- 6	Yes	95	5	0	33	48	19
C- 8	Yes	67	29	5	0	43	57
C- 9	No	10	33	57	57	43	0
C-11	Yes	62	24	14	5	5	90

? = classes in which less than two-thirds of the students were in agreement.

If the above items can be assumed on the basis of student agreement to indicate a general distinction between certain characteristics of the BSCS and non-BSCS laboratory approaches, then the following description of the two approaches seems defensible.

The non-BSCS laboratory appears to include more of the following:

1. classification of specimens;
2. identification of structures and their parts and the learning of their names;
3. work with preserved specimens and prepared slides;
4. dissections of preserved specimens;
5. use of the textbook in answering laboratory work questions.

The BSCS laboratory appears to include more of the following:

1. actual time spent in the laboratory;
2. practice in hypothesis formation;
3. the making and interpretation of graphs and tables;
4. analysis of data and conclusions.

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XIII. AN INVESTIGATION OF THE RELATIONSHIP OF SELECTED VARIABLES TO LABORATORY ACTIVITY IN HIGH SCHOOL BIOLOGY

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THE INSTRUMENTS USED IN THE STUDY

Is the relative success or failure of a particular aspect of a science curriculum program dependent on teacher acceptance of the overall rationale of that curriculum program? If the curriculum emphasizes the importance of a particular approach to the laboratory, does the extent of laboratory facilities become an important factor in terms of the degree to which the rationale of the curriculum is expressed? The study reported here was concerned with the above two variables as they relate to the Biological Sciences Curriculum Study (BSCS) program. Specifically, this study was concerned with the relationship between the degree to which laboratory activities conformed to those recommended by BSCS and two variables:

1. teacher acceptance of BSCS objectives;
2. available laboratory facilities.

THE INSTRUMENTS USED IN THE STUDY

Biology Laboratory Activity Checklist (*BLAC*)—A checklist instrument, the *Biology Laboratory Activity Checklist* (*BLAC*), was developed for use in this study. A description of this instrument, as well as a copy of *BLAC*, has been reported elsewhere in this monograph by Barnes (1). *BLAC* is composed of 60 items which describe the potential laboratory activities of a high school biology class. The *BLAC* was used to determine the degree to which laboratory activities in selected high school biology classes conform to those judged to contribute toward the attainment of BSCS objectives. Half of the *BLAC* statements represented activities which were judged to contribute positively toward BSCS objectives and half represented activities which were considered not to contribute toward BSCS objectives.

In the present study the *BLAC* was administered to the students in each of the 63 participating classes. A single score on the *BLAC* was computed for each class. The possible range of these scores was from zero to 60, the higher scores indicating a greater degree of conformity with laboratory activities judged to contribute positively toward BSCS objectives.

BSCS Biology Laboratory Facilities Checklist—The BSCS Biology *Laboratory Facilities Checklist* (*LFC*) was developed to provide guidelines for schools, administrators, and teachers in order to assist in planning for implementation of BSCS biology. The *LFC* was originally prepared by Abraham and Novak (2), BSCS staff consultants, who visited the 105 biology teachers who participated in the BSCS 1960–61 testing centers. It was subsequently revised by Schaefer (3) in 1965. It

was this version of the *LFC* that was used in the present study. The design is such that it may be used to assist in the evaluation of a school's present biology laboratory facilities in comparison with optimal facilities. The *LFC* was completed by 58 of the 63 teachers who participated in the study. A score was computed for each class, the possible range of scores being from zero to 541. A score of 541 was indicative of optimal facilities.

The Attitude Inventory—The *Attitude Inventory* (*AI*) was developed by Blankenship (4) as a measure to be used in determining the reaction of science teachers to BSCS biology. The author reviewed the BSCS literature, interviewed a number of scientists and high school teachers who were involved in the development of BSCS materials, interviewed a number of high school teachers who had not been involved wth the BSCS program, and analyzed certain teacher comments concerned with the use of BSCS in their own school situations. On the basis of this information, a large number of statements were prepared. Some of these statements expressed a view favorable to BSCS and others expressed a view unfavorable to BSCS. The final form of Blankenship's instrument contained 46 statements (5).

For use in the present study some of the items were altered or deleted so that no specific reference to BSCS was made. This was done so as to eliminate the possibility that any mention of BSCS would influence the teacher. The resulting instrument contained 30 items, 15 of which expressed an attitude favorable toward BSCS and 15 an unfavorable attitude toward BSCS. This revised form of the *Attitude Inventory* was administered to each of the 63 teachers participating in the study. The teacher was asked to respond only to those items with which he definitely agreed. A score for each teacher was obtained by a count of the number of "positive" items that were checked and "negative" items that were left blank. Thus, the possible range of scores was zero to 30, a higher score indicating a greater degree of acceptance of BSCS objectives.

A DESCRIPTION OF THE GROUPS PARTICIPATING IN THE STUDY

Three groups were selected for this study. Selection was made so as to provide a wide range of participating classes in terms of curriculum materials that were being used and the length of time that the teacher had been using them. Those selected included a group of teachers who had taught BSCS biology for several years, a group of teachers who were teaching BSCS materials for the first time, and a group of teachers who were not using BSCS materials. A description of each group is as follows:

Group EB consisted of one class of students from each of 21 teachers who were identified as having had considerable training and experience in the BSCS program. These teachers were recommended by BSCS officials on the basis of their work in BSCS. The mean number of years of experience in teaching BSCS by the group was five. Because of the limited number of teachers who had had several years of experience with BSCS, this group was composed of classes from 11 states.

Group BB consisted of one class of students from each of 21 teachers who were identified as not having had previous experience and training in the BSCS program, but who were using the BSCS materials for the first time. A state education

agency official assisted in the identification of those school districts that were using BSCS materials for the first time. The teachers in this group were chosen by their science supervisors and were located in seven cities in one state.

Group NB consisted of one class of students from each of 21 teachers who were identified as using curriculum materials other than BSCS. A state education agency official assisted in the identification of those school districts that were not using BSCS materials. The teachers in this group were chosen by their science supervisors and were located in three cities in one state.

It should be emphasized that these three groups were selected for the purpose of providing populations that would be expected to exhibit a variety of types of laboratory instructional practices.

The samples are non-random and thus generalizations about the populations from which these samples were drawn must be made with some caution. However, no effort was made by the investigator to choose particular teachers or classes for the experimental groups other than to apply the criteria of materials used and the length of time the teachers had been using them. The selection of teachers was made by supervisors and BSCS officials and the selection of classes was made by the individual teachers. Any variables that may have been operating to affect the selection procedures should not, in general, have had more effect on the slection of the teachers and/or classes in one group than in another group. The primary interest of this study was to detect the type of laboratory practices that occurred in a variety of classes and to determine whether or not they followed the practices recommended by BSCS.

HYPOTHESES AND STATISTICAL ANALYSIS

HYPOTHESIS 1

There is no significant relationship between *BLAC* class mean scores and BSCS Biology *Laboratory Facilities Checklist* scores.

The test of this hypothesis was indicative of whether or not the degree to which laboratory activities conformed to activities recommended by BSCS was related to laboratory facilities available. Since the problem was one of the relationship between two variables, the scores on the two instruments were subjected to a correlational analysis.

HYPOTHESIS 2

There is no significant relationship between *BLAC* class mean scores and scores on the *Attitude Inventory*.

The test of this hypothesis was indicative of whether or not the degree to which laboratory activities conformed to laboratory activities recommended by BSCS was related to the degree to which there was teacher acceptance of BSCS objectives. Since the problem was one of the relationship between two variables, the scores on the two instruments were subjected to a correlational analysis.

RESULTS AND CONCLUSIONS

A summary of the means of the class scores on each instrument for the three

groups is presented in Table 1. Data were obtained for all 63 classes on each of the instruments with the exception of the *LFC*. Five teachers, three in Group BB and two in Group NB, did not complete the *LFC*. In the subsequent analysis of the *LFC*, only those 58 classes on which *LFC* data were available were included in the statistical test.

TABLE 1

SUMMARY OF THE MEANS OF SCORES OF THE THREE GROUPS ON THE INSTRUMENTS USED IN THE STUDY

	Group EB	Group BB	Group NB
BLAC	39.25	33.46	28.87
LFC	400.7	346.8	284.9
AI	25.7	21.1	21.8

The two hypotheses that were tested were concerned with the relationship of *BLAC* class mean scores to (1) scores on the *LFC*; (2) teacher scores on the *AI*. All participating classes were considered as a single group in making the tests of Hypotheses 1 and 2. Table 2 presents the Pearson product-moment coefficients of correlation between *BLAC* mean scores and the two variables (*LFC* scores and *AI* scores).

TABLE 2

PEARSON PRODUCT-MOMENT COEFFICIENTS OF CORRELATION BETWEEN *BLAC* CLASS MEAN SCORES AND TWO VARIABLES: *LFC* SCORES AND *AI* SCORES

	BLAC vs. *LFC*	*BLAC* vs. *AI*
Pearson Product-Moment Coefficients of Correlation	.55	.41
t Value	4.91*	3.51*

* Significant at .01 level.

HYPOTHESIS 1

There is no significant relationship between *BLAC* class mean scores and BSCS Biology *Laboratory Facilities Checklist* scores.

A test of this hypothesis was concerned with whether or not the degree to which laboratory activities conformed to those recommended by BSCS was related to the laboratory facilities available. A Pearson product-moment correlation was computed on the scores for the entire group and the resulting correlation was .55. A *t* test was applied to test the significance of the correlation and the resulting *t* value of 4.91 indicated that the correlation was significant at the .01 level of confidence.

Thus the decision was to reject the null hypothesis. There is a significant positive relationship between the degree to which laboratory activities conform to laboratory activities recommended by BSCS and the laboratory facilities that are available.

HYPOTHESIS 2

There is no significant relationship between *BLAC* class mean scores and scores on the *Attitude Inventory*.

A test of this hypothesis was concerned with whether or not the degree to which laboratory activities conformed to those laboratory activities recommended by BSCS was related to the degree to which there was teacher acceptance of BSCS objectives. A Pearson product-moment correlation was computed on the scores for the entire group and the resulting correlation was .41. A t test was applied to test the significance of this correlation and the correlation was found to be significant at the .01 level of confidence (t was 3.51). Thus the decision was to reject the null hypothesis. There is a significant positive relationship between the degree to which laboratory activities conform to those laboratory activities recommended by BSCS and the degree of teacher acceptance of BSCS objectives.

In summary, the tests of the two hypotheses suggest that:

Concerning laboratory facilities, classes which score high on *LFC*—that is, have adequate or better than adequate laboratory facilities—tend to participate in laboratory activities that conform to laboratory activities recommended by BSCS to a greater extent than do classes with somewhat less complete laboratory facilities.

Concerning teacher acceptance of BSCS objectives, teachers who tend to be more favorable toward BSCS objectives involve their classes in laboratory activities recommended by BSCS to a greater extent than do teachers less favorable toward BSCS. The data indicate, however, that there are teachers who tend to be somewhat unfavorable toward BSCS objectives but conduct a BSCS-type laboratory, and there are teachers who tend to be favorable toward BSCS objectives but whose laboratory activities are limited and are thus not following procedures recommended by BSCS. It is not possible in all cases to predict a teacher's instructional methods on the basis of his expressed attitudes, and likewise it is not possible to predict a teacher's expressed attitude on the basis of the instructional methods or approach that he employs.

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XIV. THE DEVELOPMENT AND EVALUATION OF CURRICULA FOR ABILITY-GROUPED HIGH SCHOOL BIOLOGY CLASSES

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With the present emphasis on more adequate provision for student differences, the idea of homogeneous grouping has attained paramount importance. Research during the last ten years by Daniels (1), Drews (2), Borg (3), and others tends to support the idea that grouping accompanied by differentiated curriculum and instruction is advantageous, but that grouping *per se* has little or no value.

This study was initiated because of a need for differentiation among biology classes of nine senior high schools in a metropolitan area where the schools represent a wide range in purpose of training from vocational to college preparatory, and where a multiracial student population exists of Negro-, Latin-, and Anglo-Americans. The need for adaptation of curriculum materials to a local situation was magnified by the state system of textbook adoption wherein only one of the five state-adopted biology texts was available for use in the schools. Furthermore, a great need existed for teacher training because the text and laboratory manual, BSCS *Biological Science: An Inquiry Into Life* (Yellow Version) (4), represented a new approach to biology teaching, while the majority of the biology teachers had been trained for and had taught traditional biology. In a cooperative effort to provide more adequately for student differences, the author and eight other biologists and science educators developed and evaluated a biology program for three levels of student abilities. A significant addition to previous grouping situations was a semi-monthly in-service program in which teachers were trained to use the materials in their classrooms. The in-service program, financed by two grants from the National Science Foundation, was conducted during the 1965–1966 school year for 35 teachers. Concurrently, the teachers taught the modified materials to approximately 4,000 biology students in their classes.

ADAPTATION OF THE BIOLOGY CURRICULUM FOR THREE LEVELS OF STUDENT ABILITY

After a review of the results from the BSCS evaluation program, a considerable modification of the textbook and laboratory manual appeared necessary for slow-learner classes. This portion of curriculum modification was undertaken by the author with the assistance of a college biologist. The following guidelines were established for adapting the text and manual to the ability of slow learners:

1. Because of the bilingual problems and a resultant reading problem, a great simplification of vocabulary was considered appropriate for all written materials.
2. Because the mean mental ability of these students was low (based on the SRA tests of educational ability), and thus a short attention span was indicated for most students, reading materials of short length were considered appropriate.

3. In keeping with the BSCS philosophy, the slow-learner course was laboratory-oriented with the students performing most investigations in place of teacher demonstrations.

In view of these guidelines, the BSCS materials were modified so that during the school year the slow-learner students read only selected portions of the text. Additionally, about one-half of the laboratory investigations were newly written exercises or simplified modifications of exercises in the BSCS Laboratory Manual.

Adaptations for accelerated classes consisted of enrichment by use of additional laboratory exercises and other materials, including selections from the BSCS Invitations to Inquiry (5), the BSCS *Research Problems in Biology* (6, 7), and performance of the BSCS Laboratory Block, *Physiological Adaptation* (8). Further enrichment was provided with a study of concepts in greater breadth and depth than found in the materials for average classes, and with a more detailed class discussion.

No modifications of the text and the laboratory manual were made for average classes.

THE IN-SERVICE PROGRAM

Sessions of the in-service program were held every two weeks for a two-hour period. During the first hour, the work of the previous two weeks was reviewed, and the program for the next two-week period was discussed; mimeographed outlines of materials for the following two weeks were distributed to teachers, and difficult or new biological concepts were discussed; supplementary literature was distributed, and films and transparencies were shown. The second hour was conducted in the laboratory. During the year, three in-service meetings were held in high school laboratories where the group observed a teacher conducting a laboratory session with one ability-level group of students. At the end of the spring semester, a three-day workshop was conducted to perform an intensive review of the three programs, and to develop a set of guidelines for modified instruction of slow-learner students and accelerated students. During the 1966 summer, a teacher writing committee for each ability level developed a manual to be used the following school year.

EVALUATION OF THE PROGRAM

The author evaluated the modified program, using a sample of nine teachers and 18 classes (a total of 579 students). The nine teachers were given the following assignments:

1. Four teachers of slow-learner students were asked to collect data from two classes, with one slow-learner class receiving the modified slow-learner curriculum (experimental class) and the other slow-learner class receiving the unmodified curriculum (control group).
2. Three teachers of average students were asked to collect data from two classes, with both average classes of each teacher receiving the unmodified curriculum. These classes served as a control group for both the accelerated and the slow-learner groups using unmodified materials.

3. Two teachers of accelerated students were asked to collect data from two classes, with one accelerated class receiving the modified accelerated curriculum (experimental class) and the second accelerated class receiving the unmodified curriculum (control class).

In this manner, for each group of accelerated classes and slow-learner classes, provision was made for experimental classes using modified materials and control classes using unmodified materials, with each unit of two classes taught by the same teacher. Thus, the design provided for a negation of teacher differences within each unit of two coordinate classes. Additionally, for the accelerated and slow-learner groups who were taught the unmodified materials, a control was provided by means of the group of average students who also were taught unmodified materials.

Scores used for grouping by school counselors were obtained from a battery of *Science Research Associates Basic Achievement Tests* (9) and from the *Science Research Associates Educational Ability Test* (10). Student achievement in the biology course was measured by the score differences on pre- and post-tests of the BSCS *Processes of Science Test* (*POST*) Form A (11) and the BSCS *Comprehensive Final Examination* (*CFE*) Form J (12). A further measurement of student achievement was made from subscores of *POST* and *CFE* for kinds of cognitive ability, based on a categorization of test items according to "The BSCS Grid for Test Analysis" prepared by Klinckmann (13). In addition, a subjective evaluation of the modified curriculum materials was obtained from questionnaires presented at the end of the school year to students and teachers of the evaluation group. A diagram showing the experimental design of the evaluation program is provided in Table 1.

RESULTS OF THE EVALUATION

Complete data were collected from 504 students, which included 228 slow-learner students, 173 average students, and 103 accelerated students. Twenty-one scores from seven testing instruments were recorded for each student. Table 2 describes the five ability-curriculum groups from whom data were collected.

A number of inquiries significant to this study can be made, and answers can be determined from the data collected.

Inquiry 1. Was the grouping valid?

The significance of differences in mental ability and in academic achievement at the beginning of the school year was determined for the three ability groups. Results provided evidence that differences of means among the three groups for seven pre-scores were significant at below the .01 level of probability (Table 3). Thus, the conclusion was made that the three groups were significantly different in mental ability and achievement and that the grouping was valid.

Inquiry 2. Did significant learning occur within all groups, and was learning related to teacher-class interaction?

Because all variables could not be controlled completely, it appeared appropriate to determine at an early stage of the analyses if significant learning had occurred in

TABLE 1

EXPERIMENTAL DESIGN OF THE EVALUATION PROGRAM

Grouping Criteria (1) SRA Achievement Tests for English, Mathematics, Social Studies and Science
(2) SRA Educational Ability Test

Pre-tests	Sample Group		Post-tests
	Slow Learner		
BSCS Processes of Science, Form A	Teacher No. 1, 2, 3, 4	One class each with modified curriculum (Experimental group) One class each with unmodified curriculum (Control group)	BSCS Processes of Science, Form A
	Average		
BSCS Comprehensive Final Examination, Form J	Teacher No. 5, 6, 7	Two classes each with unmodified curriculum	BSCS Comprehensive Final Examination, Form J
	Accelerated		
Scores on subcategories of POST and CFE for 4 kinds of cognitive ability	Teacher No. 8, 9	One class each with modified curriculum (Experimental class) One class each with unmodified curriculum (Control class)	Scores on subcategories of POST and CFE for 4 kinds of cognitive ability

Measurement of gain: Differences in
(1) Mean scores of pre- and post-tests.
(2) Mean partial scores of pre- and post-tests, representing four kinds of cognitive abilities.

TABLE 2

DESCRIPTION BY ABILITY-CURRICULUM GROUPS OF STUDENTS FROM WHOM COMPLETE DATA WERE COLLECTED

Group	No. of Students	No. of Teachers	Mean Class Enrollment	Mean Grade	Mean Age	Mean of Sex-Distribution M = 1, F = 2
Slow Learner Mod. Curr.	119	4	30.12	10.81	17.00	1.44
Slow Learner Unmod. Curr.	109	4	27.72	10.74	16.68	1.48
Average Unmod. Curr.	173	3	28.96	10.31	15.74	1.52
Accelerated Mod. Curr.	52	2	26.00	10.15	16.34	1.48
Accelerated Unmod. Curr.	51	2	25.50	10.01	15.33	1.54
Entire Group	504	9	27.65	10.40	16.22	1.49

each of the five ability-curriculum groups and if the learning was related to a teacher-class interaction.

To obtain an answer to the first question, a series of double classification analyses of variance (teacher × testing) was performed for each ability-curriculum group, with the five ability-curriculum groups used as independent variables and the difference scores of *POST* and *CFE* used as dependent variables (5 ability-curriculum groups × 2 difference scores). Results of the analyses, reported in Table 4, showed that gains in mean scores were significant at a probability level below .01 for all scores, thus providing evidence that significant learning had occurred in all five ability-curriculum groups.

The second part of this inquiry was included because of the importance of possible effects of differences among teacher-class interactions on learning outcomes. (Teacher-class interaction is defined as the total situation of a particular class with a particular teacher within a particular school.) A great difference in one teacher-class combination from other such combinations within one ability-curriculum group could well influence the mean scores for that particular group. For example, if one teacher were significantly different from the other—more effective or less effective—or if one class contained a great distortion element such as the influence of student leaders to create greater motivation—or the opposite—these elements might be great enough to influence the results of the entire ability-curriculum group. Therefore, by comparing the mean scores of achievement tests for teacher-

TABLE 3

SIGNIFICANCE OF DIFFERENCES IN MENTAL ABILITY AND ACHIEVEMENT AMONG THE THREE ABILITY LEVELS AT THE BEGINNING OF THE SCHOOL YEAR

Test	Mean Slow Learner	Mean Average Group	Mean Accel. Group	Sig. of Differences
SRA Educational Ability	88.38	103.58	124.00	<.01
SRA English Achievement	44.11	54.49	66.83	<.01
SRA Math Achievement	45.71	55.35	72.47	<.01
SRA Science Achievement	44.71	54.30	68.50	<.01
SRA Soc. Sci. Achievement	44.79	53.60	66.92	<.01
Pre-test POST-Total	13.62	17.82	27.50	<.01
Pre-test CFE-Total	15.18	18.28	23.62	<.01

class combinations within each ability-curriculum group, it was possible to learn if the teachers and classes differed significantly within any of the five ability-curriculum groups.

For the analyses, computations were performed by obtaining an interaction F ratio for each of the five ability-curriculum groups, with teachers of each group held as independent variables and difference scores of the *POST* and the *CFE* as dependent variables. Thus, ten computations were performed (teachers of 5 ability-curriculum levels × 2 difference scores, one from *POST* and one from *CFE*). Results of computations from *POST* scores, given in Table 5, produced evidence that significant differences existed among all teacher-class combinations except the accelerated unmodified curriculum group. We can conclude, then, that learning outcomes, as represented by the *POST* scores, may have been influenced significantly by differences in teachers and classes for all groups except the accelerated unmodified curriculum group. On the other hand, results of computations from *CFE* scores indicated no significant differences among the teacher-class combinations except for the average unmodified curriculum group.

The differences in teacher-class interaction shown in Table 5 are apparent when results of *POST* and *CFE* are compared. The explanation may lie in the nature of

TABLE 4

SIGNIFICANCE OF DIFFERENCES IN ACHIEVEMENT AMONG FIVE ABILITY-CURRICULUM GROUPS

Ability-Curriculum Group	Pre-test Mean Score	Post-test Mean Score	Significance of Difference in Means
PROCESSES OF SCIENCE TEST			
Slow Learner-Mod. Curr.	13.34	15.75	<.01
Slow Learner-Unmod. Curr.	13.94	16.55	<.01
Average-Unmod. Curr.	17.83	23.06	<.01
Accelerated-Mod. Curr.	27.04	31.96	<.01
Accelerated-Unmod. Curr.	27.98	31.86	<.01
COMPREHENSIVE FINAL EXAMINATION			
Slow Learner-Mod. Curr.	15.49	16.59	<.01
Slow Learner-Unmod. Curr.	14.84	16.64	<.01
Average-Unmod. Curr.	18.28	22.12	<.01
Accelerated-Mod. Curr.	23.61	31.69	<.01
Accelerated-Unmod. Curr.	23.63	32.31	<.01

the two tests. The *POST* contains nine recall items in a total of 40 multiple-choice items and is designed to measure understanding of scientific principles and capability for scientific reasoning, whereas the *CFE* contains 20 recall items in a total of 50 multiple-choice items and is designed to measure specific knowledge of the course materials. Since most science teachers agree that both the teaching and learning of abstract elements are more difficult than teaching and learning simple recall of information, it was no surprise to find that differences among teachers and classes exerted a greater influence on *POST* scores than on *CFE* scores.

Inquiry 3. Was modification of material necessary to provide adequately for different learning abilities?

An analysis of the significance of differences in learning among the three ability-curriculum groups using unmodified materials was made to gain evidence that unmodified materials did—or did not—provide adequately for the different needs of students. If the grouping was valid—and evidence was obtained from Inquiry 1 that it was—and if unmodified materials were adequate for all ability levels, then differences in achievement parallel to differences in mental ability could be expected among the three levels of grouped students.

For an answer, a set of one-way analyses of variance was performed with ability levels as independent variables and difference scores of *POST* and *CFE* as dependent variables (3 groups × 2 difference scores). Results, provided in Table 6, showed that significant differences did exist in gains among the three ability-curriculum groups. For *POST* scores, the average group made a greater gain than

TABLE 5

SIGNIFICANCE OF DIFFERENCES IN TEACHER-CLASS INTERACTION AMONG FIVE ABILITY-CURRICULUM GROUPS

Ability-Curr. Group	No. of Teachers	No. of Classes	Interaction F ratio	Significance of Differences among interactions
PROCESSES OF SCIENCE TEST				
Slow Learner-Mod. Curr.	4	4	6.05	<.01
Slow Learner-Unmod. Curr.	4	4	5.37	<.01
Average-Unmod. Curr.	3	6	11.93	<.01
Accelerated-Mod. Curr.	2	2	3.94	<.05
Accelerated-Unmod. Curr.	2	2	.176	N.S.
COMPREHENSIVE FINAL EXAMINATION				
Slow Learner-Mod. Curr.	4	4	.271	N.S.
Slow Learner-Unmod. Curr.	4	4	.589	N.S.
Average-Unmod. Curr.	3	6	10.17	<.01
Accelerated-Mod. Curr.	2	2	1.63	N.S.
Accelerated-Unmod. Curr.	2	2	.120	N.S.

the accelerated group. Perhaps this was a reflection of a limit placed on measurement of gain by *POST*, as indicated by the pre-test mean score of accelerated students. Nevertheless, since *POST* contained 40 test items, and the highest score of the post-test was 37, it seems evident that discrimination among test items was adequate for accelerated students. A more reasonable conclusion may be that the unmodified curriculum did not offer sufficient enrichment for accelerated students to achieve a gain on scores more nearly in proportion to their relative mental ability. The low gain of the slow-learner group suggests that a modification of the curriculum is appropriate at that learning level. Scores for the average group indicate that the unmodified curriculum was appropriate for that group. For *CFE* scores, the achievement of slow-learner students implies again that a modification of materials is appropriate. Obviously, the accelerated group made a greater gain than the average group, a result which might be interpreted as a reflection of the nature of each test, whereby the accelerated students exhibited a greater ability for recall in their *CFE* scores. Possibly the *POST* is a better measuring instrument for a criterion of the needs of accelerated students.

Inquiry 4. Were test instruments adequate?

Earlier evaluation programs of SRA (14, 15) and BSCS (16, 17) had established a high degree of validity and reliability for all tests used in this program. Evidence was obtained from Inquiry 1 that the SRA tests were adequate criteria for assigning

TABLE 6

DIFFERENCES IN LEARNING AMONG THREE ABILITY GROUPS USING UNMODIFIED CURRICULUM

Group	Pre-test Mean	Post-test Mean	Difference Score
	POST Scores		
Slow Learner	13.94	16.55	2.61
Average	17.83	23.06	5.23
Accelerated	27.98	31.86	3.88
Significance of difference of difference scores			<.01
	CFE Scores		
Slow Learner	14.84	16.64	1.80
Average	18.28	22.12	3.84
Accelerated	23.63	32.31	8.68
Significance of difference of difference scores			<.01

students to ability groups. To learn if *POST* and *CFE* were adequate for evaluation in this study, coefficients of correlation were obtained for all possible combinations of the SRA *Test of Educational Ability* scores, and *POST* and *CFE* scores. Results of analyses showed that SRA test scores correlated highly with pre- and post-test scores of *POST* and *CFE*, indicating that the three tests measure common elements to a considerable degree and that probably at least one of the common elements is mental ability. Nevertheless, the fact that partial coefficients of *POST* and *CFE* were significant ($r = .273–.645$) provided evidence that *POST* and *CFE* measure certain abilities not measured by SRA tests. A logical assumption seems to be that these independent relationships are peculiar to special skills developed within the biology course. The use of the same forms of *POST* and *CFE* for all ability levels is justified on the basis that achievement was measured within coordinate groups of the same ability level. Furthermore, the modified curricula purported to teach the same concepts as the unmodified, thus requiring that the same test be used with the experimental and control classes. Accordingly, the conclusion was made that the *POST* and the *CFE* were satisfactory instruments for evaluation in this study.

Inquiry 5. Were learning outcomes in biology related to student achievement in English?

Intercorrelations for all possible paired combinations of test scores for the SRA *Basic English Achievement Test* and the pre- and post-test total scores of *POST* and *CFE* showed a significant relationship at the .01 level between biology learning and English achievement for slow-learner groups ($r = .371–.671$) and average

TABLE 7

SIGNIFICANCE OF DIFFERENCES IN ACHIEVEMENT AND IN TEACHER-CLASS INTERACTION FOR COORDINATE EXPERIMENTAL AND CONTROL GROUPS

Test	Modified Curriculum Diff. Score	Unmodified Curriculum Diff. Score	Sig. of Diff.	Teacher-Class Interaction F ratio Mod. vs. Unmod.	Sig. of Ratio
		Slow Learner Group			
POST (Post-test minus pre-test)	2.41	2.61	N.S.	1.45	N.S.
CFE (Post-test minus pre-test)	1.10	1.79	N.S.	.7092	N.S.
		Accelerated Group			
POST (Post-test minus pre-test)	4.92	3.88	N.S.	2.06	N.S.
CFE (Post-test minus pre-test)	8.08	8.68	N.S.	.433	N.S.

groups (r = .484–.621). The relationship was lower for accelerated students (r = .149–.586).

Inquiry 6. Did students using modified materials learn more than students using unmodified materials? Were learning outcomes related to differences in teacher-class interactions?

The information of Table 7 indicates that no significant differences in learning occurred between groups using modified materials and those using unmodified materials. Attention must be called, however, to a number of uncontrolled elements inherent in the program. Such factors generally are present within any short-lived classroom experiment, and emphasis must be given to the necessity for several years of practice before the true effectiveness of a new program can be ascertained.

The differences in teacher-class interaction, shown also in Table 7, were not significant between any coordinate groups (*i.e.*, control *vs.* experimental). As stated earlier, this outcome was expected since teacher differences were nullified by the experimental design.

Inquiry 7. Did students of different ability levels demonstrate a difference in development of types of cognitive abilities, and was the development related to differences in curricula?

Throughout the study, each test item of *POST* and *CFE* was assigned to a major

TABLE 8

COMPARISON OF DIFFERENCES IN MEAN GAIN SCORES FOR DEVELOPMENT OF COGNITIVE ABILITY GROUPS AMONG COORDINATE ABILITY GROUPS

Test and Group	No. of Test Items	Modified Curriculum Mean Gain	Unmodified Curriculum Mean Gain	Difference	Sig.
		Slow Learner Groups			
POST difference scores (post-test minus pre-test)					
Type A	9	.698	.862	.164	N.S.
Type C	31	1.765	1.899	.134	N.S.
CFE difference scores (post-test minus pre-test)					
Type A	20	1.197	.963	.234	N.S.
Type B	18	.462	.660	.198	N.S.
Type C	7	.042	.009	.033	N.S.
Type D	5	.067	.238	.171	N.S.
		Accelerated Groups			
POST difference scores (post-test minus pre-test)					
Type A	9	1.154	.784	.370	N.S.
Type C	31	3.615	3.627	.012	N.S.
CFE difference scores (post-test minus pre-test)					
Type A	20	3.942	3.980	.038	N.S.
Type B	18	2.577	3.509	.932	N.S.
Type C	7	.654	.686	.032	N.S.
Type D	5	.788	.568	.220	N.S.

type of cognitive ability according to categories identified by Klinckmann (13) as follows:

Type A—Recall of materials previously learned.
Type B—Application of knowledge to new situations.
Type C—Use of skills involved in understanding of scientific problems.
Type D—Ability to show relationships between bodies of knowledge.

The author, in cooperation with two other persons experienced in the teaching and

evaluation of BSCS materials, determined that the *POST* tests only Types A and C, while the *CFE* tests all four categories.

Information of Table 8 indicates that no significant differences in learning in any of the categories were found among the ability-curriculum groups. In interpreting these results, the low number of test items for each category should be kept in mind.

Inquiry 8. Did teachers and students consider the modified programs more satisfactory than the unmodified programs?

A questionnaire was submitted at the end of the year to all students for completion on a voluntary basis; responses were received from a representative sample of each ability level. Questionnaires were given also to all teachers, and answers were received from all. Although both the evaluation by students and teachers and the analysis by the investigator were subjective, the results suggested that slow-learner groups using modified materials were more interested in their work and experienced less difficulty than those using unmodified materials; average and accelerated students showed little difference in attitude toward the use of modified and unmodified materials.

SUMMARY

This study involved the development of modified high school biology curriculum materials for use with three ability-level groups in a metropolitan school system. The program included a special teacher-training program to aid teachers in using the materials. An evaluation of the program was made in which results were compared from a series of tests given to students in several teacher-class combinations where both modified and unmodified materials were used.

Within the framework of this study, evidence for the following conclusions was found: (1) on the basis of a series of tests the student grouping was considered valid; (2) significant learning occurred in all groups; learning in several groups, however, was influenced apparently by teacher-class interactions which may have been related to the nature of the tests; (3) results of tests indicated that modification of the materials for the different ability levels is justifiable; (4) on the basis of correlation analyses the test instruments were considered adequate; (5) differences in learning were not significant between students using modified materials and those using unmodified materials; (6) learning in biology was closely related to achievement in English among slow learners and average students, but not among superior students; (7) modification of the curriculum produced no demonstrable differences in development of different types of cognitive ability as measured by the particular test instruments; and (8) results from student and teacher questionnaires suggested that the modified curriculum was more satisfactory than the unmodified for slow learners but not for accelerated students.

A number of uncontrolled variables were present in the study, and these may have influenced the outcomes. On the other hand, the results imply that further study in this area may produce additional knowledge of considerable value. The relationships of specific curriculum materials and teaching procedures to different ability groups need much more investigation. Obviously, the development of new

materials, teaching techniques, and evaluation instruments are an important part of this need. Additionally, the parallel development of teacher training programs with all these factors in mind is a facet of the problem that deserves emphasis.

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XV. THE NATURE OF BIOLOGY TEACHERS' MANUALS AND AN ANALYSIS OF THEIR USE BY HIGH SCHOOL BIOLOGY TEACHERS

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Within recent years, a great effort has been directed toward providing biology and other science teachers with materials which reflect recent developments in science. References and resource books, textbooks and teachers' guides and commercial aids of various types are abundant and readily available to the teacher. In *The Process of Education* (1), Bruner noted that opinion is divided on how the teacher is to be aided and emphasized the importance of educating teachers to use all available teaching aids. He identified the teacher's task as one of communicator, model, and identification figure. He suggested that the teacher's task could be supported by a wise use of a variety of devices that could expand the teacher's experience, clarify it, and give it personal significance.

As more high school science materials are written, published, and used in the classroom, the need for evaluation of these materials correspondingly increases. In a survey conducted by Otto and Flournoy (2), needed research on the relative effectiveness of making use of such teaching aids in sources such as teachers' manuals and summaries, bibliographies, activities and visual materials as suggested by the authors of secondary school textbooks was emphasized. Published research in the area of using printed materials was judged to be the most incomplete and inadequate.

In the study reported here, the nature and use of teachers' manuals for high school biology textbooks were studied. The study was divided into three phases. The first phase consisted of an analysis of 16 textbook teachers' manuals published since 1950. The information collected from the analysis was used in the second phase of the study which involved the development and testing of an information-gathering instrument. The third phase of the study was the collection and analysis of information concerning teachers' reaction to and use of teachers' manuals from a large sample of high school biology teachers.

ANALYSIS OF THE NATURE OF SELECTED TEACHERS' MANUALS WRITTEN TO ACCOMPANY HIGH SCHOOL BIOLOGY TEXTBOOKS

According to Good's *Dictionary of Education* (3), a teacher's manual is defined as: "a guide containing teachers' aids, references, and related topics of interest in a given subject-matter field; usually arranged for use with a specific text." Therefore, it is not surprising to find that the stated purpose and organizational format of textbook teachers' manuals vary as widely as the colors in which the manuals are bound. It should be noted that it was beyond the scope of this study to discuss all of the various types of teachers' manuals or guides published every year. However, it was recognized that a wide range of diversity exists among the materials developed for the total high school biology program.

Requests were made of several publishing companies for copies of biology textbook teachers' manuals published since 1959. Eleven manuals published during this period and five written from 1950 to 1959 were included in the analysis. It was felt these older manuals would be of value as a basis of comparison of content with the more recent manuals.

The biology text book teachers' manuals analyzed were as follows:

1. Biological Sciences Curriculum Study. Teacher's Guide to Accompany *Biological Science: Molecules to Man* (Blue Version). Boston: Houghton Mifflin Co. 1963.
2. ————. Teacher's Manual for *High School Biology* (Green Version). Chicago: Rand McNally and Co. 1964.
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A diversity of purpose for the teachers' manuals was found. These included such stated purposes as: (1) providing materials for initiating the teachers own reorientation; (2) facilitating for the busy teacher the requisite understanding and use of new curriculum materials; (3) helping the teacher present textbook materials as a product of the process of science; (4) providing suggestions for the new and the ex-

perienced teacher; (5) providing useful information for the teacher who received training in some other field; and (6) explaining authors' viewpoints on important topics. All the teachers' manuals were found to have as an overall purpose, whether explicitly stated or not, helping the teacher do a better job in the classroom.

In addition to the stated purposes, estimated manual size, topics included in the manuals and the extent of topic coverage were examined. Thirty pages were selected to be counted using a table of random numbers. The total number of printed pages, the average number of words per sample page and the total number of words estimated to the nearest hundred were counted to give perspective to the relative size of each teacher's manual. Nine of the manuals published in 1959 or later were in the ten highest ranks in size.

Nineteen topics receiving recognition as section, subsection or heading were identified. These were as follows: (1) discussion of the manual and textbook; (2) chapter discussions and overviews; (3) discussion of concepts and objectives; (4) suggestions, outlines, lesson plans and notes; (5) vocabulary lists; (6) suggested films and filmstrips; (7) discussion of evaluation procedures; (8) answers to review and guide questions; (9) collection and preparation methods; (10) sources of materials; (11) directories of distributors of audio-visual aid materials; (12) lists of apparatus and equipment; (13) illustration and figure explanations; (14) key to tests; (15) experiment and problem suggestions; (16) answer key to the workbook; (17) lists of projects and activities; (18) suggested references; and (19) suggested time schedules. No manual was found to contain all 19 topics identified above.

For the extent of topic coverage, each page of the manuals was divided into quadrants. Then the pages were counted for each of the 19 topics. Trends based upon extent of topic coverage were identified. A de-emphasis of project suggestions, suggested time schedules, vocabulary lists, answer key to workbooks, key to tests and explanations of illustrations and figures seemed to be apparent in the manuals published since 1959. These manuals also reflected an increase in emphasis on the following topics: (1) directories and sources of supplies and visual aids; (2) suggested references and bibliographies; and (3) discussion of concepts, outcomes, overviews and general teaching suggestions. The major portion of both the older and more recent textbook teachers' manuals was the answer sections for review, discussion, end-of-chapter and unit questions.

THE DEVELOPMENT AND TESTING OF THE INFORMATION-GATHERING INSTRUMENT

The areas of study included in the instrument were as follows:

Part I—The description of the biology teacher sample;

Part II—The identification of the primary textbook and manual used last year and manual-related information;

Part III—Teacher opinion regarding the reasons for using the manual, the successful aspects of the manual, topic areas for future manuals, reasons for discounting use of the manual and reasons for never having used the manual;

Part IV—Extent of use of topics; and

Part V—The purposes for which the content was used.

Using the analysis of content previously described as a basic reference, the information-gathering instrument was developed by the investigator with the assistance of several members of the Science Education Center faculty, a psychometrician, former high school biology teachers and several other interested persons.

The mailing list of the National Association of Biology Teachers (NABT) was used to obtain the tenth-grade biology teacher sample in the study. The list was purchased at commercial rates and in no way implied NABT endorsement of the study and its findings.

A pilot study was conducted in October of 1966 using 250 randomly selected individuals from the mailing list. The test-retest method was used to determine the reliability of each item of the instrument. The instruments were coded to identify the respondent and the first and second returns.

One hundred and ninety-four first returns (77.6%) were received. Only 122 secondary level biology teachers were identified and subsequently contacted a second time. Of these, 93 second returns (76.2%) were received.

An item with less than 90% agreement between the first and second returns was examined for types of errors. On the basis of the above criterion, Part V was determined to be unreliable and was deleted from the instrument. Spacing problems were found in several of the items in Parts II and III; that is, items were located so close together on the check list that teachers checked one when clearly intending to check the item above or below. The decision was made to retain these items but to allow more space between the choices in order to decrease the frequency of error. The instrument designed for use in this study was considered by the investigator and the advisors who helped in the design of the instrument to have face validity.

ANALYSIS OF THE RESULTS

Six-thousand one-hundred and eight (6,108) individuals from the mailing list were contacted for the final phase of the study. Of the 3,147 members responding, 2,167 (69%) indicated their biology teaching responsibilities to be on the secondary level. However, only 1,359 (63%) were tenth-grade biology teachers. Generally, the tenth-grade biology teacher sample could be described as a group of teachers having at least five years of high school biology teaching experience and having within the past six years worked toward an advanced degree in some discipline. Of the 40 textbooks used, 90% were used for from one to three years. Eighty percent of the teachers had had a manual and 79% of the teachers had used all or portions of the manual during the previous year. Only 16% of the teachers surveyed had received some type of training in the use of a manual.

Seventy-one percent of the teachers who reported they did not use a teacher's manual did not have one available to them during the year under study. Of the 40 textbooks and manuals identified, six textbooks and manuals were used by 86% of the teachers surveyed (Table 1).

The five most frequently selected reasons given for using a manual were as follows:

(1) it gave suggestions for new approaches to the textbook;
(2) it gave insight into the author's views;
(3) it clarified the rationale of the chapters;
(4) it contained an adequate source of materials; and
(5) it provided materials for short quizzes.

TABLE 1

IDENTIFICATION OF THE SIX MOST FREQUENTLY SELECTED BIOLOGY TEXTBOOKS AND MANUALS

Textbooks	No. of Teachers	%
1. BSCS, *Biological Science: Molecules to Man* (Blue Version)	185	13.6
2. BSCS, *Inquiry Into Life* (Yellow Version)	313	23.0
3. BSCS, *High School Biology* (Green Version)	184	13.5
4. Otto, Towle and Moon *Modern Biology*, 1963	252	18.5
5. Otto and Towle *Modern Biology*, 1965	173	12.7
6. Otto, Towle and Moon *Modern Biology*, 1960	68	5.0

The four most frequently selected "successful" manual categories were as follows:
(1) worthwhile suggestions which enabled teachers to do a better job of teaching;
(2) aids in reorienting the teacher to the "new" approaches to high school biology;
(3) helps in planning effective laboratory sessions; and
(4) pointers on possible reasons for "unsuccessful" laboratory results.

The portion of the manual identified as the least successful was that intended to help teachers to overcome deficiencies in their backgrounds. Two types of material recommended for future manuals were correlated textbook and laboratory time schedules and coordinated manual and laboratory exercises. Two comments on discontinuing the use of the manual were that teachers had "adequate time to plan their own course" and that they had "only discontinued using some sections of the manual."

To assess the frequency with which the 19 manual topics were used, the teachers were asked to classify the topics into one of four categories—used regularly, used occasionally, never used or not included.

The five most frequently selected topics that were used regularly were:

1. discussion of chapter and unit concepts and objectives;
2. laboratory exercise suggestions;

3. chapter discussions and overviews;
4. collection, outline, and preparation methods;
5. answers to review and guide questions.

The five most frequently selected topics in the occasionally used category were as follows:

1. lists of additional references;
2. chapter discussions and overviews;
3. suggested films and filmstrips;
4. answers to review and guide questions;
5. discussion of chapter and unit concepts and objectives.

The five most frequently selected topics identified as never used were as follows:

1. directory of distributors of audio-visual aids;
2. directory of distributors of materials and equipment;
3. suggested film and filmstrips;
4. suggested time schedules;
5. lists of additional references.

The five topics most frequently selected as not being included in the manuals used last year were as follows:

1. vocabulary lists;
2. key to tests;
3. evaluation suggestions;
4. diagrams, charts, graphs, tables, etc.;
5. key to laboratory workbook.

In addition, the results were related to the six most frequently selected textbooks and manuals. These findings closely paralleled those of the general survey.

DISCUSSION

The results of this study not only indicate that the tenth-grade biology teachers participating were using up-to-date biology textbooks and manuals but also indicate that the manuals were enabling them to do a better job of teaching.

Areas of the teachers' manuals relating to the laboratory such as time schedules, problems, suggestions and textbook-correlated exercises were those in which the teachers desired more assistance. Within recent years, laboratory work has been growing in importance as an integral and active portion of the high school biology course. If the teacher has not received adequate laboratory training during his undergraduate education in biology, methods courses or student teaching, the teacher's manual could be of assistance in the most effective use of the laboratory. The findings of the study seemed to indicate that some tenth-grade biology teachers desire a more integrated biology course wherein the laboratory exercises are not independent of and not unrelated to the textbook materials.

Science educators have a responsibility to provide science teachers with curriculum materials that may hold promise for the improvement of science education at all levels of instruction. The methods course commonly offered to prospective teachers can provide information and experience regarding new curriculum programs. The findings of this study revealed that only one percent of all the teachers

surveyed had received such training in the use of a biology textbook teacher's manual.

In conclusion, it appears that the up-to-date textbook teachers' manuals are meeting many of the needs of the teachers included in this study. Although many new teaching materials, including teachers' manuals, have been developed in recent years and are apparently being used with varying degrees of success, reliable evaluation of the effectiveness of the new programs is still scanty. This kind of evaluation is beyond the scope of this study; however, the results reported here do provide some suggestions about the nature and possible use of the teachers' manuals, suggestions which, it is hoped, will be useful to current and future curriculum makers.

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2. Otto, Henry J. and Flournoy, Frances. "Printed Materials." *Review of Educational Research,* Vol. 26, No. 2 (April, 1965), pp. 115–124.
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XVI. ADDITIONAL STUDIES INVOLVING NEW HIGH SCHOOL BIOLOGY PROGRAMS

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The demand and need for evaluation of the "new" curriculum programs in science education has been recognized from the time the various projects began. However, relatively little effective evaluation aside from teacher feedback has taken place, with the exception of testing programs organized by the respective curriculum developers themselves. Reports of the evaluation of the Biological Sciences Curriculum Study materials, as conducted through their own extensive evaluation and testing programs, have been included in BSCS *Newsletters* (Published by the Biological Sciences Curriculum Study. The University of Colorado, Boulder, Colorado).

A comprehensive review of the organization, operation, and results of the BSCS evaluation program is beyond the scope of this paper. On the other hand, this monograph on the research and development relating to the new high school biology program would be incomplete without some reference to the nature and source of reports concerning BSCS's own evaluation of its program.

BSCS recognized early that development and evaluation should proceed hand-in-hand and made plans for extensive field tryout of the curriculum materials produced. The initial tryouts were done in 15 testing centers with six to nine teachers in each center and in 13 independent test schools during 1960–61. One hundred eighteen high school teachers and approximately 14,000 high school students were involved in the program at that time. One of the teachers in each center was selected as a center leader to be responsible for the general operation of the program. In addition, a college biologist in the local area was appointed to serve as a consultant for the center. Plans for evaluation of feedback from the centers were announced in BSCS *Newsletter* #5 (1) as follows:

> Systematic feedback on the experience of the Testing Center teachers and students will be obtained in several ways:
> Two members of the BSCS staff . . . will work on feedback information, and will visit each Testing Center from time to time to talk with teachers, school administrators, students, and the Center consultant.
> Participating teachers in each Testing Center will have weekly meetings to discuss their experiences with the BSCS materials; the Center Leader will send reports on these meetings to BSCS headquarters.

A third type of feedback will be obtained by administering tests to students who are taking the course, to determine to what extent the program's stated aims are being achieved. It will be necessary to construct new tests, since existing standardized biology tests are not suited to the new materials.

Based to a considerable extent on the results of feedback analysis, the BSCS textbooks and accompanying laboratory manuals were revised during the summer of 1961 and a similar, but somewhat more extensive tryout, testing and feedback evaluation program was organized for the 1961–62 school year. During this period approximately 500 teachers and 50,000 students were involved. Committees of college and high school biology teachers were set up to develop achievement tests and the entire testing program was carried out with the aid of professional testing services. Using the results of this program, the materials were again revised in 1962 and published commercially in 1963.

To aid the scholar who may want to study the detailed results of these BSCS programs, the following BSCS *Newsletter* reports are cited:

(a) BSCS *Newsletter* #6, September 1960.
(b) BSCS *Newsletter* #10, November 1961.
  (1) Ferris, Frederick L., "Report on the 1960–61 BSCS Testing Program." Pp. 3–7.
  (2) Klinckmann, Evelyn, "Preparation of Test Items and Tests for BSCS Biology." Pp. 8–11.
(c) BSCS *Newsletter* #19, September 1963.
  (1) Grobman, Hulda, "The Rationale and Framework of the BSCS Evaluation Program." Pp. 6–16.
  (2) Klinckmann, Evelyn, "The BSCS Grid for Test Analysis." Pp. 17–21.
  (3) Wallace, Wimburn, "The BSCS 1961–62 Evaluation Program—A Statistical Report." Pp. 22–24.
  (4) Grobman, Hulda, "Some Comments on the Evaluation Program Findings and Their Implications." Pp. 25–29.
(d) BSCS *Newsletter* #24, January 1965.
  (1) Grobman, Hulda, "BSCS Second Course: Background of the 1961–64 Evaluation." Pp. 3–12.
  (2) Wallace, Wimburn, "The 1963–64 Second Course Evaluation—A Statistical Report." Pp. 13–14.
  (3) Grobman, Hulda, "Comments on the Second Course Evaluation." P. 15.
  (4) Grobman, Hulda, "BSCS Special Materials Program: Background of the 1963–64 Evaluation." Pp. 16–24.
  (5) Wallace, Wimburn, "The 1963–64 Special Materials Evaluation—A Statistical Report." Pp. 33–35.
  (6) Grobman, Hulda, "Some Comments on the SM Evaluation." Pp. 36–38.
(e) BSCS *Newsletter* #30, January 1967.
  (1) Mayer, William V., "Evaluation for Curriculum Assessment and Improvement." P. 1.
  (2) Hastings, J. Thomas, "A Note on Evaluation." P. 2.
  (3) "A Report of the Biological Sciences Curriculum Study End-of-the-Year

Evaluation Program, 1964–1965." The Psychological Corporation, New York. Pp. 3–7.

Some additional articles are published in BSCS *Newsletter* #30, but these will be reported on in more detail later in this chapter.

Hulda Grobman (2) in an article listing topics in the teaching of BSCS biology that needed to be researched suggested in 1965 that "while these BSCS research efforts will continue, it is recognized by the BSCS Evaluation Committee that it is neither desirable nor possible for the BSCS itself to attempt all the investigative work related to BSCS projects and their use in the schools." The author presented a list of 119 questions concerning the BSCS Textbook Versions, Laboratory Blocks, Second Course, Special Materials, Pamphlets, Teacher Preparation, Research Problems in Biology, Single Concept Films, External Exams, and General Problems. She emphasized that in designing experiments to answer these questions, consideration should be given to the aims and objectives of any testing instruments used and their relationship to the hypotheses being tested.

Although BSCS has carried out its own evaluation program in a comprehensive manner, it is also apparent that BSCS materials have been used as the basis for a number of additional research and development studies. These add a new dimension to evaluation of the BSCS program. The preceding chapters in this monograph report examples of this kind of independent research. As previously indicated, however, these reports have been carried out by graduate students and faculty in the Science Education Center at one institution—The University of Texas at Ausitn. Abstracts of some additional studies, some as yet unpublished, are presented in this chapter. Some of them have been criticized, with varying degrees of justification, as having inadequate or faulty research designs and/or implementation. All of them have been included in this report, however, in order to show the range of research being done and to indicate areas that may need further study. None of these studies were done under the auspices of or with the financial support of BSCS. Abstracts preceded by an asterisk have been previously published in an article by Lehman (3) and are included here with the permission of the author and BSCS. Also, some additional articles have been abstracted and included. The abstracts selected follow.

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* Cain, Ralph W. and Eugene C. Lee. "An Analysis of the Relationship Between Science and Mathematics at the Secondary School Level," *School Science and Mathematics.* 43:705–713 (December, 1963).

A comparative analysis was made of the mathematical concepts in the "new" science programs (BSCS Yellow Version, CBA, CHEMS, and PSSC) and "traditional" science programs. Also, an analysis was made of selected mathematics programs for their content and sequence in order to determine the correlation existing between the mathematics programs and the mathematical content of the "new" science programs.

Specific conclusions involving the BSCS program showed there is a marked increase in the use of mathematics in tenth-grade biology from the "traditional" to the BSCS Yellow Version, and in general the coordination of "new" mathematics

programs with the mathematical content of "new" science courses is higher than for "traditional" programs.

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* Lisonbee, Lorenzo and Bill J. Fullerton. "The Comparative Effect of BSCS and Traditional Biology on Student Achievement," *School Science and Mathematics.* 44:594–598 (October, 1964).

By random sampling, an experimental group of 120 students using the BSCS Blue Version and a control group of 132 students using a "traditional" approach were selected from 3,500 tenth-grade biology students in the Phoenix Union High Schools.

With scores on the *California Test of Mental Maturity* and the *Iowa Test of Educational Development No. 6* held constant, the results of statistical analyses supported the following conclusions:

1. The BSCS and "traditional" groups did not differ significantly on the *Nelson Biology Test,* a measure of factual knowledge of biology.

2. There was a significant difference between the middle- and high-ability BSCS subgroups and the middle- and high-ability "traditional" subgroups on the BSCS *Comprehensive Final,* with the BSCS subgroups excelling.

3. The BSCS middle-ability subgroup showed a significantly greater adjusted mean on the BSCS *Comprehensive Final* than the "traditional" middle-ability subgroup, the only place in the study where a significant difference appeared between corresponding ability levels.

4. No significant differences in achievement appeared among schools on the *Nelson Biology Test,* but did on the BSCS *Comprehensive Final.*

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* Lance, Mary Louise. "A Comparison of Gains in Achievement Made by Students of BSCS High School Biology and Students of a Conventional Course in Biology" (unpublished Ed.D. dissertation. University of Georgia, 1964).

The study compared gains in scores of students using the BSCS Green Version with scores of students using "conventional" materials in three Athens, Georgia, high schools. The instruments used were the *Nelson Biology Test* and the *What Do You Think?* test of Victor Noll.

Results showed no significant difference between the achievement gains of the BSCS and "traditional" groups on either test, both of which were non-BSCS in their objectives. For both the BSCS and "traditional" groups, boys out-performed girls, ninth graders out-performed tenth graders, and the students in one school out-performed those in the other two schools.

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* Gennaro, Eugene D. "A Comparative Study of Two Methods of Teaching High School Biology: The BSCS Yellow Version and Laboratory Blocks with Collateral Reading" (unpublished Ph.D. dissertation, University of Wisconsin, 1964).

Gennaro compared classes using the BSCS Yellow Version textbook and Laboratory Guide with other classes using three Laboratory Blocks plus assigned read-

ings from the BSCS Yellow Version textbook. He concluded that inserting three Laboratory Blocks into the Yellow Version course of study did not seem to affect the level of ability in scientific reasoning as measured by scores on the BSCS *Impact Test* and scientific reasoning questions taken from the Laboratory Block tests.

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* George, Kenneth D. "The Effect of BSCS and Conventional Biology on Critical Thinking," *Journal of Research in Science Teaching.* 3:293–299 (1965).

Through analyses of variance and co-variance, the relative effectiveness of the three BSCS Versions and "conventional" biology upon the critical thinking ability of high school students was determined. The instruments employed were the *Watson-Glaser Critical Thinking Appraisal, Revised Form Zm,* and the *Otis Quick-Scoring Mental Ability Tests, Gamma Test, Form Fm.*

Results showed: (1) no significant differences between achievement in critical thinking of students of the Green and Yellow BSCS Versions and "conventional" biology; (2) students of the Blue Version scored significantly higher than students of "conventional" biology; (3) students of the Blue Version also achieved significantly more than students of the Yellow Version; and (4) the Yellow Version students achieved more than the Green Version students. However, there was only one teacher using the Blue Version in this study, and from two to four different teachers for each of the other programs. Thus, teacher background, philosophy, and ability were uncontrolled variables which may have influenced student achievement to an unknown extent.

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* Moore, C. Olan. "An Evaluation of the Effectiveness of the BSCS Approach to Teaching Biology to High Ability Students in the Ninth Grade" (unpublished Ed.D. dissertation, Arizona State University, 1965).

A superior teacher with special BSCS training selected from each of the three large high schools of Scottsdale, Arizona, taught the BSCS approach to one class of high-ability ninth-grade students and taught a "conventional" course to four other classes of high-ability ninth graders. The *Nelson Biology Test*, the BSCS *Comprehensive Final*, and two instruments designed by the author to measure science-related interests were used to make a comparison of achievement.

Results indicated a significant difference in achievement gains on the BSCS *Comprehensive Final*, showing the superiority of teaching results by the BSCS approach. Also, the BSCS students' mastery of "conventional" course content was practically equal to that of the non-BSCS students as measured by the *Nelson Test* (a "conventional," non-BSCS oriented test). In all subgroups in all tests the boys out-scored the girls and no significant change of interest in science occurred in any group.

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* Sorenson, LaVar L. "Change in Critical Thinking Between Students in Laboratory-Centered and Lecture-Demonstration-Centered Patterns of Instruction in High School

Biology." (Unpublished study involving the Salt Lake Schools, 1965. This paper was a summary of part of a doctoral study at Oregon State University.)

Sorenson compared classes which were "Lecture-Demonstration-Centered" with classes which were "Laboratory-Centered" and using a Laboratory Block. He found that those using the Laboratory Block showed: (a) greater gain in critical thinking ability, (b) a greater gain in understanding science, and (c) greater decrease in dogmatism, becoming more open-minded than the "Lecture-Centered" group. Instruments used in this study included the *Otis Quick-Scoring Mental Ability Test*, the *Cornell Test of Critical Thinking*, the *Watson-Glazer Thinking Appraisal*, the *Dogmatism Scale*, and the *Test on Understanding Science*.

• Stanko, Dianne E. "A Study to Determine the Continued Use of the Laboratory Blocks in the BSCS Laboratory Block Program" (unpublished M.Ed. thesis, The University of Texas 1965).

A significant part of this study was focused on reasons why use of Blocks was discontinued by individual teachers. The study involved 147 teachers, 119 of whom were involved in the BSCS testing program, and 28 of whom had training for the program in an NSF Institute. Data were obtained and analyzed from questionnaires returned by these teachers.

The following conclusions appear to be warranted from the study:

1. Approximately one-fourth of both the BSCS-trained and the institute-trained teachers responding were currently teaching a Laboratory Block.
2. All of the BSCS-trained teachers responding had taught a Laboratory Block at some time. Approximately two-fifths of the responding institute-trained teachers had taught a Laboratory Block.
3. Slightly more than one-half of the teachers responding had used at least some portion of a Laboratory Block without teaching a Block in its entirety.
4. Class size, inadequate funds, and inadequate length of laboratory periods seem to have been the major administrative obstacles identified by teachers as reasons for discontinuing the program. Inadequate preparation time was also identified as a prominent reason for not teaching Laboratory Blocks.
5. About 20% of the reasons offered by teachers for no longer teaching a Laboratory Block were attributed to teachers' lack of commitment to the value of the program in relation to reduction in time from regular course procedures.
6. One-third of the BSCS-trained teachers were of the opinion that Laboratory Blocks are suitable for the ablest 75% of students in first-year biology; two-thirds of the teachers thought they are suitable for the upper 50% of students. One-third of the teachers felt that they are suitable only for the ablest one-quarter of first-year biology students or for second-year biology students.
7. One-third of the BSCS-trained teachers had taught a Laboratory Block at the ninth-grade level. More than one-half of them had taught a Block to tenth-grade students, and more than half of them had taught a Block in an advanced biology course.

Although this study was limited in a number of ways—small sample size, lack of verification of reasons for some teachers who discontinued use of Blocks, no analy-

sis of programs teachers may have used in lieu of Blocks, and the small number of different Blocks available for the period studied—the study was useful in a number of ways. It indicated that the Laboratory Block program had already made a considerable impact in 1964 and had the potential for an even greater impact.

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* Turner, George Cleveland, "An Analysis of Scientific Enquiry as Used in a BSCS Laboratory Program" (unpublished Ed.D. dissertation, Arizona State University, 1965).

The purpose of this study was to develop a clear picture of what the BSCS means when referring to "scientific enquiry," to determine the extent to which the basic exercises in a BSCS laboratory manual reflect the elements of "scientific enquiry" identified in the investigation, and to determine the design of the enquiry-oriented BSCS laboratory. A checklist of the "Elements of Scientific Enquiry" was developed and used to determine the extent to which each element was present in the basic exercises from one of the BSCS laboratory manuals, but no measure was made of the validity of this checklist.

The analysis of these exercises revealed that all of the elements of "scientific enquiry" as described were touched upon. However, 39% of the components of these elements (a total of 78 descriptive statements were identified as "components") were not found in any of the exercises.

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* Hurd, Paul DeHart and Mary Budd Rowe. "A Study of Small Group Dynamics and Productivity in the BSCS Laboratory Block Program," *Journal of Research in Science Teaching*. 4:67–73 (1966).

This investigation sought to evaluate the proposition: if the compatibility of one group, *a*, is greater than that of another group, *b*, then the goal achievement of *a* will exceed that of *b*. Compatibility for a group was defined mathematically on the basis of scores on the control scale of the *Fundamental Interpersonal Relations Orientations-Behavior* instrument of Schutz. Results suggested that for non-college-bound groups using a given Laboratory Block the proposition should be reversed, for the goal achievement of incompatible groups using a Block tended to exceed that of compatible groups. Evidence for college-bound groups was not conclusive, but the trend of the data tended to support the proposition. Goal achievement was positively correlated with predicted compatibility.

There is reason to think that certain of the BSCS Laboratory Blocks place more stress on the group structure than do others. This happens by virtue of the kinds of tasks to be accomplished, the complexity of the sequencing of tasks necessary to accomplish the experiments, and the amount of time over which data must be accumulated. Hurd and Rowe suggest that Laboratory Blocks vary in the pressure they place on groups and that the incidence of overly stressed groups will be found to rise as a function of Block complexity.

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* Parakh, Jal S. "A Study of Teacher-Pupil Interaction in High School Biology Classes."

(Unpublished paper presented at the National Association for Research in Science Teaching, Chicago, February 19, 1966, Session E. The paper was a summary of part of a doctoral study completed at Cornell University.)

Although this study did not attempt to evaluate directly any aspects of the BSCS program, several classes of students taking the BSCS Green Version were involved. Classes of ten high school biology teachers from seven secondary public schools in central New York State were studied and the biology courses taught by the teachers in the sample were: New York Regents biology—seven teachers, BSCS Green Version—two teachers, and New York State Experimental Course using the BSCS Green Version materials—one teacher.

There were two major objectives of the study: (1) to develop a reliable category system for first-hand systematic observation of the teacher-pupil interaction in high school biology classes, and (2) to classify, describe, and analyze the teacher-pupil interaction in high school biology classes.

Results were put in a composite or average teacher form, and although they were not analyzed as such, differences were found among classes for practically every category of behavior in this 14-category system. Some of the findings reported were: (1) the most conspicuous feature of the observed biology classes was the preponderance of teacher talk; (2) teachers' pedagogically relevant non-verbal behavior accounted for about 8% of total time in lectures and 37% in labs; and (3) pupil talk, addressed to the teacher, accounted for 15% of total time in lectures and 13% in labs.

Yager, Robert E. "Teacher Effects Upon the Outcomes of Science Instruction." *Journal of Research in Science Teaching*. 4:236–241 (1966).

This paper reports on a study of the teacher as a factor affecting some of the specific outcomes of instruction. Eight teachers from the University of Iowa Laboratory School, wtih similar backgrounds, were selected as subjects of the study. These teachers were teaching biology to eighth-grade students using BSCS Blue Version, *Biological Science: Molecules to Man* and accompanying laboratory manual. Instruments used to measure outcomes of instruction in the study were: (1) the *Nelson Biology Test* as a measure of basic information and concepts learned in the course, (2) the *Watson-Glaser Critical Thinking Appraisal* as an indication of student growth in critical thinking skills, (3) Cooley's and Klopfer's *Test on Understanding Science* as a measure of how well the students understand the nature of scientists and the scientific enterprise, (4) the *Silance Scale for Measuring Attitude Toward Any School Subject* as a means of comparing student attitudes toward biology, and (5) a specially prepared questionnaire to rate the individual teacher's ability to make the study of biology meaningful. Descriptions of the teacher were made by the principal, the assistant principal, and the department head.

Results of the study indicate that the individual teacher affects the degree of content achievement, growth of specific skills in science such as critical thinking, and the student's attitude toward a given course. In addition, teachers demonstrate differential abilities to cause students to understand the nature of the scientific enterprise and the scientists engaged in the enterprise and have varied abilities to

make a course interesting to the students. A teacher may be strong in any one of these areas while being weak in others.

Yager, Robert and John W. Wick. "Three Emphases on Teaching Biology—A Statistical Comparison of Results." *Journal of Research in Science Teaching.* 4:16–20 (1966).

This study was undertaken at the University of Iowa Laboratory School, 1962–1963, to determine if it is possible to affect a student's understanding of science and his ability to do critical thinking by altering the emphasis of the teacher in the classroom. Three sections of randomly selected eighth-grade students, with three teachers alternating among them to reduce teacher variability, received instruction with three degrees of emphasis. The BSCS Blue Version, *Biological Science: Molecules to Man* with its accompanying laboratory manual was used as the basic textbook. The instruments used were the *Test of Understanding Science,* the *Watson-Glaser Critical Thinking Appraisal,* and the *Nelson Biology Test.*

Results showed that teacher emphasis is an important factor in influencing critical thinking and an understanding of science in students, as measured by the above instruments. Teacher emphasis did not significantly influence the mastery of the major concepts and facts of biology.

Gallagher, James J. "Teacher Variation in Concept Presentation in BSCS Curriculum Program," BSCS *Newsletter* #30, January (1967).

Gallagher states:

> The classroom, with its complex social structure and kaleidoscope of cognitive and phycho-sociological variables, has not often been the object of serious research. Content area specialists have concentrated on the sequential organization of materials and have left the direct application of these materials, either to the intuitive strategies of the teacher or, at best, to the imitation of a master teacher.

The author recognized the large-scale evaluation program of BSCS high school biology but noted that "the very nature of comparing hundreds of classes and thousands of students tends to obscure factors internal to the classroom that are potentially related to achievement." He indicated further that:

> In many respects, the major curriculum movements have operated on an assumption, often unstated, that the key variable of *student outcome* was rather exclusively a function of curriculum organization. This exuded a degree of confidence in curriculum organization that would not be held by those who have studied student outcome variables under other circumstances. Instead, student outcome or achievement is likely a function of curriculum organization, student ability, teacher content knowledge, teacher strategy in presentation of ideas, the student's past knowledge of the subject, motivation, etc.

The Gallagher investigation was designed to help define further the teaching process, through direct observation and analysis, as shown in a series of BSCS biology classes for superior students.

The author attempted to control as many variables in the teaching situation as possible so that the personal style of teaching would be the major variable to influence the teacher-class performance. The subjects were six biology teachers recognized as competent, and their classes of high-ability students who were studying the BSCS Blue Version Program with its text, *Biological Science: Molecules to Man.* Arrangements were made to tape a record of each of the classes in their discussion sections for three consecutive days while their teacher was introducing the subject of *photosynthesis.*

Detailed analyses made of the recorded class discussions were based on a three-dimensional classification system (Aschner, Gallagher, *et. al.*) (4) designed to indicate the level of conceptualization, the style of thinking and the emphasis of the instructor on skills or content. Figure 1, from Gallagher's paper, page 10, is a schematic picture of this system.

The results of the study were analyzed in terms of teacher behavior and student performance. Analyses were made of skills and content in relation to levels of conceptualization and generalization; in terms of concepts discussed; student-teacher talk; expressive *vs.* non-expressive students; BSCS test results; and sex differences.

Gallagher concluded that "there really is no such thing as a BSCS Curriculum presentation in the schools." Instead, he suggested that there is a Teacher A interpretation of the BSCS Curriculum, a Teacher B interpretation, etc. Obviously, he noted considerable variation among the six teachers involved in the study with respect to any of the variables studied.

It should be important, not only to curriculum makers, but to *all* those responsible for pre-service teacher training, to note the conclusion that:

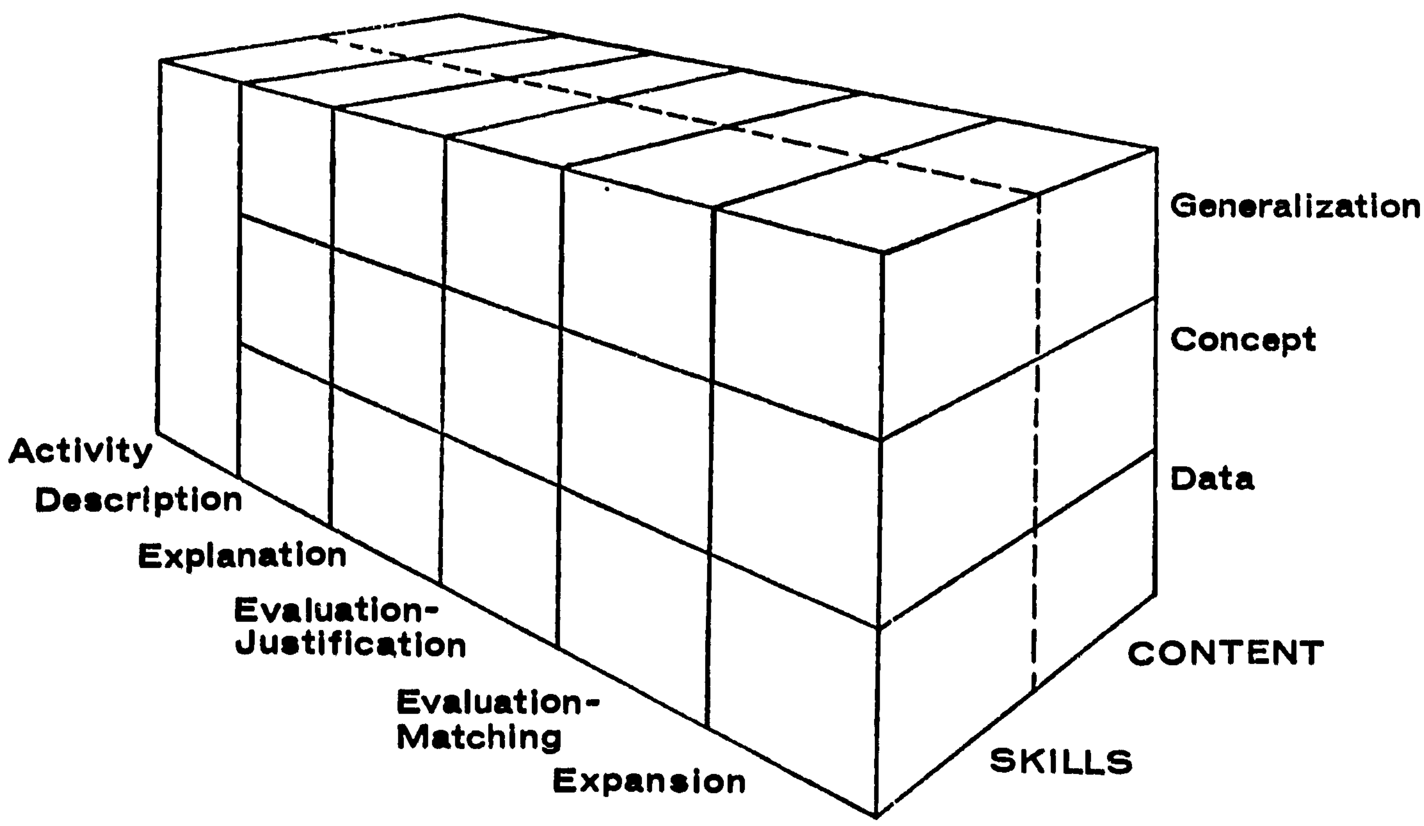
> . . . Several of the present groups showed little in their discussion sections that resembled a substantial interchange of intellectual ideas between student and teacher and, in some, the emphasis on inquiry or searching was not carried from the laboratory to the discussion period. To obtain the goal of a vibrant discussion period most teachers must be taught the cognitive skills of how precisely to conduct a class discussion, or how to stimulate innovative approaches on the part of the student. Such teaching of instructional strategies has to be as explicit as the subject area teaching if one wishes the teachers to have similar competencies.

As one quantitative example relating to this characteristics, it can be noted that the percentage of teacher talk by topic classification varied among the six teachers from 66 to 95. It is also important to note that:

> In this study there was no question but that those students who were constant participants in class discussion were superior students to those who did not participate. They were not merely talking to hear themselves talk. They did reveal that they had an informational fund and the thinking ability to hold meaningful interchanges with the instructor. At the same time there was a substantial number of students in every class who were mute, or nearly so, in the three days of discussion.

Gallagher suggests a number of areas for future research and points out that analysis of records of teacher and student performance as illustrated in this study opens a wide vista of opportunities for intensive study of instructional strategies and their immediate effect on students.

Figure 1
Topic Classification Dimensions—Classroom Interaction Analysis



Rozolis, James T. "A Comparison of Traditional High School Biology Courses and the Biological Sciences Curriculum Study Program of Courses." *BioScience*. 17–5 (1967): pp. 315–23.

This abstract and the three following are of a series of four articles that report an evaluation of high school and university biology instruction in a single metropolitan area during the period 1960–1966. Rozolis set the stage for the series in his first article:

> Two distinct transformations have occurred within the biological sciences during the interval between 1960 and 1966, both of which still concern the professors of the University of California of Los Angeles and the teachers and administrators of the school systems surrounding the University. One of these transformations was the adoption of the Biological Sciences Curriculum Study by the secondary schools in the school districts near UCLA. The other modification was the creation of interdisciplinary courses and a new Core-Studies Program for undergraduate majors in zoology, botany, and bacteriology at UCLA.

He then posed two questions: "What effect have these two programs had upon the biology courses of the secondary school and the introductory biology course at the University relative to changes in content, discipline emphasis, and method of

instruction?" and "What type of interaction, if any, has occurred between the high schools and the University relative to these new biology courses?"

Rozolis analyzed the content of text and laboratory materials in the secondary school and university biology courses to determine the extent to which emphasis had been placed on (a) the subject matter (direct reference to the body of knowledge within the discipline), (b) the learner (direct reference to the problems of man as an individual), and (c) the society (direct reference to the problems of man as a group). He classified the methods of instruction as (a) text deductive, (b) laboratory inductive, and (c) workbook application.

The study involved seven secondary school districts and the several biological sciences departments at UCLA. Rozolis conducted interviews with 33 high school teachers of biology, 27 secondary school principals, 22 administrators or supervisors at the school district level, 12 university professors, and seven university professors in administrative positions.

The secondary school biology textbooks analyzed for the study included the 1951 edition of the biology textbook (*Modern Biology*) by Moon, Mann, and Otto and the 1960 revision by Moon, Otto and Towle; these were classified as traditional. Biological Sciences Curriculum Study materials included (a) Blue Version, (b) Green Version, (c) Yellow Version, (d) Second Course, and (e) Special Materials.

The author report suggests that, in general, the BSCS materials have a greater emphasis on subject matter and less emphasis on the learner and society than do the traditional courses. At the same time the text-deductive method of instruction was used less and the laboratory-inductive method more for most of the BSCS materials when compared to the traditional materials.

Rozolis also reports extensively on interviews with the teachers and administrators in his study concerning opinions as to the advantages and disadvantages of the various materials. These reports, while extensive, are difficult to evaluate because of the small sample of educators interviewed, the relatively large number of materials studied, and the author's method of numerical summary of opinions; the latter are given in such terms as "5% of the teachers – – – –" or "7% of the administrators – – –" etc., whereas the percentages given relate not to the number of persons responding but to the total number of replies received to all questions.

In general this study indicates that among the schools involved there was a preference for the BSCS materials, and among them for the Yellow Version. Reasons given were that its conventional design, content, and laboratory methods were those that present-day teachers are most familiar with.

Rozolis, James T. "An Evaluation of the Biological Sciences Curriculum Study Program from the Professional Viewpoint and Implications for the University." *BioScience*, 17–7 (1967): pp. 452–460.

In this second article of the series in which Rozolis reports his evaluation of high school and university biology instruction from 1960–66, the author discusses in detail the advantages and disadvantages of the BSCS program compared to a traditional program.

Among the advantages of the BSCS program cited were: (a) its laboratory in-

vestigations—investigative, not descriptive in nature—emphasizing methods, not details; (b) texts based on conceptual understandings, not on details or memorization of details; (c) the inductive and analytical approach, as opposed to a deductive and descriptive approach; (d) encouragement of the introduction of new ideas; (e) materials prepared by teams of experts who are recognized authorities; (f) laboratory lessons that carry over to real life situations; (g) texts better organized and more logical than anything else available; (h) program more challenging and exciting than the traditional one; and (i) program forces teachers to better prepare themselves.

A summary of the disadvantages of the BSCS program cited by teachers and administrators would include such aspects as the amount of time and technical knowledge required by both teachers and students for preparation and execution of laboratory activities, including maintenance of living organisms; the great demands made on students in terms of reading level and knowledge of other science areas and mathematics; the highly critical role of the teacher, requiring special training in materials, methods, and testing procedures, in contrast to the training and accustomed practices of available personnel; and the opinion that the BSCS program is primarily designed for college-preparatory students.

Many other advantages and disadvantages were reported and it is likely that many of them, including the samples reported in this abstract, will evoke arguments among the proponents and opponents of the BSCS program. Further discussion of them is beyond the scope of this abstract. However, it may be noted that Rozolis said ". . . . those interviewed still believe the advantages of the BSCS Curriculum far outweigh any disadvantages."

The relationship of the university and the BSCS program was also considered in this study. A number of teachers and administrators at the high school level indicated that preparation for university work was not considered in their selection of the BSCS materials. Others indicated that the university was the dominant factor, among many, in the selection. All agreed that the BSCS Curriculum had implications for the university, particularly the nature of the university biology courses.

Rozolis, James T. "A Comparison of the Traditional University Introductory Courses in Zoology and the Newer University Introductory Courses in Biology." *BioScience*, 17–9 (1967), pp. 618–629.

This article reports the analysis and comparison of the content, discipline emphasis, and method of instruction in the traditional university introductory courses in zoology and the newer ones in biology. The courses involved were those offered at University of California at Los Angeles during the period of this study. Advantages and disadvantages were reported from interviews as indicated in the two previous articles.

Rozolis concludes that:

> It would appear that the newer courses [at UCLA] are slightly more subject-matter oriented and less learner-oriented, with no appreciable change being noted in their emphasis upon the society. Also, there appears to be no appreciable difference in the method of instruction.

However, with respect to the discipline emphasis, the newer courses definitely stress biology as a whole and are more directed toward botany and bacteriology, with much less orientation toward zoology....

Rozolis, James T. "An Evaluation of the Newer University Biology Core Curriculum from the Professional Viewpoint and Implications for Secondary Schools." *Bioscience*, 17–10, (1967), pp. 703–707.

This article describes the biology core curriculum as developed at UCLA. Reference is made, however, to the influence of the Commission on Undergraduate Education in the Biological Sciences (CUEBS) in its sponsorship of regional conferences and other activities designed to promote the development of biology core programs.

Advantages and disadvantages of the core program at UCLA as determined by interviews were discussed; however, the reciprocal influences of this program and the BSCS adoptions in the Los Angeles area are perhaps more pertinent to the purposes of the abstracts in this chapter. It was quite clear that the BSCS program was not considered by most of the faculty in the development of the University introductory biology course. It was noted, in fact, that none of the professors involved in the development of the UCLA course had been involved in BSCS or in the work of CUEBS. It was concluded that the only relationship that exists between the BSCS program and the UCLA introductory biology course is that each was "a product of the same causal factors, although each was a separate product and evolved at two different levels of academic instruction."

On the other hand, a number of different responses were given when the professors were asked if the new University courses held implications for high schools. Some suggested the high schools would be forced to improve their methods of instruction. Others indicated the need for the high schools to offer four years of mathematics. Some of the professors mentioned that the high schools should improve their offerings in chemistry and physics. A number expressed the view that the high school biology course should stress unifying principles, not a profusion of data. Other items mentioned were: (a) the importance of knowledge of a foreign language; (b) need for improvement in the education and training of high school teachers; (c) need for enrichment of the high school biology program for college-bound students; and (d) need for re-evaluation of the high school guidance program and for biology teachers as advisers for future biologists. All the professors recommended more effective communication among university and high school teachers.

Behringer, Marjorie. "Use of BSCS Laboratory Blocks with College Introductory Biology." *BioScience*, 17–10 (1967), pp. 708–712.

During the fall semester, 1966, an adapted version of the BSCS *The Molecular Basis of Metabolism* Laboratory Block, developed by Peter Albersheim, John Dowling, and Johns Hopkins III, was used at the University of North Dakota with 269 beginning biology students. The block was modified for use with an intro-

ductory biology course for nonscience majors, and for use in an audio-tutorial laboratory.

Upon completion of the six weeks' program a student achievement test was administered and a questionnaire was given the students which asked their opinion concerning (1) the degree of ease in gaining an understanding of the purpose, procedure, and results of each investigation; and (2) the degree of personal interest a student had in each investigation.

On the basis of results of the achievement test assumed to be valid and reliable and on the assumption that student achievement can be interpreted according to the system used with the BSCS Evaluation Program, it was concluded that the achievement of the students was only slightly above average even though the college students were considered better prepared to study the Laboratory Block than most tenth-grade high school students. A second conclusion was that the *Metabolism* Laboratory Block, with minor revision, is below the potential achievement of these students. This conclusion was viewed in light of the responses collected with the student questionnaire. They indicated that a majority of students considered the investigations relatively difficult, and that understanding was accomplished only with a considerable amount of study.

The author suggests that the BSCS Laboratory Blocks appear to offer "an untapped resource for the development of more effective laboratory programs for college introductory biology courses."

Gibbs, Ronald K. "An Analysis of the Effectiveness of the Biological Sciences Curriculum Study Single Topic Films in Teaching Hypotheses Construction to High School Students." (Unpublished Ed.D. dissertation, The University of Indiana, 1967).

The purpose of this study was to determine the effectiveness of the BSCS film loops in improving the ability of high school biology students to construct relevant hypotheses. The instruction consisted of presenting the students in the experimental group with a series of five different BSCS film loops following methods prescribed by a Teacher's Guide for each film. The control group did not see the five BSCS films. Two additional BSCS films were used as pre-test and post-test instruments for both control and experimental groups. Using BSCS philosophy and rationale and the help of a group of teacher evaluators, the investigator developed a hypotheses-construction examination for each of the films used. This examination was used as a basis for scoring student ability to construct suitable hypotheses for use with each of the films.

Findings of the study revealed that the ability of high school biology students to construct relevant hypotheses was significantly improved in the classes using the series of five BSCS Single Topic Films when compared to students not using this series. Basic intelligence and interpretation of readings in the natural sciences, as well as a "background in the natural and social sciences, and literature, correctness of expression, quantitative expression, and general vocabulary were determined to be important factors in the ability to construct relevant hypotheses concerning the film topics."

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