Analysis of Research IN THE Teaching of Science

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Contents

Foreword and Acknowledgments

BEGINNING IN 1950 the National Association for Research in Science Teaching and the U. S. Office of Education collaborated in preparing an annual summary of research in the teaching of science. The present bulletin, summarizing and analyzing research done from July 1955 to July 1956, continues their cooperative effort.

Throughout the years since 1950 the publication resulting from this joint effort has received favorable comment and has become an established document in the research literature of general education as well as science education. It is hoped that the organization of the present bulletin—around the three traditional school levels of elementary, secondary, and college education—will enhance its usefulness.

On the three levels, the committees were made up as shown below:

Elementary.—Lillian Hethershaw Darnell (Chairman), Drake University; Charles K. Arey, University of Alabama; J. Myron Atkin, University of Illinois; Clyde Brown, Southern Illinois University; Charles E. Burleson, San Francisco State College; Robert H. Cooper, Ball State Teachers College; Julian Greenlee, Florida State University; Willard Jacobson, Columbia University; Jacqueline Buck Mallinson, Western Michigan College; Ida Beth Schultz, State Teachers College (Lock Haven, Pa.); Hanor A. Webb, George Peabody College for Teachers.

Secondary.—George T. Davis (Chairman), University of Maine; Hubert F. Evans (Vice Chairman), Columbia University; Stanley B. Brown, University of California; Paul DeH. Hurd, Stanford University; Greta Oppe, Galveston (Tex.) Public Schools; Samuel Schenberg, New York City Public Schools.

College.—Edward Weaver (Chairman), Atlanta University; Mervin Oakes (Vice Chairman), Queens College of the City of New York; Robert A. Bullington, Northern Illinois University; Guybert P. Cahoon, The Ohio State University; Donald G. Decker, Colorado State College of Education; H. Clark Hubler, Wheelock College; John C. Mayfield, University of Chicago; Abraham Raskin, Hunter College of the City of New York; George B. Salmons, Plymouth Teachers College; M. C. Shawver, Madison College.

J. DAN HULL, *Director,*
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ANALYSIS OF RESEARCH IN THE TEACHING OF SCIENCE

Introduction

THIS ANALYSIS of research in the teaching of science contains reports of published studies resulting from a meticulous search of the pamphlet and periodical literature in the field between July 1955 and July 1956. It also contains reports of unpublished studies coming from the returns to an inquiry sheet mailed annually by the U. S. Office of Education to more than 1,200 institutions where graduate work in science teaching is in progress.

The studies reported here have been carefully evaluated and selected through applying a set of criteria formulated by the National Association for Research in Science Teaching. The work was carried on by three committees, one for each school level: elementary, secondary, and college. Thus, about 40 persons have participated in and contributed to this undertaking.

The report has the merit which derives from a cooperative project in which a large number of people participate. It also reflects the limitations of such a venture inasmuch as it permits a rather wide latitude for exercising individual judgments. The committee chairmen in submitting this report are fully aware of all the weaknesses and limitations inherent in the procedures used.

The three committees reviewed all the issues between July 1955 and July 1956 of about 50 monthly magazines which, from time to time, carried research in science teaching. The work was limited by the fact that, in both the published and the unpublished studies the committees, for the most part, were working with secondary sources, such as abstracts and articles, and not with the original documents. The chairmen of the three committees and the general chairman accept full responsibility for errors of categorizing and of interpretation in applying the criteria. Studies eliminated in the evaluation process may have been poorly represented by the abstract or by the article reviewed.

In the preparation of this report the research for the past decade has also been reviewed in an attempt to discern any trends or patterns. Although some studies of this period have landmark significance, unfortunately the number is small.

At this time now, when science and technology are playing a very important part in our life and culture, much of the research in science education lacks a broad and comprehensive plan. A considerable amount is unpatterned, makes but a fragmentary contribution to the basic concerns, and tends to deal with peripheral fringes of the major problems. Nevertheless, there is some evidence of progress towards a more patterned research program.

Downing, and later Curtis, employed a team approach to identification of the basic science principles. Curtis also used this procedure in his research on science vocabularies. Powers, over a number of years, made significant contributions to science teaching in the area of basic science concepts and their social implications. Pieper, and later Barnard, have used a basic team attack on problem solving. Mallinson has also used a plan of patterned team research in the study of the New York Regents Examinations in Science. Perhaps this procedure offers some promise for the future as a technique to be applied in an attack on broad and basic problems of science teaching.

Section I. An Examination of the Research in Science Teaching

RESEARCH FINDINGS are basic to the improvement of teaching in all areas of the school curriculum. The need for research in science teaching is particularly great at this time of so much concern over its special problems and of so many programs improve one or more of its segments.

This section of the present bulletin summarizes and analyzes the research in science teaching reported for July 1955–July 1956 on the three traditional levels of education—elementary, secondary, and college. Each study discussed is lettered and numbered in parentheses. The letter indicates the particular subsection in Section III (Bibliographies) of the bulletin where the study itself is identified, listed alphabetically by author, and numbered. For example "(E 5)" refers to item 5 in the bibliography for the elementary level. In the same way "(S 4)" and "(C 8)" refer to items 4 and 8 in the bibliographies for the secondary and college levels, respectively.

Elementary School Level

Nineteen studies at the elementary school level are included in this bulletin, a slight increase over the number included in the last previous survey. Of these 19, 7 are related to the curriculum, 9 to learning, and 3 to teacher training.

Studies Related to the Curriculum

Some research has been done to determine at what age or grade certain scientific principles should be presented to children and at what age or grade the highest level of understanding takes place.

A study in this area has been completed by Lowheed (E 7). He determined the modal age level, for grades 4 and 6, of the difficulty of the science principle, *"The more rapid the vibrations of the sound-*

ing body, the higher is the pitch of the sound it produces." Twelve classes in 7 schools, comprising 379 students from Grades 4 and 6, were used in this study. A pre-test was given on the principle. Half the students from each grade made up an experimental group and were taught the principle by means of a lecture-demonstration about 20 minutes in length. Both control and experimental groups were re-tested by 30 objective questions. The results were analyzed to determine the amount of learning at the 2 grade levels.

Major results were the following: (1) Students in the experimental groups of both grades made marked gains in learning after experiencing the demonstrations, as compared with students in the control groups, who made slight gains. (2) The principle (as demonstrated and tested) is too difficult for the 4th-grade level, which showed 17-percent mastery. (3) The principle might be learned by the 6th-grade level, which showed 48-percent mastery—but no safe prediction could be made since this is below 50-percent mastery.

Further sampling should be taken at grades 5 and 7, or 6 and 8.

Murray (E 11) studied "the principles of physical and biological sciences found in five textbooks of geography for grade 8." He set out to find the scientific principles mentioned in the average 8th-grade text and to see what areas of correlation exist between science and geography. Leonelli's list of 186 science principles was checked against selected geography texts. Thirty-eight principles appeared in each of the books. The conclusion reached was that there are enough principles common to both geography and science at the 8th-grade level to constitute a core upon which to build workable and efficient units covering both geography and science.

Schultz (E 16) used an area of environment for subject-matter learnings to help the child understand his relation to his environment, "a way of developing children's understanding of ecology." The problem consisted of finding ways to help children and teachers develop greater awareness and appreciation of the dynamics of ecology and to demonstrate that ecological principles are inherent in the democratic process and the nature of the learning process.

A study of a water-hyacinth community was developed with children in a second grade and a sixth grade. Suggested ways of working with children for the development of ecological concepts were used together with resource materials to guide their study of a water-hyacinth community.

No conclusions were sought or expected, but way was left open for testing the process and material. The study indicates how to develop worthwhile subject matter in such a way as to promote growing understanding of man's relation to his environment and also a growing understanding of interdependence and interaction of physical and biotic components of the universe that can have both esthetic and practical survival value.

Suitable and appropriate science content in both text and reference books to serve the needs of children in the elementary schools is one of the essentials for a satisfactory science curriculum.

Knight (E 6) made a study of supplementary science books, "a selected annotated science bibliography of elementary reading for grades 1, 2, and 3." A comprehensive survey of educational literature pertaining to teaching science in the primary grades gave information as to the broad areas of science from which suitable topics were selected, and also criteria for the selection of supplementary science books. Annotations were prepared for 190 books (science readers) selected on a basis of timeliness, scientific significance, style, illustrations, and typography. Most of the books were published after 1950.

This bibliography should help primary teachers select supplementary readers and also help librarians select their books.

Eriksen (E 4) made a study in the area of conservation, "a study of conservation activities in the outdoor education programs in California." The objective was to provide a broad picture of the conservation activities incorporated in programs of outdoor education in California. Some of the findings indicated that: (1) In most programs including conservation, the activities tended to be too remote from children's immediate experiences. (2) "Camper surveys of resources and needs of camp site should receive greater attention and become basic for planning specific projects." (3) Activities can be developed with an ecological and therefore a conservation approach.

Smith's (E 17) comparative study "of the nature programs in Agency girl's camps" was an investigation of the nature programs and the philosophies behind them in certain summer camps for girls. It was apparent that the directors definitely desired to make nature lore the core of their respective programs. Weaknesses and strengths in various programs were identified and recommendations were made to camp directors concerning certain items for consideration in program improvement. There is a need for improved leadership and improved nature programs in the Agency camps in this area of California.

Vincent's (E 19) study "of the science program and its improvement in the white elementary schools of Colquitt County, Georgia" was an attempt to determine present practices and ways of improvement during the school year 1955–56. Characteristics of a good elementary science program were determined from a review of current research and literature. Criteria for analysis were established.

The study of actual programs indicated a need for better application of present knowledge of child development and the learning process. Recommendations concerned equipment, better use of the immediate environment, more direct experiences and less dependence on textbooks, increase and improvement of inservice teacher education, and more attention to the physical sciences. Although the definitions and findings are neither new nor surprising, they constitute a useful summary of current thought on the subject.

Studies Related to Learning

One of the more important educational problems today, as well as in the past, is concerned with the conditions under which optimum learning takes place for each pupil and with different aids to learning. Most science educators agree that science textbooks are important factors in the learning process. Mallinson, Sturm, and Mallinson (E 9) conducted a study to determine "the reading difficulty of the unit-type textbooks for elementary science." The problem was to analyze a sampling of the unit-type textbooks in order to determine their levels of reading difficulty. The method employed was to request, from the publishers of unit-type textbooks, a sampling of the publications they believed to be among the best in their listings for use at fourth-, fifth- and sixth-grade levels and then to apply the Flesch [1] formula in determining the levels of reading difficulty of textbooks received.

The findings and conclusions were: (1) If teachers have found elementary science textbooks generally too difficult, they are not likely to find the unit-type textbook much better if they use them at grade levels suggested by the publishers. (2) The textbooks may be used, insofar as reading difficulty is concerned, at higher grade levels. (3) It is easier to shift pamphlet-type materials to suit reading abilities than it is to shift conventional textbooks. (4) Unit-type textbooks are less likely to show integration than are the conventional-type.

Atkins' (E 1) study concerns "an analysis of the development of elementary school children in certain selected aspects of problem-solving ability."

[1] Flesch, Rudolph. The Art of Plain Talk. New York: Harper & Bros., 1946., p. 197.

Tape recordings were taken at three grade levels: 1, 3, and 6. The children expressed hypotheses of their own after a science-learning experience. Responses were grouped into categories, and statistical tests were applied.

The important findings were: (1) Children in the lower grades rely more on their own experiences in formulating hypotheses. (2) Those in the upper elementary grades depend more on authority. (3) Children in the lower grades suggest more tests for their hypotheses than do children in the upper grades. (4) Children in "permissive" classrooms tend to suggest more hypotheses than children in less "permissive" classrooms.

Rimoldi (E 14) carried out a study to "find a technique for the study of problem solving." A testing technique was developed to analyze the process of thinking rather than its end product. The experimental tests concerned medical students and were administered to medical students. The examinee was requested to solve a certain problem by asking questions which he judged would give him information necessary to solve the problem. Questions which examinees might wish to ask were written on cards. Answers to the questions were on the back of the cards. Other questions, not pertinent to the problem, were also included. The cards were placed in slots on a board and thus presented to the examinee in a way which permitted him to scan the questions.

The examinees were instructed to select questions which seemed to lead most directly to a solution of the problem. The test was over when the examinee reached a solution or did not wish to ask more questions.

When scored, the test revealed the following significant findings: (1) What is the most acceptable sequence of questions? (2) Is the number of questions asked by the examinee a suitable criterion for judging his skill in problem solving? (3) Does the least number of questions always represent the most direct route or the best route to the solution?

The implication for science educators is that with increased emphasis on the teaching of problem solving, this technique could be adapted to evaluation of pupil progress in problem-solving ability in science at any level.

Martin (E 10) carried on an experiment to discover the relation of "community resources and the use of the tape recorder." The problem was to find ways to bring resources into the classrooms when it is impossible to take field trips or get speakers. Information was secured by teacher-pupil interview and teacher-pupil followup.

The following conclusions were drawn from the experiment: The tape recorder is a satisfactory and successful teaching aid for the elementary grades, affording opportunity for pupil-teacher planning and for a great deal of pupil participation. Useful as a tool to familiarize the pupil with his environment, it helps to promote good public relations between school and community.

The study gives a detailed description of a method for teaching the value of community resources.

Another study to find improved methods of teaching science in the elementary school was carried out by Stefaniak (E 18) "in a study of the effectiveness of two methods of teaching science in grades 4, 5, and 6." This was an attempt to determine whether teachers taught by the lecture-demonstration method did a more effective job of teaching than those teachers exposed to individual laboratory method.

The investigator established experimental and control groups (in-service teachers, grades 4, 5, and 6) and centered instruction around a selected list of 40 principles of science.

Pupils of each group were pretested and posttested to determine gains or losses in interest, attitudes, and science subject matter.

Results seem to favor the teaching of those instructed by the individual laboratory method, but the differences do not seem marked. The study revealed that pupils scored higher on the attitudes posttest than the attitudes pretest although no specific effort was made to teach for attitudes.

Butcher's (E 2) study concerns "an experimental comparison of the unit and traditional methods of teaching science in the 6th grade."

The purpose of the study was to determine whether children taught by the unit method attain greater achievement in language, social studies, and general study skills than those taught by the traditional method.

Two comparable groups selected from 42 children were established. The children were tested in September to establish bases for determining growth. Tests used at this time and again in May were the Stanford Achievement, the California Science, the Otis Quick Scoring Mental Ability Tests, and tests constructed by the teachers.

The findings were as follows: (1) Children taught by the unit method made more gain in each area than those taught by the traditional method. (2) The unit method in science results in a more thorough knowledge of the basic facts, in a greater improvement in all areas of the curriculum, and it is superior to the traditional method in the development of study habits.

In Ross' (E 15) study, "science for the retarded," objectives and philosophies of education for retarded children were set up using science as a medium. The conclusions based on observations and interviews with other teachers were the following: (1) In many respects education for retarded children is based on the same philosophy and has the same objectives as education for normal children. (2) The same basic laws of learning hold. (3) Science experiences help them to be better prepared for life. (4) Science has vocational and avocational implications. (5) The children's present understandings are points of departure for new learning experiences.

Onstead's (E 13) study "science for the retarded children in elementary schools" was an attempt to find effective ways to teach science to the mentally retarded. Selected research and other materials were analyzed and evaluated. Resource units were organized in which science material was adapted to the requirements of the mentally retarded. These included units on animals, plants, solar system and stars, surface of the earth, air and weather, forms of energy, and machines. Some of the conclusions reached were: (1) Experiences should help these children develop habits of more careful observation. (2) Experiences should be made objective by using concrete materials. (3) Activities should be related to everyday experiences of the children.

O'Day's (E 12) study concerned integrating 5th-grade science and certain club activities. It was an attempt to find out whether there could be integration of the work of a club (nature of club unspecified) with a workable science program in the 5th grade. Six units of work were developed based on the publications, *Adventures in Science With Jack and Jill*. The study shows that whenever teachers put their minds and efforts to making science meaningful to children, benefits such as desirable attitudes, increased science knowledge, more sustained interests, and positive integration may result.

Studies Related to Teacher Training

What type of college preparation do prospective teachers of elementary science need in order to teach science effectively in the elementary grades? Mallinson and Sturm (E 8) made a study to find the "science backgrounds and competencies of students preparing to teach in the elementary schools."

The purposes of the investigation were: (1) To determine the background and knowledge of the subject matter of science possessed by elementary student teachers who were completing their training in the schools where the investigators were employed. (2) To determine their attitudes and opinions concerning certain aspects of their preparation for teaching science. (3) To compare subject-matter competence in science with that of certain groups of high school pupils.

The following methods and techniques were used: (1) a questionnaire to determine (a) extent of training in science subject matter that elementary student teachers possess, (b) attitudes of elementary student teachers toward the various fields of science, (c) attitudes toward survey science courses at the college level, (d) estimates of their own competence to teach elementary science; and (2) amount of science that they expect to introduce into teaching. (Data were collected on elementary student teachers from two schools—56 from school A and 91 from school B, compiled into 8 tables.)

The more pertinent findings were: (1) The knowledge of elementary student teachers, both as to scope and depth of subject-matter concepts required in teaching elementary science, is wholly inadequate. (2) Teachers preparing to teach elementary science need survey courses in college science to fill some of the gaps in their subject-matter preparation and to provide a better rounded program covering the physical as well as the biological sciences.

The following important recommendations grew out of this study: An extensive study should be made to determine desirable subject-matter preparation in science for students preparing to teach in the elementary schools. An effort should be made to provide students preparing to teach in the elementary school with both an adequate and a balanced program in college science, which will appeal to these students and also take care of the problem of scheduling an adequate program.

A large number of studies have been made to determine types of training teachers are receiving today. Chamberlain's (E 3) study of "the development and status of teacher education in the field of science for the elementary school" sets out to: (1) Determine trends in preservice teacher education in science for the elementary school; (2) find problems which teachers face in teaching science in the elementary school; and (3) determine implications of value to teachers, educators, and boards of education.

Two methods were used: Over 1,000 college catalogs were studied to determine trends in course offerings and questionnaires were sent to teachers having extensive preparation in elementary school science.

Among the significant findings were the following:

1. Of 765 colleges training elementary teachers, 442 list courses in elementary science and more public than private institutions offer these

courses. In the group offering elementary science, the mean number of required semester hours of all science is 9.21. Only 80 colleges require laboratory work in the science courses.

2. Agencies that influence elementary science offerings are education department faculties, State departments of education, and science department faculties. Although a few of the institutions have been offering science courses since 1928, the rate of increase was most sharp just before and just after World War II.
3. An increase in semester hours of academic and professionalized science courses is desirable and also desirable is development of specialists in elementary school science.
4. Higher certification requirements are desirable in elementary school science.
5. About half the colleges polled are offering some of the following services and plan to continue or improve them: Summer school courses for inservice training, consultant services, extension courses, demonstration teaching, and workshops.
6. Teachers show an increasing desire for workshops, supervisory and consultant service, extension courses, and access to science education publications.
7. Teachers continue to face problems of time, space, equipment, and library resources. They feel that the usual class of 30 to 35 is too large for individual and small-group activities.
8. If teachers are adequately prepared in science, their problems related to actual teaching become fewer.

Some of the implications and recommendations from the study are the following:

1. A clearly defined trend is apparent to include more academic and professionalized science courses in the preservice training of elementary school teachers and there is a growing demand for inservice training.
2. If more science is to be taught in the elementary schools and if teachers are to receive more training, individuals and agencies responsible for making policy and financing programs should take more positive action than they are now taking.
3. Studies should be made of the present professionalized science courses for elementary teachers to determine what these courses include and how effective they are.
4. Academic science courses should be examined critically and reoriented to make them more meaningful to future elementary teachers as well as to other nonscience majors.
5. Local school systems should expand their own inservice programs.
6. Colleges are not adequately staffed to supply the growing demand for elementary school teachers better prepared in science.

In summarizing, the value of this study is that it offers definite statistical support to impressions and opinions now held by many science educators. Despite deficiencies of space, time, materials, equipment, teacher know-how, and administrative support, the agencies able to provide leadership in science education are becoming more aware of the problems and are making some progress in dealing with them.

The purpose of Goehring's (E 5) study, "the status of science instruction in the one-teacher rural schools in certain selected counties in Minnesota," was to determine the present (1953–55) status of science instruction in the one-teacher schools through questionnaires and visitations.

Among the findings were the following: (1) Thirty-three percent of the teachers had taken a course in elementary science methods. (2) About 50 percent had earned science credits during the preceding 5 years. (3) Most teachers devoted two class meetings a week for science, using a basal text series. (4) An incidental approach, usually based on the seasons, was used in about 20 percent of the primary grade classes. (5) Science achievement in classes whose teachers had taken an elementary science methods course was higher in every grade tested than in classes whose teachers were not so trained.

Secondary School Level

Twenty-two studies at the secondary school level were selected for this survey. Four of these are related to teaching procedures, 2 to the curriculum, 3 to careers in science, 5 to teacher training, and 6 to offerings and enrollments. Two are classified as miscellaneous.

Studies Related to Teaching Procedures

In one of the few experimental studies reported in the period under review, Boeck (S 2) investigated the "relative efficiency of three methods in instruction for developing understandings in 9th-grade general science." Specifically, his study compared the achievements of general science pupils: (1) who only read and discussed prepared materials; (2) who did no reading but were given demonstrations with discussion over the same material; and (3) who were taught by a combination of these methods. Instruction dealt with mirrors and mirror images over 4 class periods; 2 periods were devoted to testing (but did not include the retests given at a later time). Eight teachers representing 16 science classes were involved in the study; all were located in the public schools of St. Paul, Minn.

Six tests were used: (1) A 50-item, multiple-choice, achievement test; (2) a 32-item, nonverbal, performance test; (3) a 20-item attitude scale relating to the conduct and social climate of the class; (4) the Otis Self-Administering Test of Mental Ability (for intelligence scores); (5) the Stanford Achievement Test (for reading scores); and (6) the Iowa Every Pupil Test of Educational Development (for reading scores). The intelligence scores and reading scores were used for control purposes.

After analyzing the data by using a number of statistical procedures, Boeck found that: (1) Performance on the achievement tests (retests included) was nearly the same for each group. (2) The reading method of instruction was rated low by students. (3) Teachers exerted greater influence over achievement than did methods of instruction. (4) Students retained information equally well under the three methods of instruction.

Kahn (S. 9) sought to determine the effect of "a selected procedure for teaching the scientific attitudes to 7th- and 8th-grade boys through the use of current events in science." Using matched groups, he and a colleague taught general science to 7th- and 8th-grade boys for 6 months. During this time the experimental group was given directed instruction in scientific attitudes by a special technique using current events in science. Initial tests, final tests, and the followup tests of scientific attitudes were given to both the experimental and the control groups.

The investigator found that the experimental group scored significantly higher than the group which had received no special training. The gains of the superior group were retained almost undiminished throughout more than 4 months, during which time neither group received training in the scientific attitudes. Students of below normal reading ability showed as large and as significant gains as those of higher reading ability.

As a device to "aid in teaching elements of scientific method," Skocpol (S 19) wrote a script for an instructional sound film. The script was then evaluated by 10 experienced teachers and by the author using Keeslar's[1] criteria as standards. He concluded that an instructional sound film could make significant contributions to an understanding of scientific methods and that the capabilities of motion pictures could be sufficiently utilized to justify the use of this medium in teaching the methods of science.

[1] Keeslar, Oren. Contributions of Instructional Films to the Teaching of High School Science, I. *Science Education*, 30: 82–85, March 1946.

Often neglected in science teaching is the identification of assumptions made while carrying out experimental exercises. In a study dealing with 9th-grade general science Obourn (S 15) investigated the "role of assumptions in 9th-grade general science" essential to acceptance of conclusions to be reached in a selected group of experimental exercises, and also the ways in which a selected group of teachers make provision for these assumptions in their teaching procedures.

Forty-five experimental exercises derived from textbooks, workbooks, and laboratory manuals for 9th-grade general science were analyzed by the investigator and a jury of three for the purpose of identifying the assumptions in each exercise basic to the acceptance of the conclusions. The results of this analysis were then screened by an elaborate complex of juries which judged whether the assumptions in the experimental exercises were *essential* or *unessential* to the acceptance of the conclusions. Jurors were also asked to add assumptions not included in the original list. Counting such additions, 412 assumptions were identified with the 45 experimental exercises. After careful checks on the reliability of the ratings by the jurors, indices of agreement were made for each of the 412 assumptions.

An analysis of both original and added assumptions was made on the basis of those which were factual and those which contained an element of reasonable doubt. These data indicated that among the personnel associated with this study there seemed to be a greater sensitivity toward the factual assumptions than toward the nonfactual.

Evidence as to ways in which teachers provide for assumptions while dealing with experimental exercises was gathered by classroom observations in 11 cooperating centers. Following the observations, anecdotal reports were written; 100 of these were obtained.

Sixty-three percent of the experimental exercises observed were identical with the 45 exercises selected for analysis. A total of 138 assumptions were identified in the observed exercises. This study revealed that, for the most part, experimental exercises in 9th-grade general science are presented by the teacher-demonstration method. The teachers seemed to have adequate manipulative techniques but very inadequate experimental techniques.

Among Obourn's conclusions are the following:

1. Current experimental exercises in 9th-grade general science are generally inadequate in identifying and evaluating assumptions essential to acceptance of conclusions.
2. Juries composed of selected 9th-grade general science teachers were less critical when evaluating the essentiality of assumptions basic to acceptance of the conclusions and associated with experimental exercises selected for this investigation than were juries composed of authorities in the field of science education.

8. Ninth-grade general science teachers observed in this investigation were not sensitive to assumptions and showed little awareness of the role of assumptions in acceptance of conclusions.

The author concluded his report with nine recommendations for improvement of classroom-problem solving, particularly that aspect of it which relates to identifying and evaluating assumptions.

Studies Related to the Curriculum

Relatively few studies have been made dealing with the natural sciences in core programs. Although the content of science in general education has been extensively explored, the task of relating this subject matter to other nonscience core subjects has largely been neglected by science educators.

A study of Mikhail (S 11) of the "contributions of science to selected problem areas proposed for a program of general education in the secondary school" indicates that science can have a major place in core programs. His purpose was to suggest the science subject matter, skills, attitudes, appreciations, and interests which might be "built in" to one common design for core programs—the "problem area" design.

Sixteen problem areas (Self-Understanding, Family Living, Critical Thinking, etc.) were utilized. First, each of these was analyzed to determine possible student activities, then the contributions of science were considered in the light of these activities. All science contributions were evaluated for their adequacy as science instruction and as potential general education content.

The author found that science could make significant contributions to 13 problem areas. All contributions were classified under the following eight categories: Health and Safety, Atomic Energy, Conservation, Human Growth and Development, Critical Thinking, Values and Beliefs, Communication, and Hobbies.

An entirely different type of study related to program improvement was reported by Toon (S 22). He studied "the relative importance of factors found in high school chemistry courses as indicated by former students." By means of a checklist and questionnaire, he undertook to determine what factors in a high school chemistry course were considered important by ex-high school chemistry students who later enrolled in first-year college chemistry. He also sought information on the general effectiveness of present high school chemistry courses in meeting student needs and interests. The check-list and questionnaire were submitted to all the second-semester chemistry students enrolled in first-year chemistry at the University of California, Los Angeles.

He found that the students rated the following groups of items as most important for prestudy in the high school preparatory course:

1. Understanding basic chemical principles and concepts and the calculations based on them.
2. Skill with such mathematical operations as powers of ten, decimals, ratios, and use of the slide rule.
3. Skill with such language facilities as reading for speed and comprehension, outlining, finding salient points in a paragraph, and writing and expressing thoughts effectively.

The students gave a low rating to such course content as appreciation of chemistry, history of chemistry, industrial processes, and organic chemistry. They further indicated that high school chemistry made too little allowance for individual differences and that they preferred a logical, systematic presentation.

Studies Related to Careers in Science

The search for, or nurture of, talented students in science engaged the attention of several investigators. Finkel (S 5) reported "a study of the factors affecting the high school student's choice regarding a science career." He was particularly interested in identifying those factors which dissuade students from entering a field of science. He sent questionnaires to secondary schools of various sizes in the State of Colorado and over the Nation.

The 21 schools which returned the questionnaire reflected the thinking of 21 principals, 65 science teachers, 24 guidance counselors, and 594 senior students. Some of these last respondents were interested in science, but many were not. For purposes of comparison the author sent the same questionnaire to freshmen at the University of Denver. Fifty-six of these completed the form. Some of the data for this study were obtained by interviews with school officials.

Four sections of the report deal with specific attitudes and competencies of high school principals, guidance counselors, science teachers, and students in relation to science courses. All these respondents appeared to agree that the primary reasons why students did not take more science while in high school were: (1) Science was too difficult and involved too much mathematics. (2) The elementary school science course had been poor and uninteresting. (3) The school offered so many important and desirable courses in competition that students did not select science.

A much broader investigation having some purposes in common with the Finkel study was conducted by Stice, Torgerson, and Mollenkopf (S 21). They made "a national study of high school students and their plans." This team gathered information on adolescent motivation for college, interest in science, financial plans, and parental backgrounds. Using a 5-percent sample of the public high schools of the United States, they administered a 30-minute questionnaire and a 15-minute test of academic aptitude to 32,750 12th-grade students. In addition, the principals of these students were asked to supply background information on the schools and communities represented in the sample.

The findings in this study are based upon the questionnaire responses of 9,689 seniors. All these students scored high in the ability test and, as a group, represented approximately the top 30 percent of the entire sample.

Among the findings were the following:

1. Approximately 14 percent of the group said they had no interest in or desire to go to college, and approximately 6 percent said they had a strong interest in college but saw no way of ever being able to go.
2. Almost half indicated that expenses would be an important reason why they might not get to college.
3. Fifteen percent of the boys and 28 percent of the girls whose fathers' education had been limited to elementary school had no interest in college.
4. Although 65 percent of the boys whose fathers were in the medical profession intended to go to college without delay, only 28 percent of those whose fathers were in semiskilled occupations intended to do so; and only 38 percent of those whose fathers were farmers planned to go to college immediately. Among the girls the variation was even greater.
5. The lower the score on the ability test, the greater was the percentage expressing no motivation for college.
6. The proportion of students planning to go to college increased as the size of the school increased, with the exception of very large schools having enrollments over 1,500.
7. Approximately 25 percent of the boys said they would like to become engineers, 8 percent wanted to enter medicine, and 6 percent wanted to be physical scientists.

Taking all findings into account, the investigators concluded: (1) A striking amount of economic and cultural determinism exists in connection with going to college. (2) There is a pressing need for more scholarships to reduce the loss to higher education of high-ability students. (3) Higher education is losing up to one-half of

the top 30 percent of the Nation's high school seniors. (4) I
finances and lack of interest have about equal weight in caus
loss.

Neivert (S 12) reported a study to investigate the problems
"identification of students with science potential" and to det
what factors were responsible for their selecting science as a
The research consisted of four major components: (1) Sel
training, and following the careers of several groups of potent
ence students through high school and into colleges. (2) Admi
ing the Test of Science Reasoning and Understanding of the (
Entrance Examination Board, with an accompanying Intere
Career Choice Questionnaire, to several hundred science stud
New York City and evaluating the data. (3) Reviewing the
Science Talent Search competition. (4) Determining the cha
istics of superior science teachers mainly by a questionnaire
the sponsors of Science Talent Search winners.

Some of the major conclusions of this study were the followi

1. Three factors necessary for high science potential, and for dete ultimately whether or not a student who possesses it will cho ence as a career, are high intelligence, opportunities for devel and personal attributes.
2. Outstanding performance in science requires that the student I. Q. of 135 or above and reading and arithmetic scores of 12t or better in the 9th year.
3. Opportunities for development include a home conducive to stu a school with an enriched science program, marked by oppor for individual research, good equipment, and superior teach
4. The personal attributes needed by the potential science stud into three categories—interests, individuality, and an intrinsic His individuality includes his personality traits, mental trai work habits. An intrinsic factor which accounts in part student's strivings and inclinations is an element in committing various areas of pure and applied science. A student's inte science is sufficiently variable, however, that it cannot be use for predicting success in this field.
5. The science teacher is the single most important factor in the environment conducive to development of potential science st
6. The superior teacher who influences students to pursue science identified both by his ability as a teacher and by his personal

Studies Related to Teacher Training

In a study limited to the State of Illinois but transcending po
boundaries in significance, Nelson (S 13) investigated "what ad

trators want in the training of science teachers and the actual training of beginning science teachers." He studied the competencies desirable or necessary for the science teacher in his first years of work. The inquiry was directed at two groups of schoolmen, administrators and beginning science teachers.

A total of 205 administrators throughout the State, in schools of various sizes, completed and returned a questionnaire dealing with science teacher competencies. The competencies were placed under one or another of seven headings in the questionnaire: (1) Classroom Techniques, (2) Professional Responsibilities, (3) Application of Science to General Education, (4) Understanding Boys and Girls, (5) Other Aspects of Professional Training, (6) Training in the Subject Matter of Science, and (7) Student Teaching.

Respondents were requested to indicate whether each listed competency (in all categories except the sixth) should be considered as (1) minimal in the teacher-training program, (2) important and included in the training program, if possible, and (3) not important in the training program. Additional competencies could be suggested. The sixth category (Training in the Subject Matter of Science) presented five patterns of possible subject-matter preparation. Respondents were asked to rank these patterns in order of preference.

The findings of most interest, perhaps, are the administrators' preferences regarding the patterns of subject-matter training commonly found in the preparation of science teachers. An overwhelming majority wanted science teachers with sufficient training in several science fields so that they might teach more than one. The pattern favored by the greatest number included the above, and, in addition, intensive training in one science field.

In the second part of this study, 119 questionnaires completed by science teachers of 3 years' experience or less provided detailed information on their formal training, employment, and scope of responsibilities. In contrast to what most administrators in the sample population desired as to the preparation of science teachers, most science teachers in the sample population reported fragmentary and generally substandard preparation.

Brown (S 3) studied "the training background of Wisconsin high school chemistry teachers." By means of questionnaires he gathered information on the scientific backgrounds and actual program responsibilities of high school chemistry teachers. From 260 returns he was able to gain detailed information on teacher qualifications in chemistry for the State as a whole.

Some of the major results of this inquiry were the following:

1. The majority of chemistry teachers carry, as part of their teaching load, one or more subjects in addition to their major subject. Only 21 teachers taught chemistry alone.
2. Of the 261 respondents, 98 were required to teach chemistry and 2 other subject combinations; 18 were teaching in more than 3 subject fields. Only 107 taught science alone.
3. A tremendous range of scientific background exists among Wisconsin chemistry teachers.
4. Teachers in smaller schools carry the heaviest teaching loads and generally have the least scientific background.
5. Measured by Wisconsin standards, 29.3 percent of the respondents were unprepared to teach chemistry.

The training needs of science teachers in Georgia were analyzed by Ivey (S 8). His sources of information were the science teachers themselves. Specifically, he undertook to determine the areas in which high school science teachers feel that they should be competent or already are competent, and in which they feel they need further training. A questionnaire was prepared and sent to all science teachers in the State. The data were grouped in the following categories: Biological Sciences, Physical Sciences, Biological and Physical Sciences, and Professional Education Courses. Under each category teacher competencies were arranged in descending order according to frequency of mention by the respondents.

The findings in this study are presented in more detail than can be reported here. Only those competencies which occur in the upper fourth of each category and in which the respondents indicate a need for further study are given below:

1. Biological Sciences: aquatic biology, plant diseases, birds, weeds, embryology, microbiology, sex education, trees, plant breeding, genetics, and grasses.
2. Physical Sciences: television, radioactivity, astronomy, atomic physics, electronics, radio, general geology, plastics and rubber, modern developments and their applications in chemistry, and modern developments and their applications in physics and electricity.
3. Biological and Physical Sciences: plastics and rubber, drugs, narcotics, and home appliances.
4. Professional Education: making simple types of laboratory equipment, planning and carrying out projects for a science fair and research projects suitable for secondary science, planning the total science program, directing students in individual projects, sponsoring a science club, acquiring materials and equipment for science classes, counseling students, and constructing achievement tests.

Shawver (S 18) conducted an inquiry on "the science teacher supply for the State of Virginia." A questionnaire to the deans of the major colleges and universities in the State invited them to report on the number of students in the classes of 1955, 1956, and 1957 preparing to teach high school science. Further, the respondents were asked to report the number of teacher candidates who were majors in general science, biology, chemistry, and physics for each of the above years.

He found that for each year about 40 science majors were expecting to teach in secondary schools. He concluded that this number was approximately half the actual need each year in Virginia.

Mallinson (S 10) completed a five-part inquiry on "the status of science teaching in Michigan" having purposes related to several of the studies already reviewed. Specifically, he sought information on these five questions.

1. What combinations of science courses are taught by science teachers in Michigan?
2. How many different science courses may be taught by any one science teacher?
3. If a science teacher teaches courses other than science, what are they?
4. Do the subject-matter backgrounds of science teachers enable them to carry out their assignments successfully?
5. What types of training do administrators want science teachers to have?

Questionnaires were sent to half of the high school administrators in Michigan. Each administrator was requested to forward additional questionnaires to a junior high school science teacher and a high school science teacher in the same system. A total of 209, or over 80 percent, of the questionnaries sent to teachers were returned.

Some of the major findings in this study were the following:

1. The majority of teachers in class A, B, and C schools teach only one science. However, except for teachers in class A schools, the majority of the teachers who teach only 1 science, teach only 1 or 2 sections of that science. Many of their subjects are unrelated to science.
2. For those who teach more than 1 science, 90 percent of their combinations fall into 4 categories: (a) biology and general science, combined with physical education; (b) biology and general science; (c) chemistry and physics, combined with mathematics; (4) chemistry, physics, biology, and general science.
3. Many teachers who are teaching only one science do not have a major or minor in that particular field. This is especially true in small schools and usually so as regards physics.
4. In the majority of class A, B, and C schools, administrators emphasized that they want science teachers who are broadly rather than narrowly

trained in science. They were clear in stating that they want teachers who are sufficiently trained and versatile enough to be able to handle any and all science assignments.

5. There seems to be a belief that anyone can teach general science. It is possible that over half the classes in general science are taught by teachers whose breadth of training is insufficient to teach the course successfully or who have little or no science background at all.
6. Of all/the sciences taught, biology can be viewed with the greatest amount of satisfaction.

Studies Related to Course Offerings and Enrollments

A number of surveys of varying scope dealing with course offerings and enrollments (and usually with other matters) have been completed in different parts of the country. Most of these, taken individually, have limited significance and interest for a national audience because of their limited meaning. However, taken together, they do suggest trends and often provide the best information available on the status of secondary science over large areas of the country.

In a study of national scope, Smith (S 20) reported an investigation of "trends in junior high school science." He investigated the weekly classtime, topical coverage, and pupil enrollment in general science during the 10 years from 1945 to 1955. A questionnaire was sent to members of the National Science Teachers Association in each part of the country. Replies were received from 104 schools in 29 States. He found that: (1) General science has gained in minutes per class and in classes per week at each grade level where commonly offered. The highest percentage gain is in the 7th grade and the lowest in the 9th. (2) Course enrollments have gained during this period and follow that grade pattern. (3) Course content varies little. There now appears to be a tendency to achieve a better balance among the biological sciences, the physical sciences, and the earth sciences.

Pella (S 16) examined "the status of science offerings in Wisconsin high schools." His study concerns the following: (1) The science courses offered in 425 public high schools; (2) the nature of the teaching loads of science teachers; (3) the amount of pupil school time devoted to science in each school; (4) whether any relationship exists between the teaching load of the teacher and the amount of pupil school time devoted to school science in each school; and (5) whether any relationship exists between the teaching load of the teacher and the amount of pupil school time devoted to science. The sources of information were the reports submitted to the State department of public instruction. The results of this inquiry are presented in both textual and tabular form under such headings as Science Offerings, Science Course Combinations Taught by Teachers, Nonscience Courses Included in Science Teacher Loads, Pupil Time Devoted to Science, and Enrollments in Science.

In the spring of 1956 the high school principals of Essex County, N. J., conducted a "countywide mathematics-science survey of the coursework completed by the graduating seniors" (S 4). Of the 5,074 records examined, slightly more than half were those of college-preparatory students. All 22 public high schools in the county participated.

Sixty-two percent of the graduates took general science, 69 percent biology, 38 percent chemistry, 31 percent physics, and 9 percent other science courses. Ten percent of the graduates completed 4 years of science, 23 percent 3 years, 33 percent 2 years, and 26 percent 1 year. Six percent graduated without having taken any science.

"The science teacher, science course offerings, and enrollments in Nebraska public schools" were investigated by Hoffart (S 7). His study was concerned with the professional preparation of science teachers, their teaching loads, the types of courses offered, and the enrollments in these courses. All data were secured from the applications for approval and accreditation submitted by Nebraska school administrators to the State department of public instruction. He compared his results with those of three previously completed theses dealing with similar problems.

In general, science instruction is gaining in Nebraska. Both the percentage of schools offering general science, biology, chemistry, and advanced science and the student enrollments in these courses have increased significantly in the last three decades. Only physics has declined.

The professional preparation of the science teachers in 1954–55 appeared to be somewhat improved when compared with that of science teachers in former periods. However, their professional preparation in science was still far below the recommendations made in 1946 by the Committee on Science Education of the National Society for the Study of Education.

"An investigation of secondary chemistry offerings" was undertaken by Bliss (S 1) in Oklahoma as part of a national study conducted by the American Chemical Society. The author determined the number of schools offering biology, chemistry, and physics; the number of classes in each science; and the enrollments for each science in the sample schools. The survey covered 350 schools. Data were obtained through the State department of education.

The author found that biology was offered in 215 schools and studied by 72.4 percent of the students in these schools; that chemistry was offered in 71 schools and studied by 20.1 percent of the students; and that physics was offered in 54 schools and studied by 7.4 percent of the students.

A research report of the State department of education includes detailed information on the status of "science and mathematics teaching in New Jersey high schools" for 1956 (S 14). This information covers science course offerings, enrollments, class sizes, teacher supply and preparation, teaching assignments, and teacher compensation. Some of the conclusions were the following:

1. All New Jersey public high schools offer all the major science courses to their pupils.
2. According to accepted standards, the size of science classes is reasonable.
3. The percentage of boys and girls enrolling in advanced science classes during recent years has increased despite the fact that conditions contributing to high retention rates have kept in school many who would not ordinarily be expected to enroll in such classes.
4. Increased offerings in general science provide basic instruction for pupils less likely to profit from more advanced courses either from the standpoint of interest or ability.
5. Science teachers are, on the whole, well qualified from the standpoint of undergraduate preparation for their teaching assignments.
6. The large numbers of teachers assigned to instruct only in the biological sciences or the physical sciences are impressive.

Miscellaneous Studies

The factors which underlie science achievement in secondary schools have attracted investigators for years. In a recent study, Gould (S 6) investigated these factors, "predicting biology Regents grades from personality of 9th-grade students." Specifically, he sought to determine whether a distinctive pattern of certain components of personality is prevalent among high school students who elect biology as a major subject and whether this pattern is lacking among those who elect some other major. Five subproblems were investigated: (1) Is there a relationship between I. Q. and achievement in general science? (2) Between I. Q. and certain personality components?

(3) Between achievement in general science and certain personality components? (4) Between achievement in biology and certain personality components? (5) Between achievement in a nonscience major subject and those factors of personality found significant in (3) and (4) above?

The 20 personality traits considered in this study are those dealt with on the Bell Adjustment Inventory, the Bernreuter Personality Inventory, and the Mental Health Analysis. These, as well as the Otis Quick Scoring Mental Ability Test, Gamma Form BM, and the A. C. E. Cooperative Science Test for Grades 7, 8, and 9, Form R, were given to 157 high school boys and girls. All these students had completed 1 year of general science. Also used in the study, but with only part of the sample population, were the June 1948 Biology Regents Examination and the students' final grades in all subjects for the 1947–48 school year.

Among the findings were the following: (1) There was a correlation of 0.75 for both boys and girls between I. Q. and achievement in general science. (2) There was little or no relationship between I. Q. and any one of the personality traits measured, or any combination of them. (3) Only one personality component, "feelings of inadequacy," showed a substantial (positive) relationship with achievement scores in general science. (4) No substantial relationship was found between any personality component and nonscience achievement scores. (5) The best fitting personality pattern associated with achievement in biology included such components as: "close personal relationships," "adequate outlook and goals," "social participation," "dominance-submissive," "social adjustment," and "health adjustment."

Schenberg (S 17) studied "the nature and extent of the employment of laboratory assistants in the high schools of the United States." Specifically, he undertook to compile information concerning the employment, qualifications, duties, turnover, and recruitment of laboratory assistants in 47 cities distributed over the country. A questionnaire was used to gather this information. He found that: (1) Only three cities—Baltimore, New York, and Newark—employ laboratory assistants on their high school staffs. (2) Four cities—Atlanta, Boston, Oakland, and San Francisco—make special provisions for using high school students to assist science teachers. (3) The other cities also make some special provisions but their science teachers are accustomed to seek and obtain student assistance on a purely voluntary basis. The author recommended that the National Science Teachers Association get behind the movement to employ laboratory assistants in large high schools.

College Level

Forty-seven studies at the college level were reported by the committee for this bulletin. Of these, 13 are classified as curriculum studies, 11 as methods and resources, 4 as teacher training, 3 as testing and evaluation, 4 as elements of the scientific method, 6 as texts and production of texts and syllabi, 2 as characteristics of science students and scientists, and 4 as miscellaneous.

Studies Related to the Curriculum

Arnold (C 1) conducted a study designed to develop a first-year "general education college chemistry course," which would serve the general education student as well as the specializing student. His course was based upon the modern philosophy of science and education, with emphasis upon objective scientific thinking. The author established 4 basic assumptions for development of the course, and used 7 criteria for the selection and organization of content in keeping with the basic assumptions. A list of statements relating to the structure and behavior of matter was prepared and submitted to a jury of 9 chemistry teachers and 9 specialists in general education, who rated the statements. Of the statements, 376 were judged essential and, when arranged in logical sequence, became the basis of the course.

Meier (C 21) studied reports of "biology for a general education program," and attempted to relate these to teacher education. He stressed the characteristics of the biology course in general education in terms of appreciations and understandings of scientific attitudes and method, laboratory experiences, the relation of biology to health and welfare, and stress on biological principles.

Klotz (C 12) described a program of outdoor education at Concordia Teachers College. This project included a 2-week outdoor education workshop, 1 week in camp, the other on campus. Aquatic life, birds, insects, reptiles, wild flowers, geology, soils, astronomy, and conservation were studied. The experiences of living together were considered to be very valuable. Many school systems are now conducting programs of outdoor education. Teacher education of this kind increasingly becomes the responsibility of teachers colleges.

Sonneborn (C 32) has conducted a study which clearly states his reasons for including protozoa in the college general biology or zoology course. He stresses that protozoa provide opportunities for students to observe nature and make discoveries and acquire enthusiasms for biology. Simple instructions and useful teaching aids are presented in the article. Advice on the culture of protozoa is given. The article offers valuable practical directives to the college biology instructor.

Dunbar (C 9) suggests the feasibility and desirability of using lecture-demonstrations in teaching organic chemistry. He identifies and discusses some factors involved in the lack of widespread acceptance of demonstration techniques as an aid to teaching this subject. The author gives general advice for demonstrations together with some specific examples of possibilities.

Wood (C 39–40) presented two studies dealing with the "construction of special slide rules and nomographs for the teacher of general chemistry." He presents a very thorough treatment of the considerations involved in the theory, construction, and use of specially constructed slide rules for particular application in the solution of mathematical problems arising in chemistry. According to the author, a particular advantage in the use of such devices is the possibility of assigning numerical problems to chemistry students on an individual basis with the assurance that solutions may be determined readily by means of such special slide rules as are suggested. The ideas reported seem practical and helpful to all who work in the area of chemistry education at the college level.

Van Deventer (C 35), in a study concerned with "the use of subject-matter principles and generalizations in teaching," set out to isolate, state, and justify some scientific principles which are functionally unifying in broad areas of scientific knowledge. These principles are the ones that lie between the basic ideas common to all science and the subject-matter principles generally associated with particular branches of science.

The author's thoughts about the problem come from the research of other persons who seek to identify the basic ideas and principles underlying science and the scientific attitude, and also from his own analysis. This analysis is part of a long-term objective for constant reexamination of what we teach and how we teach it. An immediate objective is to gain a basis for a block-and-gap technique in selecting subject matter for a nonspecialist course in elementary science.

The author suggests that a relationship must exist between subject-matter principles in science and the basic assumptions and ideas constituting discernible elements of scientific attitude. He proceeds to analyze the generalizations of science into four levels or strata: (1) The basic ideas and assumptions of scientific attitude, (2) area principles unifying or relating separate scientific branches, (3) subject-matter principles in the separate scientific branches, and (4) the facts of science which support the generalizations. The analysis is illustrated and justified with specific examples drawn primarily, but not exclusively, from the biological sciences. The author emphasizes the laboratory as affording opportunities for work which is worthwhile as well as exploratory-experimental and experiential. He refers to certain experimentation in science education at Western Michigan College.

Perlman (C 24) compared the historical treatment of scientific discoveries (case histories) and contemporary science problems in the laboratory program of a college physical science course designed for general education. Students subjected to two procedures were compared as to their ability to use the scientific method of thinking. In most instances there was little difference in results with the two groups.

Sleeman (C 30) utilized the evaluation of Castleton Teachers College by the American Association of Colleges for Teacher Education as the foundation for developing "a proposed science program for general education" for the people of Vermont, and for providing firsthand experiences for the students, with more attention to the social implications of science. He maintains that the proposed science program may develop student interests, demonstrate possibilities of practical application, lead to a functional understanding of science concepts, and contribute to critical thinking—by presenting vital problems in relation to the life of the people in Vermont.

Simmons (C 29) studied "vitalizing biology with a live-animal project." The course is required of all students at Albany State College in Georgia. Experiments in nutrition, dissection, reproduction, and physiology were briefly reviewed. Rats and mice were the animals most frequently used and the students took care of them. The students also carried out many of the experiments, especially those on nutrition, while the instructor carried out certain of the dissection demonstrations. The purpose was to give the students experiences with laboratory organisms so that they might gain an insight into the methods of biological science.

The author suggests a series of student activities with live animals. He maintains that these activities would be useful in college biology courses designed for general education purposes.

The National Science Teachers Association, as reported by Carleton (C 7), has conducted a research team conference for science teachers. Thirty-two selected experienced teachers met in a 2-week summer conference at Oregon State College and San Jose State College. The participants interviewed more than 30 research scientists, and prepared and recommended specific laboratory exercises based on the insights gained.

Studies Related to Methods and Resources

Schwab (C 28) discusses the nature of scientific inquiry, stressing that scientific inquiry itself, as well as its conclusions, should be a part of the liberal curriculum—all the way from elementary courses in many fields to survey courses in general education. Survey courses, he feels, have two serious weaknesses: "Superficiality and dogmatism in its graduates and adolescence in its contact." The principles one acquires from a course based on inquiry have a longer life expectancy. One particular theory concerning the particles, masses, charges, and motions which constitute the atom may, for instance, have a very limited life and a limited applicability. On the other hand, the technique of seeking explanations of physical and chemical phenomena, in terms of particles of some mass, charge, and motion, will persist as long as theories of this kind are useful and will continue to be capable of revision and enlargement to encompass new phenomena. Schwab insists that the traditional curriculum must gave way to one of materials that reflect inquiry. Materials and their treatment must constitute a second inquiry, engaged in by student and teacher alike and aimed at practicing the art of inquiry and getting a grasp of that full meaning of a body of knowledge which only the inquiry that produced it can supply.

Lahti (C 13) studied "the inductive-deductive method and the physical science laboratory." He set out to ascertain the effectiveness of the laboratory in developing students' ability to use the scientific method. (The author defines the scientific method in terms of its philosophical meaning and in terms of the research approach, adopting the latter for purposes of his research.)

Lahti used written tests to measure students' ability to design an experiment, collect the data, and measure their ability to interpret the data. He constructed a performance test to measure their ability to solve a problem with simple equipment placed before them. For this experiment he used students from a natural science class of non-science majors.

The author compared four methods of teaching: the inductive-deductive (problem-solving), historical, theme (or discussion), and standard. The data were subjected to statistical analysis. Once collected, the data were interpreted equally well by the students regardless of the method used. The inductive-deductive method was significantly superior to the other methods in promoting the ability to develop a line of attack and it was also successful in developing problem-solving abilities in content-centered problems.

According to this study, the ability of students to formulate plans and to design an experiment appears to be the crucial aspect involved. The individualized inductive-deductive laboratory appears to offer a means of developing students' ability to use the scientific method, which is defined in terms of the context of discovery and the context of the study.

West (C 38) studied "the project method of teaching biology." He reports on a course required of all majors in the biological sciences at Northern Michigan College. Included in the report is an excellent statement of course objectives, identification of student and instructor activities, photographs of student projects, and descriptions which give the reader an insight into the bases of the course. This course was designed to allow students to work on problems or projects in biology of prime concern to them.

The report gives evidence of the extent to which the project approach has been reflected in improved science fair projects of secondary school youth taught by former students who took the course. An analysis is made of 113 recent projects of students covering a 5- or 6-year span. The course enrollment is limited to 24 students because of laboratory facilities.

Smith (C 31) conducted "an experiment in teaching general chemistry by closed-circuit television" at the Pennsylvania State University. He set out to study the feasibility of using moderate-cost TV equipment for instructional purposes and the acceptability of this type of instructional medium to the persons involved, and also to determine the limitations and advantages of closed-circuit television in teaching various types of courses.

The course in college general chemistry consisted of 2 lectures, 1 recitation, and two 3-hour laboratory sessions a week. Only the lectures were given over television, other parts of the course remaining unchanged. About 450 students were divided into 3 groups. The first was taught in the originating room of the televised lectures, the second watched the lecture-demonstrations on television receivers, and the third received regular lectures. Three chemistry teachers alternated in giving the lecture-demonstrations. The article describes in detail the television equipment and techniques used, lists the technical staff, and describes modifications needed in the instructional procedures.

The experiment was evaluated by objective tests and student-reaction questionnaires. Smith found no significant differences in the scores of the three groups on the examinations. Thus, he judged that the students' learning was not handicapped by the experimental procedures. Most students found the procedure quite acceptable, and a small majority found it as interesting as conventional lectures. One significant difficulty was lack of color on the television screen. Another was insufficient size in the reproduction of blackboard presentations.

The author concludes that teaching chemistry classes by television is quite feasible for the lecture phase, but that, at present, with the serious problem of lack of color and smallness of screen, it would be unwise to adopt this method as a regular procedure. However, in the future this conclusion may be reversed.

Blumenthal (C 5) studied "the effects of multiple instruction upon learning in college physics." He set out to investigate and predict end-term achievement of students who attend split session of lecture, recitation, and/or laboratory, with the achievement of students who do not. His subordinate problems dealt with acquisition of physics knowledge, problem-solving abilities, and end-term success in achieving these. ("Split session" was defined as a different instructor for lecture and recitation.)

The author's findings and generalizations were the following: Physics students whose lecturers also serve as their recitation instructors show greater end-term physics knowledge than students whose lecturers and recitation instructors are not the same. There is no significant difference in end-term physics knowledge between students having the same instructors in recitation and laboratory and those having different instructors. There are no significant differences in achievement of students who do or do not attend split sessions. Students with a good *general* scientific knowledge at college entrance generally have a greater factual knowledge of physics at the end of the first course in that subject than students who did not have a general scientific knowledge. Students who display ability in mathematics and, to a lesser extent, a good general scientific knowledge at college entrance generally show a greater achievement in physics problem-solving abilities at the end of the semester than students who do not display this ability and knowledge at college entrance. Ability to reason is not significantly related to end-term physics knowledge or to physics problem-solving abilities.

This study concerns a question, the answer to which may be different under varying conditions. The point of view is often met in the literature of the subject that the outstanding member of a department should give the lectures in elementary and general education courses. Perhaps the chief determinant in this regard is the number of students enrolled in the course. Further, there may be more significant criteria than test scores for sectioning classes. It would be useful if other studies designed in different ways were conducted in this area, in various sections of the country, and in both large and small institutions.

Summerbell (C 34) and others conducted an experiment dealing with "simulated research for freshmen" which introduced a study of unknown solutions into the last weeks of a course in college general chemistry. The object was to have each student undertake a simulated research problem. Certain standard procedures were omitted from the course. The authors concluded that much enthusiasm was generated and that the students gained a very real understanding of the qualitative scheme and of the general nature of scientific procedures. Best of all, the students were given, they said, some measure of the excitement of experiment.

Gaier (C 10) conducted a study on a "technique of problem solving as a predictor of achievement in a mechanics course" designed to compare the ability to solve problems with prediction of achievement. Problem-solving ability was measured by the Balance Problems Test of Cross and Gaier. Achievement was measured by final grades in the Airplane and Engines Mechanic course, and by scores on two mechanical job-knowledge tests. (The study was supported, in part, by the United States Air Force.)

The investigators discovered that final grades were positively related to the number of problems correctly solved in the BPT and to the tendency to prefer principles over facts in their solution. The usefulness of this study lies in the fact that it tends to support the hypothesis that understanding of principles should be emphasized in science classes rather than memorization of isolated facts.

Ward (C 36) set out to compare the relative effectiveness of two methods of instruction ("group study versus lecture-demonstration in physical science") in achieving two objectives of general education: (1) Recall and recognition of facts, principles, and symbols; and (2) more understanding of implications of facts and principles, of pertinent reading matter, and of problem situations.

The author utilized the group-study versus the lecture-demonstration method in a physical science course for general education college students. (This was a Ph. D. thesis undertaken at Chatham College. The author himself served as the only instructor for equated groups and taught them by each of the two methods.)

The same subject-matter topics were taught, the same visual aids used, and the same reading assignments made. Every effort was made to keep the experiment perfectly controlled. Tests were administered and the results subjected to extensive statistical analysis.

Ward concluded that the group method resulted in a longer retained, more-understanding type of learning and in greater expression of individual differences on the part of the upper subgroup of the students. Further, the lecture-demonstration method resulted in greater expression of individual differences in a longer retained, more-understanding type of learning on the part of the lower subgroup of students. This method also resulted in greater expression of individual differences in a longer retained, recall-recognition type of learning on the part of the lower three-fourths of the students.

The author suggests which method might be used if certain outcomes are desired. For example, based on conclusions from his study, he recommends that the group method be used if the purpose is to produce greater expression of individual differences or more understanding-type learning of subject matter among the most capable students.

Calhoun (C 6) and others conducted "an experiment in student-centered histology teaching." The authors first made a study of the literature. This indicated that conventional teacher-centered classes are not conducive to optimum development of student ability, responsibility, and initiative. Sections of students, each led by a graduate student, who was a member of the class, were assigned a subject to study by themselves. Lectures were given by the graduate students and other members of the class. The regular instructors were on hand to help if they were needed. The effectiveness of this method was studied by means of a questionnaire.

The authors concluded that the student lecturers were poor speakers, the lectures were too bookish at times, the students had a tendency to lecture on details, and they lacked adequate preparation. The study showed that more supervision in group planning was indicated, although the project did inspire and increase class interest and made for greater class unity. It also developed responsibility and self-confidence in students and the students became better acquainted with one another.

Leib (C 14) conducted a study pertaining to "demonstrations in physics with simple equipment." The author's purpose was to suggest some demonstrations which may make physics more interesting without neglecting its intellectual aspects. He introduces well-considered demonstrations with a defense of physics. The author's demonstrations, although well chosen, are not original, and his discussion of them is analytical. His plea for improvement of physics instruction through experimentation in the laboratory suffers somewhat from lack of refinement in the suggestions he makes for demonstrations.

Studies Related to Teacher Training

Weaver (C 37) conducted a study of the "place of the college in training teachers to educate students and the general public in conservation." The author prognosticates in the interest of broad conservation-education programs at the college level. His criteria are apparently derived from his broad experiences in conservation education. The approach he advocates is wholesome and he recommends intensiveness for conservative programs. Operational principles are enunciated and the work appears practical without detailed specificity. Anyone interested in this area might refer to the *Handbook for Teaching of Conservation and Resource Use*, prepared by Richard L. Weaver for the National Conservation Committee of the National Association of Biology Teachers in conjunction with the American Nature Association (Washington, 1955).

Mallinson and Sturm (C 18) conducted an investigation to determine the "science background" and knowledge of the subject matter possessed by elementary student teachers, to determine their attitudes and opinions concerning certain aspects of their preparation for teaching science, and to compare their subject-matter competence in science with that of certain groups of high school pupils. (This study is reported in the first part of this section, devoted to research at the elementary school level.)

Nelson (C 22) conducted a study to determine competencies desirable or necessary for science teachers in their first years of work (as seen by the administrators who hire them) and for beginning science teachers in Illinois. (This study is reported in the second, or secondary school part, of this section.)

Haenish (C 11) has reported a statement, in part historical, setting forth the "guiding principles and procedures" of the American Chemical Society's attempt to improve the training of chemists in American colleges and universities through setting up minimum standards and lists of approved institutions. The article presents a short table giving the relative number of chemistry Ph. D.'s in schools reporting each year from 1950 through 1955, who did their undergraduate work at schools not on the ACS list.

Studies Related to Testing and Evaluation

Mallinson and Buck (C 19) report "an investigation of the New York State Regents Examination in Science." The problem was to investigate the attitudes of certain science teachers from New York State toward the Regents examinations in science and to analyze and evaluate certain characteristics of the Regents examinations for biology, chemistry, earth science, and physics, for certain years.

The authors' method and techniques involved an analysis of responses of pupils who obtained passing grades on various Regents examinations and an analysis of statistical methods and questionnaires to teachers. The study is divided into 8 sections, with a statement of the problem and the methods and a summary for each of the first 7 sections. The eighth section contains the summary and conclusions for the entire study.

The authors concluded that most teachers favor the use of the Regents examinations and feel that the New York State science program is the better for their use. However, a frequent criticism of the teachers was that the examinations do not measure growth in the so-called general education objectives. The authors also concluded that the Regents science examinations are far more reliable and valid than teacher-made tests in the same area and compare favorably with commonly used standardized examinations. Further, the authors concluded that the Regents examinations are not prejudiced in the interests of any particular group within New York State and that a better system of scoring the examinations is not indicated. The study did not elicit any evidence that the examination system in New York State should be abolished.

Randall (C 27) reports on a "general science testing program." He sought to determine how science teaching in Louisiana high schools could be improved. He prepared an examination containing items on astronomy, chemistry, geology, meteorology, and physics, which was mailed to science teachers and used in a competitive testing program involving 226 selected pupils from 90 public and 3 parochial schools.

The author concluded that the number of schools and the number of pupils had increased since the previous year and that the percentile scores had also increased. The increases, he concluded, suggested an improvement in subject-matter mastery in general science as well as an improvement in teaching by the general science teachers. The study did not include any items in the biological sciences.

Carlin (C 8) conducted an "investigation of grades in the first semester of college chemistry attained by students who had had a course in chemistry at the high school level and students who had not had such a course." His study was concerned with whether a course in high school physics contributes to success in first-semester college chemistry, whether there were differences in grades between the sexes, and whether there was a correlation between Q and T scores attained on the American Council on Education Psychological Examination and grades attained in the first semester of college chemistry.

Carlin used the matched-pair technique with 800 subjects, 400 with high school chemistry and 400 without. Within each of these groups he set up subgroups of those who had taken high school physics and of those who had not. He converted the coefficient of correlation to *t* and compared it with the critical ratio at the 1-percent level of significance.

The author's findings and conclusions were that the 400 students who had taken high school physics excelled the 400 who had not, indicating that a course in high school physics had a positive influence on grades attained in first-semester college chemistry. Students who had taken high school physics (126), but not high school chemistry, surpassed the 126 who had taken neither high school physics nor chemistry (critical ratio of 1.62), indicating that it cannot be stated with confidence that a significant difference exists. The 98 who had taken both physics and chemistry in high school, compared with 98 who had taken chemistry but not physics, showed a critical ratio of 2.55 in favor of the former, which was significant at the 5-percent level.

The foregoing was the first significant indication that there is a carryover of knowledge and skill from high school physics to the first semester of college chemistry. Students who had taken both physics and chemistry in high school were found to be far superior to those who had taken neither, with a critical ratio of 6.136. Also, students with both high school chemistry and physics were superior to those with high school physics but not to those with high school chemistry (critical ratio 4.126), which was significant at the 1-percent level.

The results of Carlin's investigations indicate that a course in high school chemistry contributes more to success in first-semester college chemistry than a course in high school physics. However, the results also indicate that students who had taken a course in high school physics were more successful in college chemistry than those who had not taken it. These differences were found to be about the same when scores for male and female were compared separately, with no significant difference in achievement as between the sexes. Positive correlations were found between grades attained in college chemistry and both Q and T scores on the American Council Psychological Examination, with greater correlation for those who had taken high school chemistry. Further, the relationship between grades in first-semester college chemistry and Q and T scores was closer for males than for females.

Studies Related to Elements of the Scientific Method

Randall (C 26) conducted "an experimental study on the teaching of scientific thinking in a physical science course." He undertook to determine the extent to which a random group of 36 nonscience majors in a first semester nonlaboratory physical science course (with demonstrations) developed their critical evaluation of scientific articles as one means toward developing ability to think scientifically and comprehend and profit from the factual information contained in the course. The experimenter used standardized tests and two which he himself devised but did not include in his report. Since he had no control group, his conclusion that the lecture-discussion-demonstration method was effective has a limited validity, if any.

Bender (C 4) conducted a study summarizing "articles concerned with concept formation." Her purpose was to provide ready access to what is known about concepts and to stimulate research efforts in a field greatly in need of a study. She obtained references from the *Readers Guide* and the *International Index*. Her findings were that the modified memory type of experiment is perhaps the most frequently used in studying concept formation and that some feel that the concept originates as a hypothesis which the subject then proceeds to test while others feel that it is the result of pure abstraction. Certain factors, such as efforts to learn, personality type, motivation, sex, and the requirements of the task, appear to influence the subject in the learning of concepts. Among concepts tested, a certain hierarchy seems to exist: Concepts of concrete objects are learned first, followed by those of spatial form, color, and number.

Navarra (C 20) reports a study of "the development of scientific concepts in childhood" in terms of a young child's interaction with the physical phenomena of his environment. Although not reviewed in the college-level section, this study does have some implications for college-level science educators interested in elements of the scientific method.

Studies Related to Textbooks and the Production of Texts and Syllabi

Arthur (C 2) compiled scientific information related to activities in industrial arts and produced a sourcebook for teachers of science and industrial arts. Topics included were heat treatment of metals, electroplating, fluorescent lighting, ceramics, selection of wood, automobile brakes, and silk-screen stenciling. The author suggested methods for helping students locate and learn the facts.

Banner (C 3) studied the program of the Michigan Department of Conservation to determine the factors of behavioral change involved in achieving program objectives and published his findings in the form of a syllabus including objectives, content, and procedures.

Major (C 17) conducted a study to determine the "readability of college general biology textbooks and the probable effect of readability elements on comprehension." The Flesch reading-ease formula was employed to estimate probable grade level of readability. Two hundred liberal-arts freshmen (not likely to major in the biological sciences) were randomly divided into three groups with approximately the same number of above-average and below-average students in each group. Differences in comprehension of graded reading material were considered significant at the 5-percent level of confidence.

The investigation involved three phases:

1. *The readability elements and concept load in a biology passage.*—Three graded passages were constructed with estimated readability at the levels of approximately the 10th, 12th, and 14th grades. The vocabulary load was reduced about two grade levels by definition, example, or context. Readability of the third passage was reduced two additional grade levels by eliminating the less essential biological terminology.
2. *General biology texts.*—A nationwide survey was conducted to determine the ten general biology texts most extensively used and preferred during the academic year 1953–54.
3. *The readability elements of number of syllables per 100 words and the average number of words per sentence.*—The findings and conclusions were reported by phases: (a) Comprehension improved significantly when the vocabulary load was reduced and when both vocabulary and concept loads were reduced. (b) The mean readability score for the books ranged from the lower quartile to the median in the difficult category. Above-average students will probably encounter difficulty with 32.8 to 70.8 percent, and average students with 53.6 to 84.7 percent, of the reading assignments. (c) The difficult passages occurred at the beginning and in every other section of the textbooks. (d) Increased readability resulted from reduced sentence length and reduced syllable count. The comprehension of above-average and average students improved significantly when the readability was increased by one grade level.

This study seems to indicate that the general complaint of students about the great extent of "technical" terms in biology texts may be true.

Studies Related to the Characteristics of Science Students and Scientists

Strauss (C 33) conducted a study on "background traits of a group of biological and social scientists." The subjects were males who had earned the Ph. D. degree within 2 years before the interview. Thirty biological scientists and 30 social scientists were interviewed. The interview consisted of 81 semistructured questions and required 3 to 4 hours each. It was recorded on plastic disks and transcribed verbatim.

Analysis of the interviews yielded 134 clusters of categories to serve as the basis for coding. A readability check of the coding produced 75 percent agreement. Tabulation permitted a comparison (using the Chi-square technique) between the biologists and social scientists.

The main investigation was preceded by a pilot study in which 20 subjects were interviewed. The findings and the generalizations from the pilot study indicated no evidence for "scientific aptitude." Drive was the most apparent factor in achievement, one part coming from academic interest. Another and more important part was probably stimulated by frustrations in early life, family tensions, or physical and social handicaps. A difficult childhood was common among the men. As children, many had been avid readers. Only a few had been outstanding high school students.

College experiences played a greater role in stimulating interest in scientific work. Many were more successful in college than in high school, and then did even better in graduate school. The biologists required an average of 8.7 years and the social scientists 12.5 years to complete their graduate work.

In the opinion of the subjects, scientific research does not require exceptional intelligence. They placed much emphasis on interest, perseverance, and other traits and a high value on a broad, well-rounded education before specialization.

There appeared to be few significant differences between the biological and social scientists. Their personal traits seemed characteristic of scholars in general. There was strong evidence that the biologists had been inconspicuous but determined nonconformists in their boyhood, that they became interested in their field at an earlier age, and that they had more stable interests. The social scientists appeared to be more sensitive to people and to interpersonal relations and more willing to conform. They received better marks and participated more freely in extracurricular high school and college activities. Most of the men were happy in their work at the time of the interview. Nearly all the scientists reported that they enjoyed being with people and that they participated freely in social activities.

This study, like others, endeavors to locate future scientists, approaching the matter through hindsight, as it were. It suggests possibilities for future investigations and raises the question as to whether results would be similar for chemists, physicists, astronomers, anthropologists, psychologists, and the like. Would older scientists have different traits? The results of Strauss' study should be compared with similar studies in this field by Brandwein, Woodburn, and others.

Phillips (C 25) conducted an investigation of "the relationship between success in college chemistry and a background in high school science and mathematics." Records were utilized of some 600 students enrolled in chemistry for the fall and spring terms of 1949–50 and 1952–53 at the City College of San Francisco. IBM cards were prepared showing grades in high school chemistry, Algebra 1 and 2, chemistry entrance tests scores, the ACE and L scores, ACE arithmetic fundamentals score, grade in Chemistry 17 (a remedial mathematics course), Chemistry 1A, and also other pertinent facts. Correlations were run according to the method outlined in Croxton and Cowden, *Applied General Statistics* (Prentice-Hall, 1939).

The findings were that none of the factors considered was of prognostic value. However, several of these factors gave sufficiently high correlations to indicate that they are important. (In this connection, the reader is referred to two reports of MacCurdy's study (C 15) (C 16) which deal with the characteristics of superior science students and their own subgroups.)

Miscellaneous Studies

Oakes (C 23) presented a paper at the 1956 NARST meeting, "Explanations by College Students," which analyzed the original writings of authorities on definitions and usage, and the extravagant claims of both scientists and students in support of their explanations for scientific phenomena. The paper is an excellent approach to semantics, taxonomy of words, and scientific phenomena. It is replete with examples of statements made by students in college classes which reflect animism, personification, moralistic overtones, needs of the organism, non sequitur reasoning, causation of evolutionary and other behavior, teleology, and the like.

Oakes summarizes and recommends: (1) College students use animistic, anthropomorphic, and teleological concepts to account for biological phenomena, and certain of their explanations are "pre-scientific" and "Aristotelian" and involved overlapping and duplication among the varieties enumerated above. (2) Scientific attention to this aspect of scientific thinking might well be taken into account as one criterion for selecting textbooks. It would be valuable to develop classroom procedures designed to remedy and replace these teleological explanations. If (as seems to be true), teleological, animistic, anthropomorphic, and other "unscientific" explanations are widespread among students, then perhaps correcting these misconceptions might well be made one of the objectives for biological science courses.

Section II. Interpretations and Recommendations

THE COMMITTEES that provided the material upon which this report is based surveyed all issues, from July 1955 to July 1956, of about 50 journals which from time to time have carried reports of research in science education. In addition, the committees reviewed the abstracts of unpublished studies in science education collected annually from more than 1,200 institutions by the U. S. Office of Education.

Although the search was as meticulous as possible, no claim is made that every study was located. Both the National Association for Research in Science Teaching and the U. S. Office of Education are committed to a policy of profiting by the work of previous committees in an attempt to improve the techniques and the product.

The interpretations and recommendations in this section are those made by the chairman for each level and the general chairman. Thus to some degree they may reflect personal bias, although every precaution was taken to insure objectivity. For any errors of judgment or for faulty interpretations, the general chairman accepts full responsibility.

Elementary School Level

Dean George Mallinson, in an earlier survey of the research in the area of elementary science, has pointed out that over the past few years the research at this level has generally sought to determine the extent to which the success of a program of science instruction in the elementary school depends upon—

1. The training of the teachers.
2. The design of the curriculum.
3. The methods of evaluation.
4. The use of text books.

Science as general science rather than the earlier nature study has now been a part of the elementary school curriculum for more than 30 years. During this period a large body of experiential knowledge and a considerable body of sound research have accumulated to produce reliable guide lines for future progress.

However, with all the available information, no basic status studies have been carried out and repeated at intervals. Thus, it has been impossible to state authoritatively that there are any trends in elementary science. In the current survey, however, two basic status studies were reported, one by Vincent (E 19) and the other by Goehring (E 5).

What is needed is a series of broad status studies, carried out generally at the national level and applied to more specific issues at State and local levels, to provide a reliable basis for curriculum revision in elementary science and curriculum planning at the secondary level. With the current proposals for a 12- or 14-year sequence in science offerings, it becomes very important that more exact information about the program in the elementary school be made available.

Curriculum planners in elementary science are constantly faced with the need for more information concerning the grade or level placement of science concepts. Two studies, one by Lowheed (E 7) and the other by Mallinson, Sturm, and Mallinson (E 8), throw some further light on this difficult problem. The critical need for full and complete information on the problem might well make of it a topic for some directed team research.

Several studies are reported in this survey which relate to the learning of science principles and concepts. Among these are studies by Murray (E 11), Schultz (E 16), and Knight (E 6). Each has no doubt made a significant contribution to the literature. However, this again is an area in which there is a need for planned and concerted team research to provide a more reliable basis upon which to plan the learning experiences of young people.

There appears to be a growing concern over the country about the development of scientific attitudes and the abilities of critical thinking or problem solving. The elementary school offers a peculiarly important place where the development of these less tangible outcomes should be started. In this survey three studies are reported which deal with these important aspects of science instruction: one by Atkin (E 1), one by Rimoldi (E 14), and one by Stefaniak (E 18).

Among the studies which the committee recommends in the area of problem solving are the following: (1) Techniques for setting up problems to be solved in a unit of work, (2) learning experiences to help pupils identify problems, (3) processes involved in proposing and testing hypotheses, (4) learning experiences to help pupils evaluate evidence, and (5) learning experiences to help pupils draw conclusions from data.

This survey reports two studies related to science instruction for retarded pupils, one by Onstead (E 13) and the other by Ross (E 15). These no doubt are very important contributions to the literature because the problem of the retarded child is an ever-present one. However, all the current concern over the need to identify and provide for the child gifted in science, and the realization that this should be done in the middle and late elementary grades, may signify that some research studies should be devoted to these problems, too.

The important problem of young children's science interests has occupied a considerable body of research. No studies in this area are reported in the present survey, however. Increasing concern that children with science potential should be identified early suggests a need for a series of more refined and searching studies of the factors which motivate these children.

Studies related to teacher training have been reported by Mallinson and Sturm (E 9) and by Chamberlain (E 3). The current shortage of science teachers and the current nationwide programs to improve science teachers might point to the need for a searching examination of our teacher education programs. And, despite a reasonably large accumulation of research in this area, there still is a need for much more research in the problem of providing improved teacher training in science.

Several studies in this survey are related to the elementary science textbook. When one considers that perhaps the most unique thing about science learning is the experiment, it is surprising to discover that no studies are currently reported which deal with the experimental exercise as a learning situation in elementary science.

At the junior high school level the individual experiment has almost disappeared in favor of the pupil and/or teacher demonstration. Children in the elementary school should have a rich experience in direct learning through experimental exercises. To accomplish this end there may be a need for a group of studies on the most promising experiment techniques for various levels of the elementary school and on the closely allied problems of facilities and equipment.

Although many of the studies on the elementary science level reported in this survey are to some extent incidental, fragmentary, and peripheral, certain of them are of major stature and have made significant contributions to the literature concerned with basic major problems of science teaching.

Secondary School Level

Few, if any, general features of the research reviewed by the committee differ from those cited in former summaries of reviews. The volume of research is still disproportionately low; many areas of secondary science education remain either virgin territory or little explored; the results of even the best studies are dimmed by lack of an overarching research plan; a surprising number of studies were poorly designed (and therefore omitted from this review); and most of the investigations dealt with securing information on existing conditions in the field.

Obviously, the questionnaire is the most popular investigative device among researchers in secondary school science. Where precise description is not material to a valid conclusion, where items can be answered without the possibility of personal bias (unless, of course, such bias is sought), and/or where the number of returns permits a high order of confidence in the generalizations derived, then, without doubt, the questionnaire can be an efficient instrument of research. Too often, however, none of these conditions prevail, and no measures are taken to correct for the resultant distortion.

The great incidence of status studies is unquestionably a reflection of uneasiness felt by most educators over the health of science education in all its aspects in the public schools. Perhaps it is inevitable that these studies have come *after* the critics have had their say, rather than before. The results of some surveys may be reassuring to the professionals, but the intelligent layman will remember only the misgivings of the detractors.

General science, biology, and chemistry appear to have claimed the attention of investigators equally. Only physics seems to have lagged. Perhaps the recent emphasis on reorganizing high school physics courses will create an interest ultimately leading to increased research in this field.

College Level

Some of the current research in science education at the college level serves to foster development of new and important practices. At the same time, much of it is concerned with sustaining and strengthening present practices. Although it is difficult to specify the extent to which research in any area influences another area, there is some evidence that education research at the college level is not closely coordinated with the practice, or vice versa, as it might be. If this is true, it may be caused by a lack of "readiness" to accept available research studies in science education or perhaps by a lack of information about them.

An analysis of the current studies indicates a somewhat disconnected approach to research in science education at the college level. If one used the studies reported in the present survey as a base for developing a definition of college-level research in this field, he would be struck by the concern for curriculum revision and methodology. Of the 48 studies reported on the college level, 24, or half, are specifically concerned with curriculum and methods.

Without doubt, curriculum and methods are important and justified, but a question arises: What studies are needed on other basic problems related to science teaching at the college level?

With all the activity in retraining science teachers through workshops and institutes supported by Federal funds, industry, and other agencies, perhaps it is a little premature to expect that the research would reflect some interest and concern for the nature and effectiveness of these programs.

A considerable proportion of the college-level research covered by this survey is concerned with identifying certain objectives stated as principles, generalizations and concepts, or with reporting variations in methods of presentation and/or evaluation. A considerable amount of the data comes from opinions, social statistics, and other sources that tend to be secondary in nature. Too few imaginative designs and techniques are utilized and seemingly there is too little concern for a basic philosophy of science education or of value determination in the use of statistical procedures.

Only three studies are reported on scientific method or problem solving, yet perhaps at no other time in the history of science education in America has there been greater need to use the scientific method. This is particularly true at the elementary and secondary levels. If young people are to be trained to use the method of problem solving, their teachers must understand it and be able to use it themselves. Teachers are prone to teach as they have been taught. Thus, it seems important to point up the very great importance of, and need for, much more research at the college level in scientific thinking and attitudes.

The effective use of the laboratory in college science has been an almost perennial problem reflected in the research literature. The current review includes a few studies related in one way or another to the laboratory. This appears to be an area which could become the focus of some searching studies in how adequate and effective present laboratory programs are in teacher training in science.

This survey of research in science education at the college level seems to indicate a need for greater emphasis on action and cooperative research to develop new designs for experiments, especially in universities that grant higher degrees.

It seems evident that most college faculties are concerned with the problem of individual differences. Research appears to indicate a rather wide awareness of the broad range of abilities or traits revealed by class performance records. Rejection of ability groupings continues, however. This is reflected in studies now underway pertaining to success, and prediction of success, of students with or without certain high school or other experience in the sciences, or to attributes alleged to be characteristics of scientists.

Research in science education at the college level appears to be in need of redefinition. This comes from the belief that observing bit-by-bit and day-to-day conditions under which learning takes place requires an approach quite different from the approach required by observing change in student behavior. More specifically, there appears need for investigations of the following kinds of conditions: (1) Where present behavior is maintained or eliminated; (2) where new behavior patterns are acquired; and (3) where continuing behavior is developed, shaped, structured, and maintained. More fundamental concern for experimental determinations and verifications also appears to be needed.

The research at this level, true also at the elementary and secondary levels, reflects concern over many basic issues. However, the approach to these problems is somewhat fragmentary and lacks a planned and concerted attack through which sufficient data might accrue to solve the problems. Perhaps this situation demands some basic assessment of the issues, a clear definition of specific problems, and a carefully planned frontal attack through individual and team research.

General Considerations

This fifth annual review of the research in science teaching represents many man-hours of conscientious labor by a group of devoted and competent people. The general chairman wishes to pay a tribute to this group and to express appreciation for the fine cooperation which has prevailed throughout the undertaking.

The National Association for Research in Science Teaching has formulated a list of criteria which have been used by the various level committees over the years in selecting the studies to be reported. An examination of the criteria will reveal that they are rather rigorous. On the basis of these criteria, many studies were rejected this year, as in previous years.

However, when one examines the research reported over the past several years and the current review, with these criteria in mind, he finds some evidence of a need to improve the criteria or to apply them more rigorously to the studies examined. Some of the studies, both in previous reviews and in the current one, do not measure up to a standard that would add stature to research in science education. Nevertheless, the committee decided to summarize a number of them in the present report because they describe techniques that might prove useful for future studies.

The point just made is particularly important at this time because certain outside groups have questioned the value of some of the science education research. Many organizations, agencies, and institutions are currently engaged in programs directed toward improvement of science teaching. The personnel concerned with these programs depend, to a large degree, upon the research group in science education for basic information to provide sound guidance for their undertakings.

The science education fraternity, and more especially that segment of it set apart because of its concern for research, must be very certain that the product which it reports can bear up under the scrutiny of others in our field and in related fields.

A considerable number of studies reported in this survey can contribute to this end. Others among them add little, either to the stature of our profession or to the improvement of science teaching.

The overall pattern of the survey reveals concentration in some areas and a paucity of research in other areas. Some of these areas of concentration are of relatively little concern when one views the long-range improvement in science teaching. Since this point has been specifically discussed in earlier sections, it does not need to be elaborated further.

On the other hand, some of the areas having relatively little reported research appear to be of greater concern, both as to current problems and problems with longer range implications. A matter of critical importance, this should enlist the serious consideration of science educators everywhere, particularly those who are in a position to direct research.

Another aspect of the broader pattern of research needs consideration. At present, considerable attention is being directed toward the problem of on-the-job research for science teachers. Some who are developing plans for this type of research hold the belief that part of it could very well be done by teachers and directed toward solving some of the troublesome problems that now confront science teaching.

Granted that such a program of research could be effected, it would be of only limited value if each research worker merely picked up some small, fragmentary problem and pursued it narrowly. The program could, however, make a significant impact on the general improvement of science teaching if it were planned and carried out as a frontal attack on broad basic issues with teams of investigators working on a definite pattern of studies.

Many millions of dollars are being spent annually to improve science teaching in America. Some of this money comes from private sources, but most of it comes from the Federal Government. This means that the Congress of the United States and an imposing segment of our industrial economy believe that science teaching in this country is exceedingly important. It implies further that they have discerned critical problems currently facing the Nation, which are deeply rooted in our science teaching, and that they are determined these problems shall be solved.

The science teaching profession is confronted with a challenge of no mean proportions. We must assume the leadership and direct the programs in such a way that the teaching of science will be upgraded to the level that is demanded.

Basic research is of greatest significance in the long-range improvement of science teaching in America. Without it, little progress can be made. The peripheral and fragmentary nature of some of the current unpatterned research in this area will not produce the sound data needed for the present and long-range improvement of teaching.

More urgently right now, perhaps, than at any other time in the history of science teaching in America, high-level groups need to act concertedly to do the following:

1. Determine the basic issues, problems, and need for improvement (both present and long range) in science education.
2. Critically evaluate presently available research findings in terms of the issues, problems, and needs defined above.
3. Designate areas of science teaching where more research is needed.
4. Design a comprehensive plan of research in science education to solve the basic problems.
5. Formulate a program of cooperative team research which can carry out the necessary studies.

As one phase of such a broad program of studies in science teaching, the U. S. Office of Education has now begun the series of basic status studies listed below. The major purpose is to obtain data important for the solution of current problems and to accumulate findings from which trends can be assessed with some degree of reliability. Each of the studies will be repeated at regular intervals:

1. *Science and Mathematics Teaching in the Public High Schools of the United States.*
2. *Science and Mathematics Teaching in the Public Junior High Schools of the United States.*
3. *Science and Mathematics Teaching in the Public Elementary Schools of the United States.*
4. *Science and Mathematics Teaching in the Teacher Training Institutions of the United States.*

Section III. Bibliographies

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PS-15-58