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Analysis of Research in the Teaching of Science

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by

Ellsworth S. Obourn

and

Charles L. Koelsche

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Foreword And Acknowledgments

THIS PUBLICATION CONTINUES the annual series of bulletins begun in 1950 as a cooperative undertaking between the National Association for Research in Science Teaching and the Office of Education. The present bulletin summarizes and interprets the research in science education from July 1956 to July 1957.

The improvement of teaching in science, as in all other subjects, depends to a large degree upon the extent to which the findings of research are translated into action by science consultants and classroom teachers. The purpose of this bulletin is to assemble the research findings in science education in such a form as to be most useful for this and other purposes.

Over the years since 1950 the series of publications resulting from the joint efforts noted above has received favorable comment and wide distribution. The bulletins have become established documents in the research literature of general education as well as of science education.

At no other time in the history of science education in America has there ever been a climate so favorable to the immediate and long-range improvement of the subject as now. Through the efforts of the National Science Foundation and many independent industries and foundations, millions of dollars are being made available annually for upgrading science teachers from all levels. The passage of the National Defense Education Act by the 85th Congress has provided additional millions of dollars over a 4-year period, part of which will be available to State and local school systems for strengthening science instruction.

In this framework the role of research in science education assumes ever-increasing proportions. Without the guidelines which sound research can supply, the millions of dollars now available for improving science instruction will not be able to yield their maximum potential. It is hoped that this publication and others in the series can provide some basic findings to that end.

The Office of Education is grateful to the deans of graduate schools, to the directors of research in State departments of education and local public school systems, and to the many other individuals whose contributions have made this bulletin possible.

The Office is also grateful to the General Chairman and the chairmen and members of the three committees of the National Association for Research in Science Teaching listed below.

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ANALYSIS OF RESEARCH IN THE TEACHING OF SCIENCE

Introduction

What research in the teaching of science was completed between July 1956 and July 1957? What findings and conclusions resulted from these studies? What implications do these findings have for the improvement of science teaching in the schools? In what areas was the research during this period concentrated? What important areas appeared to be neglected? What directions are indicated for further research?

To assist in getting answers to these and other questions, the U.S. Office of Education in cooperation with the National Association for Research in Science Teaching continued the annual study which has been carried on since 1950. The association maintains a standing committee to review and summarize the research. Science teaching at the elementary, secondary, and college levels is represented by separate sections on the standing committee.

The committees made a meticulous search of the book, pamphlet, and periodical literature for the period July 1956 to July 1957. The issues of more than 50 magazines which have carried published research in science education were reviewed. Frequent use was also made of other sources such as the Education Index. In addition, the committee members reviewed abstracts of unpublished studies in science education which are obtained annually by the Office of Education. Inquiry blanks for these unpublished studies were mailed to over 900 institutions and individuals who have knowledge of current research work in the field of science education.

From these two sources the master list of research studies was made. The studies reported in this bulletin were selected from this master list by applying a set of criteria (see pp. 33–34) which the National Association for Research in Science Teaching has established for the evaluation of research in science teaching.

The work of the committees was handicapped by the fact that, in both the published and unpublished studies, they were for the most part working with secondary sources, such as abstracts and articles, rather than with original documents. The chairmen of the three committees, the chairman for the National Association, and the chairman for the Office of Education accept full responsibility for any errors of category or interpretation in applying the criteria for selecting the studies.

Some studies were eliminated by this evaluation process, because they failed to meet the criteria. It is entirely possible that these would have met the criteria if the abstracts and published articles had been prepared with that purpose in view.

Section I. An Examination of the Research in Science Teaching

RESEARCH FINDINGS must be translated into effective action by school administrators, science consultants, and classroom teachers if they are to make an impact on the improvement of instruction. The research reported in this section has been classified first into three categories; namely, elementary level, secondary level, and college level. Within each of these categories there is a further breakdown which attempts to cluster the studies around those problems of science teaching to which they contribute.

Each study is identified by author and also by a letter and number in parentheses following the author's name. The letter indicates the particular subsection of section III (Bibliographies) of this bulletin where the study is identified, listed alphabetically by author, and numbered. For example, "Simon (E 8)" refers to item 8 in the subsection for the elementary level. In the same way, "Easter (S 4)" and "Combs (C 9)" refers to items 4 and 9 in subsections for the secondary and college levels, respectively.

Research on the Elementary Level

The studies reviewed by the elementary level committee were taken from the pamphlet and periodical literature of the period July 1956–July 1957; and also from the abstracts of unpublished studies collected by the U.S. Office of Education for the same period. For preliminary analysis, 13 studies were selected from these sources, 1 from the periodical literature and 12 from the abstracts of unpublished studies. This number represents a decrease from the 19 studies reported in the last survey.

Of the 13 studies, 8 met the criteria, see pp. 33–34) and thus qualified as research studies suitable for inclusion in the present bulletin. Three have been classified as curriculum studies, three as learning studies, and two as teacher training.

Studies Related to the Curriculum

Cuno (E 1) attempted to determine from such sources as courses of study, teachers' manuals, and textbooks in elementary science for children, what specific content materials in science to teach children in the kindergarten and primary grades (1–3).

The major problem of this study was to select the appropriate subject matter and from this to prepare learning experiences for the grades involved. Selected courses of study, elementary science textbooks, and teachers' manuals were analyzed. From the analysis the learning experiences for the children were built.

The important findings from this study were (1) that more background material on specific science concepts is needed for teachers in the kindergarten and primary grades; and (2) that more selective science concepts and related learning experiences are needed for children in these grades.

Pella and Solberg (E 4) sought to determine "What can one fifth-grade class in Beloit, Wis., learn about atomic energy?" Thirty-three fifth-grade children had instruction in atomic energy from their regular teacher through books, TV programs, a filmstrip, and bulletin board materials; and from a professor of physics from a local college, who gave supplemental talks. The children posed certain questions about atomic energy which they wanted answered and then used the resources noted above to find the answers. The children presented reports, prepared bulletin board materials, held discussions, and constructed an apparatus to demonstrate a chain reaction.

Before starting the study and again at the close of the study, each child wrote a paper on what he knew about atomic energy. The two papers of each child were then compared.

From this study the following conclusions were drawn: (1) Fifth-grade pupils are interested in atomic energy. (2) Boys and girls evidenced equal interest in the study unit. (3) Many differences were noted in the nature of the specific learnings achieved by individual pupils. (4) Fifth-grade pupils can learn many things about atomic energy as a result of systematic study.

Simon (E 8) conducted a study to determine whether or not space travel should be taught as a topic in elementary science. This topic, because of its newness, is not generally included in textbooks for the elementary level.

The study consisted of attempts to (1) present an understanding of problems scientists face as they attempt to conquer space, (2) identify the natural phenomena they encounter, (3) seek experiments to be used to give children an understanding of the difficulties and obstacles space scientists and space travelers face, and (4) locate sources of information in the Los Angeles area which would be helpful to the teacher in stimulating a class in a study of space travel.

The findings showed: (1) Many of the concepts involved in the study of space travel are actually the same concepts that are studied in the usual elementary science program and only the point of reference needs to be changed. (2) The intense interest currently expressed by elementary school pupils should be utilized by the inclusion of a space-travel unit in the science program of the elementary school.

Studies Related to Learning

The conditions under which children learn most readily and to the greatest degree continue to be a perplexing educational problem. Munter (E 5) conducted a study which was designed (1) to note and describe developmental patterns of responses to questions of a cause-and-effect nature in the field of science, and (2) to determine how children's thinking in this field develops with regard to age, experience, and formal training.

Five questions of a cause-and-effect nature in the field of science were given to 90 pupils in each of grades 3, 4, 5, and 6. The pupil responses to these questions were recorded and then analyzed qualitatively. Later these responses were quantified with scores ranging from 0 to 4, depending on their degree of correctness. These data were organized and statistically analyzed and graphic representations were made.

The findings of the study were that: (1) The correctness of a response tends to increase with the age of children, (2) responses may differ greatly among children of the same age, (3) the correctness of responses made by an individual child varies from question to question, (4) there is no definite pattern in the type of responses among different grade levels, and (5) the depth of response tends to increase with age-and-grade level.

Garvey (E 2) conducted "An Investigation To Determine the Stability of Science Interests of Five-Hundred Grade School Children" in the city of Providence, R.I.

A questionnaire was constructed, using as a basis the eight "Major Science Area Concepts for the Fifth Grade," appearing in *Science Experiences in the Elementary School*, grades 4, 5, and 6, published by the Department of Research, Providence Public Schools.

The questionnaire was administered twice in a period of 5 days to 500 fifth-grade children in 10 elementary schools (public and parochial) in various geographical and economic areas in Providence. The coefficient of correlation between the responses of the first and second administrations of the questionnaire was calculated to determine whether there was any indication of stability in children's science interests.

The Spearman rank-order coefficient of correlation was calculated to be 0.99. This is indicative of a very high stability between the choices made on the first and second applications of the test instrument. To determine whether the frequencies of response in this questionnaire investigation were significantly different from those which would result if only chance were operating, the chi-square test was applied to the results of the first administration. The results were found to be significant at the 1-percent level. It was therefore considered safe to assume that some factor other than chance was operating. This other factor could be called a preference or an interest factor.

Johnston's (E 3) study sought to find "the relative achievement of the objectives of elementary school science in a representative sampling of Minnesota schools."

The problems considered in the analytical survey were to determine (1) to what extent the objectives of elementary school science were being achieved in Minnesota schools; (2) what pupil, teacher, and teaching situation factors contributed to the achievement of these objectives; and (3) what are the implications for the education of elementary teachers.

In the conduct of the study, questionnaires were sent to 478 superintendents of Minnesota elementary schools and to a proportionate stratified random sample of 87 Minnesota fifth-grade teachers. Science activity logs were kept and submitted by a subsample of these teachers. The fifth-grade pupils were pre- and re-tested on science materials. Appropriate statistical treatment involved cluster sample analysis for estimation of population means, analysis of variance and covariance, and the "T" test of the significance of means.

The findings of the study revealed that: (1) There were significant gains between pretest and retest means on the science test in 58 of the 87 fifth-grade classes; (2) the difference between mean gains of 3 IQ groups (over 120, 95–115, below 90) on the pretest-retest, was not significant; (3) the number of years of teaching experience was the only teacher or teaching situation factor which showed a statistically significant relationship on the science pretest-retest (0.05 level).

The following less-than-optimum conditions in fifth-grade science teaching were revealed by the survey: (1) The tendency to emphasize biological science at the expense of physical science; (2) the emphasis on textbook reading and discussion as a teaching method and the limited use of experimental and laboratory activities, directed observation, and research reading; and (3) the fact that pupils with high IQ's did not gain significantly more on the science tests than did pupils with lower IQ's.

Studies Related to Teacher Education

There are many persistent and recurring questions related to the education of teachers for elementary science. Some of these are the following: (1) What difficulties do elementary teachers encounter that prevent the elementary science curriculum from functioning as well as it should? (2) Are science courses in the teacher education departments of our colleges inadequate in that the teacher's training does not carry over and function in the classroom? (3) Is there a lack of interest? (4) Is there a lack of direction on the part of public school administrators?

A study was conducted by Piltz (E 6) in this area. The purpose of the investigation was to determine what factors, in the opinion of classroom teachers, handicap science teaching in the elementary school, and what relationships, if any, exist between the aspirations of teachers and the difficulties they think they face.

A questionnaire was submitted to a random sample of elementary school teachers in an attempt to identify recognized difficulties encountered in science teaching. The reliability and validity of the questionnaire and the conclusions drawn from its use were tested by a variety of appropriate statistical techniques.

Conclusions drawn from the answers to the questionnaire were checked through personal interviews with a sample of teachers and through classroom observations and discussions. Among the major findings were the teachers' beliefs that—

1. They were handicapped by a lack of physical facilities such as work and storage space, equipment, and utilities.
2. They were incompetent in such teaching techniques as selecting and interpreting content and developing attitudes in children. (Specifically, 75 percent of the teachers had difficulty in helping children discover facts for themselves.)
3. They made too frequent use of textbook reading as the primary method of instruction.

4. Those teachers with higher aspiration levels tended to teach more science but experienced the same difficulties as other teachers.
5. Their difficulties could be overcome through a better understanding of science and how to teach it.

Richardson (E 7) conducted a study concerned with the need for inservice consultation assistance in upgrading the science contributions to the objectives of elementary education.

The purpose was to assess the awareness of county superintendents of schools to the need for consultation services at the local school district level for upgrading the contribution of science activities to elementary school objectives.

The procedure was to ask each of 21 county superintendents the following questions: (1) Do your county schools need more contributions of science activities in the elementary school curriculum? (2) Do you feel the need for the availability of a list of science specialists who would be willing to help at the local school district level in upgrading the science activities in the elementary school?

The findings were: (1) Nineteen of the 21 superintendents answered "yes" to the first question; (2) 18 answered "yes" to the second question.

Research on the Secondary Level

The Secondary Committee included in this bulletin a total of 25 studies. Since seven of these are largely of a survey nature, they are not analyzed in this bulletin; they are, however, listed together as a group under *Surveys*. (See p. 23.) These surveys deal with various aspects of science instruction, including science offerings, enrollments, student preferences, and teacher preparation.

Of the 18 studies analyzed here, 3 are related to science teachers, 3 to curriculum, 4 to teaching procedures, 2 to measurement and evaluation, and 4 to achievement in science. Two are classified as miscellaneous.

Studies Related to Science Teachers

DeLoach and Boysworth (S 3) reported a study on the turnover of chemistry teachers in 52 Alabama high schools for the period 1942–53. All of the schools offered chemistry each year during those 12 years. Data were obtained from correspondence with schools and from records of the State department of education. Once obtained, the data were summarized in five tables. Some of the findings were: (1) Whereas 16 teachers taught chemistry for at least 10 consecutive years in the same school, 177 teachers taught it for fewer than 2 consecutive years. (2) One hundred teachers, nearly half the total (218), taught chemistry for only 1 year during the 12-year period. (3) Of the 47 schools having just 1 chemistry teacher on the staff each year, only 7 schools had no turnover during the period; one school had 8 different chemistry teachers in 12 years.

Teachers whose field of college specialization was not science but who nevertheless were teaching science in the secondary schools of Massachusetts during the 1954–55 school year were the subject of an analytical study by Victor (S 17). His purpose was to gain information about such teachers as persons and as guides to learning science. Accordingly, by means of questionnaires and interviews, he gathered taxonomic information on "converted" science teachers. He also obtained [gained] information, again by questionnaires, from their principals, and, for control purposes, from qualified science teachers throughout the state.

A total of 52 "converted" science teachers in 44 schools was studied. Questionnaires returned by their principals yielded information on 46 of them. The control group of qualified science teachers numbered 54. Statistical treatment of the responses in the questionnaires included the use of the T-test, the chi-square test, and the coefficient of correlation. Some of the findings are as follows:

1. Ten percent of the "converted" teachers had taken no courses in science, and 25 percent had taken just one or two semesters of any science. Since becoming "converted" science teachers, they had made little or no effort to study further in science.
2. Most of the "converted" science teachers were teaching science part-time, and were usually assigned to teach general science or biology. Their college majors generally had been social studies and physical education.
3. The "converted" science teachers did not use varied and effective instructional practices as often as the qualified science teachers. They also received less inservice training and had a lower degree of job satisfaction toward teaching science.
4. There was no difference in the extent to which both groups ("converted" and qualified) were aware of and taught for the varied objectives of science education when first beginning to teach science. Usually the "converted" science teachers were given little advance notice of their assignments to teach science.
5. The "converted" science teachers ranked methods of teaching science first in importance of help needed, while the qualified science teachers considered help in planning and organizing class work most important.

The "converted" science teachers ranked understanding science content low in importance.

6. The "converted" science teachers who received much inservice training used varied and effective instructional practices more often than those who received little inservice training.

7. The results of this study indicate that the "converted" science teachers need specific help and supervision in broadening their science backgrounds and their knowledges of techniques and methods of teaching science, in developing their abilities and skills in handling equipment and in expanding their concepts regarding the objectives of science education.

Problems and proposals connected with the supply of science teachers in New York City were investigated by Schenberg (S 11). Information was obtained from a questionnaire sent to 54 academic and 31 vocational high schools on questions related to unqualified teachers of science classes, future demand for teachers, substitute teachers lacking professional study, housewives who qualify as science teachers, inducements for substitute science teachers, and the identity of each married woman who had quit the profession since 1940.

The major conclusion of this study is that New York City high schools are facing a crisis in science education today. Fourteen suggestions for remedial action are listed.

Studies Related to the Science Curriculum

Blanc (S 2) made an analysis of high school biology textbooks "in order to determine the topics and areas receiving major emphasis by authors and publishers of biology textbooks for the high school level." His survey included 10 current textbooks in the field, selected at random, which carried a revision date of 1951 or later. The investigator found that, according to the 10 textbook authors, the most important areas in the field of biology are (1) conservation of natural resources, (2) study of the human body, (3) study of flowering plants, and (4) genetics and eugenics.

The individual topics which the textbook authors emphasized most were (1) structure and function of leaves, (2) foods and nutrition, (3) process of digestion, (4) principles of heredity, (5) physical factors of the environment, (6) inheritance in man, (7) evidence of change in evolution, (8) conservation of forests, (9) sense organs and sensation, (10) soil and water conservation, and (11) conservation of wildlife.

The mathematical processes needed in learning high school chemistry and physics were investigated by Lockwood (S 7). The purpose was to evaluate the "generally accepted belief that high school students often avoid chemistry and physics because of the level of difficulty of the mathematics content in these courses."

The author examined seven chemistry texts and eight physics texts intended for the secondary level in order to determine the mathematical processes needed for an understanding of all the texts and for the successful completion of all the end-of-chapter problems and activities. A tally was then made of these processes. All the textbooks reviewed had copyright dates between 1950 and 1956. He concluded that—

1. If the primary function of the first course in algebra is preparation for chemistry and physics, then emphasis should be placed on those mathematical processes used most frequently in these courses.
2. Students successfully completing the first course in algebra have no valid reason for avoiding chemistry and physics because of the level of difficulty of mathematical content of these courses.
3. The quantitative approach to chemistry and physics probably should be retained, since deletion of mathematics from these courses would deprive the student of valuable experience in the application of mathematics to problems in chemistry and physics.
4. The assumption underlying the belief that some students avoid chemistry and physics because of the high level of mathematics content of these courses is not valid.

Duplication in learning some basic principles of physics was investigated by Wise (S. 18). The study was undertaken to determine whether high school pupils who completed a course in ninth-grade general science could definitely increase their understanding of some basic principles of science by completing either a course in high school physics or a survey course in science at the junior college level. Also studied for possible duplication was the high school physics-junior college science sequence.

The area of heat was used as a sample topic in the study. After three preliminary tests were constructed and administered, a single, final test was constructed and administered to a broad sampling of students in high school general science and physics and in junior college physical sciences. An intelligence test was also given to all these students. Comparisons of the mean scores of classes were based on an analysis of variance between groups of students who had completed the various combinations of coursework in science. An analysis of covariance with the intelligence factor held constant was the basis for similar comparisons.

Wise's conclusions were the following:

1. Pupils who have completed a course in general science at the ninth-grade level may usually expect that their understandings of basic principles

of physics will be increased as the result of the completion of a course in high school physics. Such an increase in understanding may not, however, be expected to accompany the completion of a physical science survey course taken at the junior college level.

2. Pupils who have both general science and physics in high school may not expect that the completion of a survey course in the physical sciences at the junior college level will add materially to their understandings of the basic principles of physics.
3. Courses offering a survey of the physical sciences at the junior college level are no more effective than are courses in general science offered in the junior high school in developing qualitative understandings of the basic principles of physics. It seems reasonable to assume that a similar situation may exist with principles from other areas of science. It follows that in planning a program of general education, the major effort to develop qualitative understandings of important principles of science need not be postponed until the college years.

Studies Related to Teaching Procedures

In an experimental study, Scott (S 12) compared two methods of teaching 10th-grade general science. Specifically, he undertook to learn how the inductive method of teaching compares with the textbook method in developing pupil abilities to apply science principles. Students in the experimental group were matched with their counterparts in a control group on the basis of tests for mental maturity, reading ability, and knowledge in science. As students in the control group were being taught science by conventional methods, those in the experimental group were induced to study and discover relations between data in order to arrive at their own generalizations. At the end of the course, a test on scientific principles was administered to all. Comparisons were made between the initial and final tests given to both groups.

Scott's major findings were the following:

1. Both groups had a higher mean score on the science test at the end of the course than at the beginning.
2. In May (at the end) the experimental group made higher scores than did the control group.
3. According to the average scores, the gain of the experimental group over that of the control group was very significant.
4. A high correlation existed between mental age and scores.
5. According to the average scores, (*a*) boys in the experimental group outgained girls in that group; (*b*) girls in the control group outgained boys in that group.
6. The percentage of members of the experimental group who correctly answered those questions which required the application of principles

was higher than the percentage of members of the control group who so answered.

7. In 10th-grade general science, students taught by the inductive method made more progress than students taught by the textbook method.
8. Both methods of teaching 10th-grade general science are conducive to student growth.

Richter (S 9) analyzed drawing and learning in biology. The investigator sought information on two basic questions: (1) What is the relationship between the ways in which pupils see objective materials (charts) used in biology classes and the ways in which they learn the related subject matter? (2) What is the relationship between certain drawing characteristics and the possible personality components of the pupils? A large number of drawings of biological charts were secured from biology classes. Scores on verbal and nonverbal intelligence tests and on subject matter tests were also secured. After judges had rated the drawings for accuracy, an average accuracy score was calculated for each pupil. The author also rated all the drawings for the presence or absence of certain characteristics frequently considered as indicating aspects of personality. All data were finally analyzed by intercorrelational techniques.

Following are the findings of Richter's study:

1. There is some correlation between the average accuracy score and the scores from achievement and intelligence tests.
2. A few specific structural characteristics appear consistently in the drawings and are reliably correlated with measures of learning, drawing accuracy, and intelligence; they may give information about possible personality components.
3. The level of reliability seems to be affected by either the drawing motif itself, by something in the drawing situation, or by emotional factors in the pupils.
4. For some characteristics, variability is more highly correlated with good performance than is consistency.
5. A few psychological characteristics are significantly correlated with learning even though there is no logical reason for a correlation.
6. The findings suggest that visual, nonverbal aspects of intelligence may be important in learning from visual aids of all kinds.
7. There is some indication that the characteristics that predispose toward success in pretests differ from those that function in posttests. The author believes that this finding should be given further study.

The effects of using biographical sketches in teaching high school chemistry were studied by Easter (S 4). By using an experimental approach to the study, he gained objective information on "whether or not classtime should be taken from the teaching of chemistry fundamentals to give attention to the activities and scientific achievements of famous chemists." Two comparable groups of students were given instruction in chemistry similar in all respects, except that for the experimental group men and events in chemistry were emphasized by the presentation of biographical sketches.

Evaluated in this study was achievement related to the following six objectives: (1) Fundamentals of chemistry, (2) men and events in chemistry, (3) scientific method, (4) scientific attitude, (5) scientific interest, and (6) science activities and ambitions. For five of the six objectives, the exception being the objective of scientific interest, mean differences between the experimental and control groups were tested by the analysis of covariance technique. The IQ and geometry scores were control variables in the analysis of covariance tests of significance, and stratification was on the basis of sex.

The author contends that "it was demonstrated by this study that an increased emphasis upon biographical sketches results in an increase of (1) achievements in knowledge of fundamentals of chemistry, and (2) achievement in knowledge of men and events in chemistry." This study did not demonstrate that an increased emphasis upon biographical sketches results in an increase in (1) achievement in scientific method, (2) scientific attitude, (3) scientific interest, or (4) science activities and ambitions.

Simendinger (S 14) gathered experimental evidence on the ability of students to identify and evaluate assumptions in science. Her purpose was twofold: "(1) To determine the effectiveness of two teaching techniques upon growth in the ability of eighth-grade pupils to identify and evaluate science assumptions, and (2) to compare growth in this ability with growth in the ability to recognize nonscience assumptions and with growth in general problem-solving ability."

Nine classes were divided into three groups and for 18 weeks were taught general science by a problem-solving method. The method for each group differed: In group I teacher-planned experimental exercises and assumptions were stressed; in group II, pupil-planned exercises were used and assumptions were stressed; in group III (control), teacher-planned exercises were utilized, with no emphasis on assumptions. Pre- and end-tests in subject matter were given to each group in order to measure general problem-solving ability, the ability to identify science assumptions, and the ability to evaluate them. The gains were treated statistically through analysis of variance, using levels of IQ and sex as predictors and the teaching method as the variable. This analysis resulted in a three-by-three-by-two factorial design.

Simendinger's conclusions follow below:

1. Unless emphasis is placed upon science assumptions, combined with pupil-planned experimental exercises, the pupils will not be aware of these assumptions.
2. As a result of stress on science assumptions, combined with either teacher- or pupil-planned experimental exercises, students will improve in their ability to recognize nonscience assumptions and in general problem-solving ability.
3. A method using teacher-planned experimental exercises, stressing their assumptions, is superior to a method which also uses teacher-planned experimental exercises without the emphasis on assumptions, with regard to acquisition of subject matter.
4. No one sex or level of IQ appears generally superior to any other in any of the abilities studied.
5. A high correlation exists between the initial ability to identify science assumptions and the initial ability to evaluate them, while a marked relationship is evidenced between the developments of these abilities.

From her findings the author also noted certain implications:

1. It is possible to bring about significant growth in problem-solving ability in a normal teaching situation, without loss of subject matter.
2. Of the techniques employed, the teaching technique using most pupil participation and stressing science assumptions, yields the greatest growth in the ability to identify and evaluate science assumptions.
3. The abilities involved in problem solving, like the ability to identify and evaluate science assumptions, are distinct abilities.
4. The ablity to identify science assumptions is either very closely related to the ability to evaluate them, or is identical with it.
5. Training in science assumptions does not appear to transfer automatically to nonscience assumptions.

Studies Related to Measurement and Evaluation of Achievement

By employing film slides in color, Goehring (S 5) measured student abilities to solve physics problems. He set out to "construct and determine the reliability and validity of a film slide test designed to measure the ability of high school pupils to apply a scientific method of thinking to the solution of practical problems in the area of mechanics in high school physics." A preliminary test was prepared which originally included 107 film slides and 101 written items (multiple-choice type) intended to measure problem-solving ability.

After a panel of judges had rated each question and picture, 27 items were selected for inclusion in the test. A synchronized tape recording was then made to present orally the problem situations pictured in the projected slides and described in the questions related to them.

A second written test (minus pictures) of 26 items was prepared in order to determine the understanding of examinees of the principles of mechanics involved in the picture test. Both instruments were further refined after being administered to 412 students. An item analysis of the picture test included computation of item discrimination indices as well as item difficulty indices. The final film-slide test contained 24 items; the final principles of mechanics test, 20 items. After further testing, a reliability coefficient for the film-slide test was computed by analysis of variance.

Goehring found that it is feasible to measure through the media of projected film slides and related written items the ability to apply a scientific method of thinking in the area of mechanics in high school physics. Further, the tests used in this study appear to be sufficiently reliable and valid for classroom use.

Mallinson (S 8) reported an analytical study of the difficulty of different types of items included in certain New York Regents Examinations. Her purpose was to identify the types of questions which students avoided or found difficult in science examinations. The questions and answers selected for study were those included in part II (essay only) of the Regents Examination for biology, chemistry, earth science, and physics given in January and June, 1949 and 1950. Each item was studied to determine its type (recall, application, etc.), popularity, and relative difficulty. The data used in this analysis were part of a larger investigation involving the review of 31,317 examination papers.

The author's findings follow:

1. In general, this analysis seems to indicate that in all subject matter areas, the items giving the most difficulty were those that require an application of facts and principles—that call for an understanding of the applications of science in everyday life. In all four areas this type of item proved both difficult and unpopular.
2. The earth science and physics examination had fewer unpopular and difficult items than the biology and chemistry examinations. This may be due, at least in part, to the fact that fewer students elect biology and chemistry and those who do elect them are in general the more able ones.
3. It would appear that science teachers might well spend more time trying to help students understand the importance of scientific facts and principles in our daily lives, and to develop in them the ability to extend and

apply the knowledge they derive from their study of science. In short, teachers must help students understand relationships, rather than cause them to become mere walking encyclopedias of scientific facts.

Studies Related to Achievement in Science

Smeltz (S 15) conducted a retention study in chemistry. By using a sample population of students in five public high schools, he set out to "determine to what extent the learnings of high school chemistry acquired by pupils during the 11th year of high school were retained 1 year following the completion of the course."

Information was obtained through the use of standardized chemistry tests, a test for mental maturity, and a questionnaire. The chemistry tests were administered to 180 pupils of average intelligence, the first one before they took the chemistry course, the second when they had completed two semesters of study, and the third a year later. Achievement was measured by the differences in the raw scores of the first two tests; retention, by the differences in the raw scores in the first and third tests. Coefficients of correlation were obtained between achievement and retention, achievement and intelligence, and intelligence and retention.

The author's conclusions were these:

1. Pupils who had chemistry during the 11th grade retained approximately 68 percent of the course information 1 year following completion of the course.
2. The amount of chemistry retained was more closely related to achievement than to intelligence; intelligence was also related to achievement.
3. College-bound pupils retained more chemistry than terminal students.
4. Pupils enrolled in physics retained more chemistry than pupils not enrolled in physics.
5. Sex was not a factor in the amount of chemistry retained.
6. There was no significant difference in the types of learnings in chemistry retained.

Shepler (S 13) completed an analytical study dealing with achievement in secondary school science as related to pupils' relative preference for the field. Two complementary hypotheses were tested: (1) "On the same levels of mental ability, student accomplishment in science study increases with increase in degree of subject preference. (2) On the same levels of subject preference, student accomplishment in science increases with increase in degree of mental ability."

A total of 827 12th-grade students were given the *Terman-McNemar Test of Mental Ability*, the science subtest of the *Harry-Durost Essen-*

tial High School Content Battery, and a specially constructed instrument requiring them to make preferential choices of activities in the following 6 scholastic fields: science, languages, mathematics, social studies, fine arts, and the manipulative arts. The scores on these three measures were transformed into standard scores with common mean and variance. The data were analyzed in various ways, as were the scores of a special population subsample of 250 cases. The subsample members were chosen so that, in aggregate, they would form a normal distribution as to mental ability, but with chance variation as to years of science study and preference for science.

The following inferences and conclusions were made:

1. Both of the hypotheses stated above are supported in satisfactory degree.
2. As a predictor of science accomplishment in groups with heterogeneous mental ability, level of mental ability is the best indicator of level of potential accomplishment.
3. In groups homogeneous as to mental ability, level of preference for science study is the best predictor of an individual's potential accomplishment in science study for his level of mental ability.
4. Preference for science study was found to be somewhat higher with higher levels of mental ability, and higher for boys than for girls. Also, there is close correspondence between number of years of science study and level of preference for this subject.

Certain data reported in a former investigation [1] on the use of sound motion pictures in high school biology were given further study by Smith and Anderson (S 16). In the former study the investigators demonstrated that there were significant differences in achievement of different ability groups as a result of the use of educational films. It was demonstrated that there was a significant difference in achievement in the same direction for a group of high ability students and a group of low ability students, and that no differences were observed in a group from the middle ranges of intelligence. Since this result appeared to be an anomaly, it served as a stimulus and point of departure for the present study.

The authors hypothesized that two kinds of learnings were actually involved in the performance of the students investigated: that the superiority of the top group of students over their control group was achieved as a result of exceptional performance with principal-type items (on the *Nelson Biology Test, Forms AM and BM*); whereas, the superiority of the low group over their control resulted from superior performance with fact-type items.

Accordingly, items in the standardized test were classified, where possible, as fact-type or principle-type. The examination papers for

[1] Kenneth E. Anderson, Fred S. Montgomery, Herbert A. Smith, and Dorothy S. Anderson. Toward a More Effective Use of Sound Motion Pictures in High School Biology. *Science Education:* 40:49–50, February 1956.

both the high group and the low group were then rescored in order to obtain a fact score and a principle score. Already available were the intelligence test scores for each of the students in the two groups. The scores obtained were processed by using the analysis of variance and covariance techniques. Pretest scores and intelligence were used as control variables.

The results of the analysis yielded statistically significant differences in favor of the experimental methods of teaching biology principles. These differences were found in both the high and low groups. The differences among the instructional methods (as evidenced by the fact subscores) were not, however, significant for either group. The authors concluded that "the analysis offers no support to the hypothesis that two different kinds of learning were involved."

In another study, Anderson, Page, and Smith (S 1) studied "the lower and upper ends of the spectrum of academic achievement and intelligence among high school seniors for the purpose of gaining a better understanding of variability existing in groups frequently regarded as homogeneous." The specific purposes, all related to science achievement, were (1) to determine the percentages of seniors (both boys and girls) designated as exceptional in science achievement; (2) to determine the relative contribution of schools of varying size to the exceptional groups in science achievement; (3) to ascertain the degree of relationship existing between science achievement and achievement or ability in four other areas (mathematics, social studies, English, and intelligence) for the groups designated as exceptional in achievement or ability as measured by tests in those areas; (4) to describe the variability in achievement or ability as measured by the tests in the four other areas of those seniors designated as exceptional in science achievement.

The authors used data on the academic achievement and intelligence of 1,445 Kansas high school seniors who had taken the *Essential High School Content Battery* and the *Terman-McNemar Test of Mental Ability, Form C.* A senior was designated as exceptional if his score on a particular test (science, mathematics, social studies, English, or intelligence) placed him in the upper or lower 10 percent of the frequency distribution for that test. By segregating the upper and lower 10 percents on each of the 5 tests, the authors obtained 10 exceptional groups of seniors. Five test scores, sex, and size of school were tabulated for each of the 145 individuals in each of the 10-percent groups.

Following is a summary of the findings which relate primarily to science:

1. It is evident that, in spite of almost equal numbers of boys and girls in the original sample of 145 seniors, the upper 10-percent group in science contained a significantly greater percentage of boys than girls: 67.6 percent boys, as against 32.4 percent girls.
2. Apparently, size of school was not a factor in science achievement for the exceptional groups.
3. The seniors in the upper 10-percent group in science achievement tended to be more consistent as to achievement in the other areas tested than did the lower 10-percent group. The correlations of the scores in the other exceptional groups for mathematics, social studies, and English with the scores in science revealed that the upper groups were more consistent in science achievement than the lower groups. The only exception was in the case of intelligence, where both correlations were significant and positive and not significantly different.
4. Perhaps one of the most surprising features of the results was the relatively small overlap between mathematics and science. To some extent this is no doubt a function of the test which tends to emphasize the nonquantitative measures in science. Nonetheless, one might well have expected to find a considerably greater percentage of overlap.
5. The distribution of science scores for the lower groups in mathematics, English, social studies, and intelligence overlapped to some extent the distributions of science scores for the upper groups in these areas.
6. The upper group in science was more variable than the lower group as to achievement in mathematics and social studies. The reverse was true in the case of intelligence.
7. If one considers the average age of seniors at the time they took these tests to be about 17, the lower group in intelligence had deviation IQ's ranging from about 63 to 89, and the upper group, from about 120 to 143. In spite of this, 52.41 percent of the lower group achieved enough in science to place them in the lower-middle 40 percent in science achievement and 2.76 percent achieved enough to place them in the upper-middle 40 percent. Also, 42.76 percent of the upper group were sufficiently low in science to place them in the upper-middle 40 percent in science achievement. Five seniors, or 3.45 percent, placed in the lower middle 40 percent in science achievement and two seniors, or 1.38 percent, placed in the lower 10 percent.

   The same comparisons for the other four areas revealed slightly less variation for social studies, but some more variations for mathematics and English. These findings suggest that an acceptable criterion for exceptional performance in science and other academic areas must b sought outside the province of intelligence. Apparently there are forces other than intelligence at work leading to exceptional achievement in science and other areas, such as motivation, originality, and creativity.
8. The specific findings of the study point up more clearly than ever the phenomenon of individual differences in science achievement and in other academic areas, as well as the great variability within individuals. In a sense, this study documents to a considerable extent present statements of the kind of education essential in a democracy. The broadly stated purposes of education have emphasized the uniqueness of each

individual and the necessity to provide for the fullest development of his potentialities. This study also gives further evidence that these ideals are soundly conceived.

Miscellaneous Studies

Outdoor laboratories used in teaching natural resource conservation were studied analytically by Hibbs (S 6). Four related problems were investigated: (1) Where are the schools which have had notable success in developing and using outdoor laboratories? (2) What are the procedures which these schools employed in procuring and developing their outdoor study areas? (3) How are the laboratories being used in teaching conservation? (4) What are some guiding principles by which other schools might develop and use outdoor laboratories?

The author acquired detailed information on the four problems by reviewing literature, conferring with school personnel, and making firsthand observations of outdoor laboratories in five States (Michigan, North Carolina, Ohio, West Virginia, and Wisconsin). From the information gained, he formulated the following 10 principles:

1. The primary function of the outdoor laboratory is to provide learning opportunities necessary for implementing a sound conservation education program.
2. The school superintendent should assume responsibility for the outdoor laboratory and provide effective leadership for its development and use.
3. The school district should provide an appropriate land area for development and for use as a laboratory (as a place) to provide conservation learning opportunities.
4. A master plan should be prepared to develop and use the laboratory area.
5. A school should provide an opportunity for school personnel, pupils, parents, agencies, organizations, and other interested individuals to participate in planning, developing, and using the outdoor laboratory.
6. A qualified faculty member should be assigned the responsibility of coordinating the conservation education program, including development and use of the outdoor laboratory.
7. Inservice training, relevant to the use of outdoor study areas, should be provided for all school personnel.
8. The outdoor laboratory should be used for its intended purposes from kindergarten through high school.
9. The principal and other faculty members should cooperate in scheduling classes to provide maximum opportunities for use of outdoor laboratory facilities.

10. Conservation instruction in the outdoor laboratory should be planned to provide maximum opportunities for pupil participation in direct, purposeful experiences.

Rogers (S 10) made a determination of the prevalence of certain important general science misconceptions among 9th- and 10th-grade children. To do this he compiled a list of 74 science misconceptions and had a panel of judges classify each misconception in 1 of 3 ways: (1) has serious implication for the behavior of the individual; (2) has some implication for the behavior of the individual; and (3) has slight implication for the behavior of the individual. Five inventory forms were then constructed with 60 items each. One-third of the statements in each form were true in order that the students would not discover that they were being tested for misconceptions.

The forms were distributed widely among 9th- and 10th-grade science classes over the Nation, and 2,525 usable answer sheets were obtained. An item analysis was made of each misconception in the five inventory forms used at the 9th-grade level. Reliabilities of the five forms ranged from 0.745 to 0.824.

The following are some of the misconceptions which were believed by at least 50 percent of both boys and girls in the 9th and 10th grades of the sample, and were judged by the jury as having serious or some implication concerning children's behavior:

When tobacco smoke is blown through a handkerchief, the yellow mark produced is due to nicotine.

Gasoline burns in the liquid state.

There is always a calm before a storm.

Cream is heavier than milk.

Water always boils at the same temperature.

Water always freezes when its temperature is reduced to 32° Fahrenheit.

Frost is formed usually on the outside of a window.

If you can see many stars in the sky, we will have fair weather.

The sun is the center of the whole universe.

Magnets will pick up many kinds of metal.

Artificial ice is different from natural ice.

A rattlesnake always warns before it strikes.

Those who learn slowly retain more of what they learn than those who learn fast.

Those who threaten to commit suicide seldom do.

A barking dog never bites.

When a dog is fond of a man, it shows that person to be trustworthy.

A drowning person who goes down for the third time is lost.

Women with red hair are quick tempered.

Surveys

The following seven studies are largely of a survey nature and therefore are not elaborated, but rather only listed. They deal with such aspects of science teaching as enrollments, offerings, student preferences, and teacher preparation.

DELOACH, WILL S. Chemistry and Physics Enrollments in Tennessee High Schools. *Science Education*, 41 : 197–199, April 1957.

HUFFINGTON, PAUL E. Enrollment Trends, Offerings, and Teacher Certification in Science and Mathematics—Maryland County High Schools. Baltimore : Maryland State Department of Education, 1957. 16 p.

KERCHEVAL, J. W. Some Data on Science Instruction in Iowa High Schools. *Science Education*, 41 : 191–197, April 1957.

MCCAIN, WENDELL M. A Study of the Curricular Offerings, Student Enrollments, Teacher Preparation, and Teaching Loads in Physical Science in the Public Senior High Schools of the State of Washington. (Unpublished master's thesis, University of Washington, 1956.)

RANDALL, ROGER E. Science Teaching in Negro High Schools in Louisiana. *Science Education*, 41 : 65–68, February 1957.

———. Science and Mathematics Courses Offered in Certain High Schools of Louisiana. *Science Education*, 41 : 202–208, April 1957.

SCHENBERG, SAMUEL. A Study of the Science and Mathematics Courses Elected by the 1956 Senior Class, and the Number of Seniors Who Planned to Specialize in Scientific Fields in the Academic High Schools in New York City. New York : Board of Education, 1957. 31 p.

SHANNON, HENRY A. A Picture of Science Work in 632 White High Schools of North Carolina for 1955–56. Raleigh : North Carolina State Department of Education, 1956. 2 p.

Research on the College Level

This current survey of science education research at the college level covers 28 studies selected from the more than 80 which composed the original group. These 80 studies were obtained from the periodical literature and from the abstracts of unpublished studies collected by the U.S. Office of Education.

Most of the studies examined on the college level were not considered qualified for analysis in the present publication. It should again be pointed out, however, that some of the excluded studies would have met the criteria if the abstracts and published articles had been prepared with the research purposes in mind.

The 28 studies in this section fall into the following classifications: 4 related to curriculum; 4 to methods and resources; 13 to teacher education; 1 to status; 2 to texts, syllabi, and courses; and 4 to science personnel.

Studies Related to the Curriculum

Combs (C 9) studied the effect of certain curriculum patterns on student achievement in biology through comparing scores made by students who participated in a social studies oriented core, a science-mathematics oriented core, and a general science subject matter core, with student achievement in a "limited participation situation" (students without formal education in science). She concluded that: (1) The less education these students had in general science the higher the correlation between intelligence and achievement in biology; (2) students participating in the social science core scored higher in biology achievement than those who participated in the science-mathematics core; and (3) none of the core patterns appeared to have significant meaning for biology achievement.

Hilton (C 14) developed a technique for the selection of laboratory experiments in a college physical science course designed for general educational purposes. Six criteria were used for selecting 12 experiments which were then taught for 2 semesters. Using a student-evaluation technique he found: (1) 93 percent of the students considered the study of physical science valuable to nonscience majors; (2) 75 percent felt the laboratory work worth while and helpful in understanding science concepts; (3) 88 percent felt that the laboratory provided experiences in the application of scientific method; (4) in spite of student opinion, no statistically significant difference existed between the performance of those with and those without laboratory experience.

Sosinsky (C 23) used matched groups in "a comparison of an integrated course in general chemistry and qualitative analysis of 1-year duration with separate courses in general chemistry and qualitative analysis in a school of pharmacy." He found that on four of six parts of a general chemistry examination, the two groups were alike in achievement; however, the group taking the standard separate courses was generally superior.

Mendenhall (C 21) studied the growth of ideas leading to present-day concepts of the atom. He illustrates clearly the importance of the study of the history of scientific ideas and their place in the total intellectual history of man. He assembled a comprehensive bibliography related to the growth of the atomic concept and brought out the need for recognizing that concepts of the atom will undergo further modification and development.

Studies Related to Methods and Resources

Bainter (C 3) studied "the outcomes of two types of laboratory techniques used in a course in general physics for students planning to be teachers in the elementary grades." She attempted to ascertain the relative effectiveness of the traditional and problem-solving methods of instruction. Using matched pairs of students, she found (1) there was no difference between the two methods in teaching facts or generalizations; (2) the problem-solving method was superior in teaching the application of physics facts, principles, and generalizations in interpreting social and physical phenomena and in developing most aspects of critical thinking (although not the topic of measurement); (3) neither the traditional nor the problem-solving method was superior in teaching the use of apparatus.

Blackshear (C 4) investigated "the relative effectiveness of two methods of teaching biology." Two groups rotated between a traditional content centered method and a problem-solving or scientific method technique. The data were analyzed, using the analysis of variance and covariance, multiple correlation, and regressions.

The author's findings were the following:

1. There was no significant relationship between intelligence and the ability to use the scientific method.
2. The control group (subject or content) was more effective in applying principles.
3. No differences were detected in the relative effectiveness of the two methods.
4. There were no significant differences between the sexes in their use of the two methods or their ability to use the scientific method.
5. For effective teaching, science teachers should use a variety of methods.

Lahti (C 18) studied "the efficiency of the physical science laboratory in promoting a general education objective" or more specifically, "does the use of laboratory experiments of a problem-solving nature lead to a greater ability for designing an experiment and interpreting its results?" In making comparisons of laboratory teaching, he found that the use of problem-solving situations in the laboratory was effective in teaching an understanding of the scientific method; and that out of the four methods used, the inductive-deductive method produced more learning than the other three methods.

Crooks (C 10) used students in beginning college science courses as respondents. Through them, applying the Flesch scale, he found that they rated all of 20 well-known science textbooks (1) as "dull" on 7 of the categories, and (2) as "fairly difficult" on 2 of the categories. In addition, the author discovered that all 20 textbooks offered serious reading handicaps for the students.

Studies Related to Teacher Education

Bliss (C 5) conducted an opinion survey of college and high school teachers of science in regard to the preparation and certification of high school science teachers. There were 89 respondents to his questionnaire. He found: (1) A slight majority of the respondents agreed that the present 30 semester hours of required college science is sufficient preparation for teachers of general science; (2) a distinct group of the high school teachers regarded the 30 semester hours as inadequate for the preparation of teachers in biology, chemistry, and physics; (3) most of the respondents urged a 23–32 semester-hour requirement in each of the fields of biology, chemistry, and physics.

Brown (C 6) studied the "undergraduate professional education of elementary school teachers with special emphasis on the preparation for teaching science in the elementary schools of Mitchell County, Ga." On the basis of the returns to a questionnaire, she recommended (1) a greater amount of study in such science fields as astronomy, entomology, and earth science; (2) more specific preservice and inservice science courses for elementary school teachers; (3) less emphasis on foreign language and history requirements in the college program for elementary school teachers; (4) more emphasis on the necessity for continuous curriculum and course revision; and (5) more emphasis on preteaching or professional laboratory experiences in practical situations.

Bryant (C 7), in an effort to apply the "factors of effectiveness" developed in an earlier study by Warren M. Davis, used teachers who were considered to be "good teachers" of elementary school science, and discovered that, while these teachers accept the factors, few of their practices measure up to them. She found that her respondents indicated that: (1) Inadequate college preparation was the most pertinent reason for default of practice; and (2) college science teachers and others responsible for the education of elementary school teachers appeared to use other factors than those prevalent in the literature to make decisions as to what will be most useful in the preparation of teachers of elementary school science.

Carlin (C 8) attempted to discover "whether or not courses in chemistry and physics at the high school level contribute to success in beginning college chemistry." He found that both high school physics and chemistry contribute more to success in college chemistry than does either high school physics or high school chemistry when taken alone.

Fleck (C 11) studied courses in general college chemistry in an attempt to formulate aims for, and ways of improving, physical science courses as taught at the high school level. He concluded that many courses in general college chemistry are inappropriate for preparing prospective secondary school teachers of physical science. He urged that more emphasis be placed on integrated science courses for such teachers.

Gawley (C 12), in a three-way study, developed criteria for a general methods course in science education for New Jersey secondary school teachers. A questionnaire prepared from course topic listings in college catalogs, was sent to a list of colleges and universities to ascertain actual course offerings. Later, another questionnaire, which included 116 of the same topics as the first, was prepared and sent to New Jersey secondary science teachers for rating on a numerical scale. There were 495 replies. From them the author developed a proposed course in general methods for the New Jersey teachers colleges. The other two members of the research teams, Pregger (C 22) and Sutman (C 26), developed criteria for a special methods course in physical science education, and also criteria for a special methods course in biological science education at the same institutions.

Kruglak (C 17) sought to identify, by means of a questionnaire, "what kind of cooperation with colleges do high school teachers of physics want?" He found that these teachers want such cooperative activities as joint sponsorship of science fairs, frequent meetings, more information about careers in physics, and provision for special attention to gifted students.

McIntosh (C 20), in one of several evaluations of National Science Foundation academic year programs, found that—

1. A general feeling of apathy and/or antipathy pervaded the students in the institute group from time to time.
2. The feeling was increased by the rigorous lectures.
3. The original placement of most of the group in a single class in mathematics and biology was especially assailed as arbitrary, considering the diversity of preparatory backgrounds.
4. The physics course was held in high regard, but the first-semester chemistry course was berated (although the second-semester one was judged an improvement).
5. The engineering course was considered to have missed its objective.
6. Many of the group were dubious about the second-semester mathematics course.
7. Most of the group approved the avowed aims of the program but felt that the selection methods and other aspects needed improvement. They believed, however, that another year's program would be better.

Speak (C 24) studied by means of a questionnaire "the academic science training of Kansas secondary teachers of biology in relation to their expressed needs." He found that the teachers in class AA schools were better qualified than those in other class groups. He listed what these teachers considered to be the most needed and related courses.

Stollberg (C 25) paid a personal visit to 44 colleges and universities for the purpose of making "some observations concerning the education of science teachers." More specifically, his problem was to secure answers to such questions as: (1) What are effective techniques for recruiting increased numbers of science teachers? (2) What trends exist in terms of education for problem solving? Data and question sheets were sent ahead of the visit.

The 44 institutions were scattered over the entire country. The visits, lasting for 1 or 2 days, were used for interviews with workers in science and science education. From the study, Stollberg formulated a list of pressing problems regarding the recruitment and preparation of science teachers, such as: (1) How can science teachers keep up to date? (2) How can we identify the characteristics of excellent science teaching? (3) How can the shortage of science teachers be met?

Syrocki (C 27) considered the criteria for selecting, developing, and validating experience units in general biology for prospective elementary school teachers. He formulated a list of general biological principles and validated them by using elementary school teachers as judges. He formulated criteria for the selection and development of laboratory experience with biology and validated these by using college teachers as judges. Finally, he developed a rating scale for validation.

Studies Related to the Status of Science Teaching

Adams (C 1) sought to determine some of the basic changes in science teaching anticipated by science teachers. In a rather lengthy survey he placed particular emphasis on techniques of science instruction, on facilities for instruction, on provisions for superior students, and on predictions for changing trends.

Studies Related to Texts, Syllabi, and Courses in Science

Hennings (C 13) prepared a monograph designed to assist the science teacher in the effective consideration of the ecological basis of conservation. He developed a procedure for organizing materials around problem areas and emphasized ecological relationships and teachers' responsibilities regarding these relationships. He also suggested the implications for teaching.

Wallen and Mayor (C 28) collected information concerning "the contribution of colleges to the improvement of the teaching of science and mathematics in high schools." They sent a questionnaire to 809 4-year colleges with enrollments of over 500 each, seeking data on the following questions: (1) Are special subject matter courses offered to teachers only for graduate credit, to help them improve their competence in areas where they do not have the usual prerequisites for graduate study? (2) Are correspondence courses offered for teachers of science and mathematics? (3) Are offcampus extension courses offered for teachers in these areas? (4) Is other assistance offered to high school teachers?

A total of 727 replies were received. From them, Wallen and Mayor learned the following facts:

82 colleges offered subject matter graduate courses for teachers, some of the courses having no prerequisites.

679 offered no correspondence courses in science or mathematics.

28 offered correspondence courses in mathematics and 66 in some branch of science.

39 offered correspondence courses in professional education.

15 offered extension courses in astronomy, 82 in biology, 30 in botany, 28 in chemistry, 37 in geology, 113 in mathematics, 31 in physics, 15 in physiology, 28 in zoology, and 30 in "other" fields.

198 offered extension courses in professional education.

495 offered no extension courses.

These 495 colleges offered teachers other assistance, however, as follows:

Career guidance and help in classroom activities—419.

Lecture series open to inservice teachers—99.

Representatives at inservice conferences—165.

Scholarships—99.

Summer institutes—155.

Workshops—182.

Studies Related to Science Personnel

Ash (C 2) investigated the personality differences between college students majoring in the natural sciences and those majoring in the social sciences. He used the *California Test of Personality* with which to collect the desired data. Through the use of correlation techniques, he discovered that there were no statistically significant differences between the two groups as to (1) morale, (2) social adjustment, (3) family relations, (4) emotionality, or (5) economic conservatism.

Keller (C 16) assembled a large sample of answers to questionnaires on sex and related these to certain social and physical aspects of personality. She found that misinformation about sex is widespread among college students and recommended (1) teacher education in nondirective techniques as one base for establishing initial permissiveness, (2) extension of programs of sex education into adult groups, and (3) examination of the misinformation and misconceptions about sex from the anthropological and sociological viewpoints.

MacCurdy (C 19) developed a scientific aptitude inventory by using a jury of experts. He then tested the validity of the Westinghouse Science Talent Search as a basis for selecting potential scientific manpower replacements. Although the author did not attest the validity of the aptitude inventory, he did report the production of a self-administered test with directions for scoring and for interpreting results.

Hoyt, Ellsworth, and Katz (C 15) correlated grades in engineering physics with grades in the total engineering curriculum. They sought to identify the kinds of students enrolling in engineering physics, the extent to which performance could be predicted, and the prognostic value of such a course. The analysis, covering 439 students enrolled for 5 semesters, involved statistical computations, grades, scholastic aptitude scores, and educational histories.

Following are findings from the study:

1. On aptitude tests, students in a beginning course in engineering physics made substantially better scores than the average freshman.
2. The scholastic aptitude tests did not adequately predict achievement in physics or engineering.
3. A good predictor of final course grades could be the first three quiz scores (a correlation of 0.88 was found).
4. Course grades bore a close relationship to overall grade-point averages (a correlation of 0.88).
5. Course achievement was closely related to the possibility of graduation.

Section II. Interpretations and Recommendations

THE COMMITTEE of the National Association for Research in Science Teaching, which provided the basic material from which this report has been assembled, surveyed all issues, July 1956 to July 1957, of approximately 50 journals that from time to time have published reports of research in the field of science education. In addition, each committee reviewed the abstracts of unpublished studies in science education collected annually by the U.S. Office of Education from more than 900 institutions where studies in this field have previously been done.

Despite the fact that the search was as meticulous and inclusive as possible, it is probable that all studies in science education for the year involved were not located. Both the National Association for Research in Science Teaching and the U.S. Office of Education are committed to the policy of improving this service by profiting from the work of previous committees.

The interpretations, recommendations, and general considerations set forth in this section are those of the chairman of the three levels—elementary, secondary, and college—together with those of the two general chairmen, one representing the association and the other the U.S. Office of Education. Thus, to some degree the material in this section may reflect the points of view and personal biases of this group, although every possible safeguard has been used to insure maximum objectivity. For any errors of judgment or misinterpretation, the general chairmen accept full responsibility.

In the year under review, the difference in number between the studies reviewed and those selected for report was greater than in any previous year. Because of this it seems appropriate to list once again the criteria applied in the final selection of a study.

These criteria were drawn up by a committee of the National Association for Research in Science Teaching and later adopted by vote of its members. A copy of the criteria is in the hands of each committee member with full instructions as to its use. Although the personal judgments of the various committee members must of necessity enter into the final application of the criteria, they do operate to produce some degree of objectivity.

What Constitutes a Research Investigation in Science Education? [1]

The Overall Committee on Research of the National Association for Research in Science Teaching presents the following set of criteria for identifying research investigations in the teaching of science:

In order to be classed as a research investigation, a study must satisfy the criteria in one of three categories: A. *Experimental studies.* B. *Analytic studies.* C. *Synthetic studies.*

A. *Experimental studies* include comparisons of learning under different methods or conditions of teaching and all other investigations that involve pupils in one or more types of learning situations. They are characterized generally by the following steps or techniques:

1. A statement of a carefully and specifically defined and delimited problem.
2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
3. The development and use of an appropriate experimental design.
4. The collection of data and their treatment by appropriate statistical techniques.
5. A presentation of the findings and of the conclusions that seem justified by them.

B. *Analytical studies* are systematic attempts to determine from published materials, cooperating teachers, field studies, and other sources such factors as the aims that govern or that should govern the teaching, subject-matter elements that are taught, the relative importance of topics, facilities needed for teaching, and the like. Analytical studies are characterized generally by the following steps or techniques:

1. A statement of a carefully and specifically defined and delimited problem.
2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
3. A selection or invention of a technique appropriate to the problem and also one that provides means by which the validity and the reliability of analysis may be determined and maintained.
4. A presentation of the findings and of the conclusions that seem justified by them.

C. *Synthetic studies* are investigations in which various curricular materials, resource-use data, instructional suggestions, references, aids to teaching, and the like, are brought together into some unified pattern so as to be helpful in an educational situation. Synthetic studies are characterized generally by the following steps or techniques:

[1] *Science Education,* vol. 37, No. 1, February 1953.

1. A statement of a carefully and clearly defined need or objective.
2. The development of criteria for maintaining selectivity in the use of materials and the consistent use of the criteria in thorough studies of materials appertaining to the need or objective.
3. The development of a practical pattern or technique for organizing the materials that met the criteria.
4. The preparation of a substantial publication that summarizes the results of the studies.

It is obvious that the foregoing types, or categories, of research are not mutually exclusive in all respects. Analysis often enters into studies that are primarily experimental. Certain types of synthesis may appropriately be a part of an analytical or a curricular study. Leaders in science education should attempt to judge the merit of each study that is completed and to report to the Office of Education on their prepared forms all studies that qualify as research under one of the three categories. Attempts should also be made to report all other studies that although not readily classifiable, are nevertheless thorough, substantial, and definitely constructive.

Guybert P. Cahoon
Francis D. Curtis, Chairman.
Charlotte Grant
Betty Lockwood Wheeler

Elementary Level

In attempting a critical assessment of the research in elementary science reported for the year 1956–57, one should first note that two important documents bearing on this subject have been produced in recent years. The first of these is entitled *What Research Says About Science in the Elementary School*[2] and the second, *Elementary School Science: Research, Theory and Practice.*[3]

Elementary science has been recognized as a part of the school curriculum for more than 100 years. Before 1925 most of the emphasis was on nature study. Beginning in the mid-1920's with the pioneer research of Craig, there has been increasing emphasis on a type of elementary science program which more nearly meets the needs of young people than was true of the traditional nature study.

With the growing acceptance of a point of view which recognized that the interpretation of the physical environment is a natural facet of the development of young children, it became more and more apparent that much research was needed to establish a sound basis for

[2] By Gerald S. Craig. Washington: National Education Association, Department of Classroom Teachers, 1957.
[3] By Maxine Dunfee and Julian Greenlee. Washington: National Education Association, Association for Supervision and Curriculum Development, 1957.

the elementary science program. In the early years of this movement many experiments were conducted, but very few were supported by adequate research data.

As the movement gained momentum and as more school districts began to put elementary science into the curriculums, it became apparent that research was needed in such areas as (1) the purposes of elementary science, (2) the nature of the elementary science curriculum, (3) types of learning experiences in elementary science, (4) teaching materials and aids in elementary science, and (5) teacher education as related to elementary science. These areas supply a valuable base for assessing the current research in elementary science.

Over the years there has been an ever-increasing volume of studies devoted to most of the areas named above. Among these many have made significant contributions and a relatively few stand out as landmark studies. Between 1940 and 1950 there was a marked increase in the number of research studies in elementary science.

Since 1950, the interest in this area has increased a hundredfold and there has probably been more research done than in the preceding 100 years. Over the past decade much of the reported research has been directed toward (1) curriculum content and instructional techniques and (2) teacher education as it relates to elementary science.

The recent acceleration of interest and concern for science in the schools of America has been directed as much to the elementary as to the secondary level. Schools in increasing numbers are providing more time for elementary science as well as improved courses. School administrators, consultants as well as lay folk, are showing a quickened interest in the science program, and many State and local school systems are engaged in revisions of their courses of study.

The current activity in the revision of science offerings and content in the secondary school is creating a need for reevaluation of the instructional materials in the elementary school. The need for more specialized scientists has created a demand for better provisions for the pupil who is talented in science. This problem has sharp implications for the elementary science program as well as for research, since it has been fairly well established that young people who select scientific careers get their interests early, many of them in the last years of the elementary school.

Another factor which should influence the quality and quantity of research in elementary science is the increasing need for more science in the day-to-day lives of those who are not science specialists. As the influence of science and technology increases, the demands for more and better science both in the elementary and secondary schools will increase.

Thus it would seem reasonable to add to the listing of areas of needed research in elementary science suggested above such other areas as the following:

1. Early identification of pupils having science talent.
2. Provision for the talented pupil.
3. Development of interest in science.
4. Development of abilities in critical thinking through elementary science.
5. Development of desirable attitudes.

In the area of elementary science research for 1955–56, 19 studies were reported for analysis. Seven of these were classified as curriculum studies, 9 as learning studies, and 3 as teacher-education studies. The present report includes only 8 studies selected from the total of 19 identified by the reviewing committee. Three of these are classified as curriculum studies, three as learning studies, and two as teacher-education studies.

A careful examination of the total 27 studies reported in this and the previous analysis reveals only a few measuring up to the critical need for research in elementary science. Among them would be those studies devoted to science principles, to the development of problem-solving abilities, and to some aspects of teacher education.

On the other hand, studies related to textbooks and supplementary references, science in girls' camps, outdoor education, courses of study and the like, while perhaps of some limited local importance, can hardly be said to contribute much toward the long-range improvement of the elementary science program.

In the current analysis the curriculum studies of Cuno (E 1), Pella and Solberg (E 4), Piltz (E 6), and Simon (E 8) appear to be worthwhile contributions to the literature. This is especially true of the last two, which seek some evidence for the feasibility of introducing the concepts of atomic energy and space travel into the elementary curriculum.

Each of the three learning studies appears to have been directed toward basic issues in the field of elementary science: Munter's (E 5) toward children's thinking, Garvey's (E 2) toward the stability of science interests, and Johnson's (E 3) toward ascertainment of the degree of reaching objectives. It should be pointed out, however, that in the first two studies the samples were so limited as to make the general application of the findings somewhat questionable.

It would appear from this analysis that, except in a few cases, there is a need for those who are in a position to direct research in elementary science to set higher standards for the following aspects of the research: (1) The nature of the problems to be investigated, (2) the statistical design of the studies, and (3) the rigor with which the studies are carried out.

Secondary Level

The review committee brought together a total of 51 studies dealing with or related to some aspect of school science on the secondary level. Although this figure represents a considerable increase over the number of investigations considered for review last year, it is doubtful whether the increase represents a real expansion of research activity. A considerable number of studies reviewed this year were completed in the summer of 1956 before August 1; that is, before the beginning of the period currently under discussion.

Of the total studies reviewed, only 25 are included in the current report. Twenty-six studies—51 percent of the total—were judged by the committee to be unsuited in relation to the established criteria. Eleven of these were rejected because they did not come within the limits of research as defined. The majority of rejects, however, were discarded because the studies violated various requirements of sound research. Some of them lacked orderly plans, either for securing data or for determining their validity. Some of them, in other respects sound, presented conclusions which were overstatements of the actual findings. Other studies in this group were eliminated for having attempted to prove the obvious or for having utilized selected data to prove a position long since established.

The number of investigations by academic professionals, that is, science educators employed in academic institutions, about equaled those by degree candidates. Those two categories of investigators account for nearly all the research considered.

The committee derived its material from chiefly two sources: three issues of *Science Education* and the abstracts sent to the U.S. Office of Education. Only eight research reports were found in other journals, and only one of these was accepted for review. Three additional studies were reported in research bulletins of boards of education.

According to the three broad classifications of research recognized by the association, the 18 studies described in the current review may be grouped as follows: 3 experimental, 14 analytical, and 1 synthetic. The 7 survey-type studies listed at the end of the review fall, of course, in the analytical category. These status studies, dealing with enrollments, course offerings, and teacher loads, represent the dominant investigative interest during the period under review.

Regarding its review activities this year, the committee wishes to make the following observations:

1. For excellence in dealing with one or more (in some cases, all) of the following aspects of craftsmanship in educational research—choosing a significant problem, validating data, using statistical analysis, and reporting—the studies of these investigators are noteworthy: Anderson, Page, and Smith; Mallinson; Simendinger; Smith and Anderson; Victor; and Wise.
2. Insofar as the studies reflect the science courses which our secondary schools actually offered during 1956–57, one can say that surprisingly little curriculum experimentation was attempted throughout the Nation.
3. Many studies are being completed which merely duplicate the work of former investigators. Some of the duplicates appear to be little more than exercises in research technique rather than serious attempts to add to our fund of information about science education.
4. If candidates for the degree in M.S., M.A., and M. Ed. are required to conduct research and write theses for their degrees, then their institutions have a responsibility to help them learn the methods of scholarly investigation and reporting.
5. Science educators speak with confidence in recommending problem solving as a desirable teaching objective. However, experimental psychologists have encountered difficulty in identifying the many ramifications in the complex of mental activities and emotions involved in problem solving. We in science education must use extreme care in conducting research on problem solving in view of the complexity which has been recognized by experimental psychologists in dealing with this area.

College Level

Even though the National Association for Research in Science Teaching and both reviewing committees have defined and categorized science education research, an overview of the college level research reported in this bulletin indicates that further efforts in this direction are necessary. It must be granted, however, that college-level studies in this area do not readily lend themselves to orderly schemes of classification.

In the earlier years there was an intense fervor among such men as Curtis, Downing, Powers, Craig, Pieper, and other forward-looking science educators for systematic teacher-education research in the areas of methodology, learning theory, curriculum, and the like. These men gave systematic attention to procedures, concept and principles formation, the social implications of science, problem-solving techniques, and they even promoted the formation of bureaus and centers for research in science education. They wrote many convincing articles on the advantages and importance of research activity, both to the field and to the individual investigator. Although some of their techniques, judged by present-day standards, may appear a little bewildering, these researches exhibited a great eagerness to invent new methods and designs. Tests, scales, experiments, statistical methods, and the like were then so new that they often assumed the major role in investigations rather than a minor role as useful tools, aids, or devices.

Much of the research reviewed for possible inclusion in this analysis does not represent improvement over those earlier efforts. There is too little awareness of the need for research involving the observation of groups as groups, their structure, interaction, and dynamics; or of the need for research in the elements of observable behavior or appropriate methods of analysis of group data.

Review of the pertinent literature pointing to the need for an investigation is often inadequately done, if at all. Library research, methods of citation, and recognition of the frontier studies are all too frequently of a casual nature and inadequate scope. The case study, as a method, especially in an anthropological frame of reference, is overlooked or absent. Also overlooked or absent is recognition of new techniques for analyzing data.

There is a conspicuous absence of new experimental designs, and of progressive elimination of the person-to-person matching techniques as a significant factor. There is too little research based on the assumption that research may be more effective if conducted by those responsible for putting it into action. There is great need for more emphasis, not only on what people learn but also on how they learn; for emphasis on the learner rather than on teacher techniques; for more emphasis on process and less on product and things; for greater emphasis on group research, cooperation in planning and evaluation, and unity rather than diffusion. The psychologist, statistician, and science educator must learn to work together more closely, and in a more coordinated fashion.

In a recent review of college level research in science education covering the past 20 years, Miles and Van Deventer[4] say the following:

> Most of the research in the teaching of college science has been for introductory courses—these studies have focused on instruction by television; the objectives of science teaching including fundamental subject matter principles, scientific methodology, and scientific attitudes; the retention of learning; sequent courses; laboratory; status, content and trends; and competencies desirable for instructors.

[4] Miles, Vaden C. and Van Deventer, William C. Research in Teaching College Science, *College and University Bulletin*, vol. 11, No. 6, March 1959.

General Considerations

There appears to be considerable evidence to support the contention that in general the number of investigations in science education has been increasing over the past few years; yet for the past 2 years the number selected for this annual survey has decreased in every category. In 1955–56, 19 studies were reported in elementary science, 22 in secondary science, and 40 in college science. This made a total of 81 studies. The present report contains 8 studies for the elementary level, 18 for the secondary (in addition, 7 surveys were listed) and 28 for the college, making a total of 54.

The personnel concerned with the selection and evaluation of these studies are fully aware of the shortcomings inherent in the process used and, moreover, feel that the criteria cited earlier in this report may not be the best that could have been used. Granting all of the above, however, it is still difficult to understand why there should be such a sharp decline in studies reported on each level at a time when an increasing number of research studies is being conducted.

The need for good research studies in science education has never been more critical than at present, when so many organizations and agencies involved in some aspect of long-range improvement plans are seeking guidance from research findings. The pioneer researches of men like Powers, Craig, Downing, Curtis, and others have been mentioned earlier in this bulletin. These men were deeply concerned with research on some of the broad and unresolved issues of their day. They carried on this research as a part of their academic responsibilities.

When one considers the large number of outstanding leaders in science education today who are qualified to do research, as compared with the number during the time when the men named above were active, it becomes apparent that there has been a sharp decrease in research studies from this source. An examination of the 54 studies analyzed in this bulletin will reveal that most of the studies have been done either by classroom teachers or by students writing theses. Few have been done by professors of science education.

Most of the studies reported appear to have been done as partial fulfillment for advanced degrees. No doubt this accounts for much of the fragmentary character of the research and for its narrow local interest and limited application.

The comments above are not to be taken as criticism of such studies. Rather, more of them should be encouraged, for they do make contributions to the solution of many local problems. It is also quite probable that the persons conducting such studies will, through their experience, be better qualified and will be stimulated to attack some of the broader problems that confront science teaching.

At a time when science and technology are becoming dominant factors in the culture, there is need that science teaching should realize its fullest potentials. And yet there is an overwhelming body of evidence to indicate that this is not now true. Millions of people are influenced by superstition and unfounded belief. Other millions are preyed upon by charlatans who seek to take advantage of the low level of scientific literacy of the public mind. Somehow science education must break through this barrier and become more functional in the lives of people. We must find the reasons why science education does not now achieve more of the outcomes which it seeks. And once we find the causes, we will need to find ways to alleviate the conditions and make the necessary improvements.

This is only one area of science education, that of learning, where many deeply involved issues lie. Others could be mentioned which are of equal or greater importance. These pose the broad and significant problems for research in this field which call for the best talent that can be found in science and allied areas. The broad unresolved issues must be isolated, the cluster of problems requiring solutions must be defined, and the hypotheses must be stated and tested.

Only when these steps have been taken will researchers in science education be in a position to conduct studies which have significance for the steady improvement needed over the next decade.

Recommendations

Based on this analysis of the current research in science teaching and on the general considerations discussed above, the following recommendations are made by the Committee:

1. That those responsible for directing research in science education attempt to focus on studies which are most likely to result in significant findings with broad implications.
2. That those responsible for directing research in science education hold to high standards in the statistical design, in the conduct of the studies, and in the interpretation of the research data.
3. That immediate steps be taken to define the major unresolved issues in science teaching.
4. That, once these major unresolved issues are defined, they be followed by a definition of clusters of problems which must be solved in order to resolve the issues.
5. That hypotheses be proposed for testing in the solution of the problems.
6. That all available research in science education be assembled and abstracted for the years following the last abstract (1939).

7. That available research bearing on the unresolved issues in science education be evaluated and that a bibliography be compiled under headings related to these issues.
8. That a comprehensive plan for coordinated research in science education be made, adopted, and put into operation throughout the country.
9. That specially designated centers for research on given issues be set up at several universities and appropriate lines of communication among them be established through a central clearing-house agency.
10. That able university scholars in the field of science education engage, in greater number than at present, in broad research studies as a part of their academic responsibilities.

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