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ABSTRACT
This report presents a summary of research in science education at the secondary level during the years 1965-1967. The report is organized around the findings of investigations in several areas, including teacher education, teacher and student characteristics, evaluation and educational objectives, instructional procedures and classroom organization, programed instruction, achievement, attitudes and interests, the culturally disadvantaged, science and society, and the administration of science programs. Science education researchers are provided with (1) background information for their own studies, (2) sources of material, (3) ideas for aspects of science education which should be investigated, and (4) opinions which might be relevant to their professional efforts. The bibliography of 183 documents lists both the documents included in the text of the review and other documents analyzed but not included in the review. (LC)

SCIENCE EDUCATION INFORMATION

REPORTS

RESEARCH REVIEW SERIES - SCIENCE
PAPER 1
A SUMMARY OF RESEARCH IN SCIENCE EDUCATION
FOR THE YEARS 1965-67, SECONDARY LEVEL

by

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September, 1969

SCIENCE EDUCATION INFORMATION REPORTS

The Science Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Center for Science Education. The Reports include five types of publications. General Bibliographies are being issued to announce most documents processed by the Center for Science Education. These bibliographies are categorized by topics and indicate the availability of the document and the major ideas included in the document. Special Bibliographies are being developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest area. Guides to Resource Literature for Science Teachers are bibliographies that identify references for the professional growth of teachers at all levels of science and mathematics teaching. This series will include six separate publications. Occasional Papers will be issued periodically to indicate implications of research for science and mathematics teaching. Research Reviews will be issued to analyze and synthesize research related to science and mathematics education over a period of several years.

The Science Education Information Reports will be announced in the SEIAC Newsletter as they become available.

RESEARCH REVIEWS - SCIENCE

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a two-year period of time. These reviews are organized into three publications for each two-year cycle according to school levels--elementary school science, secondary school science, and college science.

The publications are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Center for Science Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Your comments and suggestions for this series are invited.

Robert W. Howe
and
Stanley L. Helgeson
Editors

A SUMMARY OF RESEARCH IN SCIENCE EDUCATION

FOR THE YEARS 1965-1967, SECONDARY LEVEL

INTRODUCTION

The purpose of this summary is to provide an organization of the research in secondary school science education reported to ERIC during the years 1965-1967. Those reports that have been summarized were chosen because (1) they seemed to represent significant findings and because (2) they could be classified into a relatively small number of categories.

No effort has been made to summarize research methods except for a few unique procedures. What is presented is a summary of the findings of the research. The Bibliography includes many more items than are summarized.

As will be apparent, some of the studies reported could be placed in more than one of the categories. However, it is hoped that the organization of the studies will show up some gaps in research - gaps which should probably be closed by immediate efforts of researchers in science education.

TEACHER EDUCATION

Perhaps a way to begin the improvement of teacher education in science is to assess existing pre-service programs in order to determine their inadequacies and weaknesses. Several such studies were conducted during this period. Anderson (6) set up criteria to evaluate teacher training programs in five states and found the majority of these programs inadequate with respect to some of his criteria. For example, in most institutions students took less than fifty per cent of their courses in science and were not provided with breadth and depth in science. Many institutions lacked special science courses for prospective teachers. Nicholas (115) found that the pre-service education of biology teachers in general omitted BSCS content. Gallentine (54) found that high school biology teachers, for the most part, did not take courses appropriate for teaching modern high school biology. He recommended an increase in the number of biology courses in the undergraduate program. Skinner and Davis (142), in evaluating the preparation of earth science teachers in Ohio, found that the teachers' backgrounds were adequate but not impressive. All held bachelor's degrees, and almost one-fourth had earth science undergraduate majors. Most of the teachers had some credits in earth science. The teachers recognized their own deficiencies in preparation and attested to the importance of NSF summer institutes in upgrading subject matter competency. Bailey (9), while analyzing the problems of beginning junior high school science teachers in a regional study, found that two-thirds had not majored in science and over fifty per cent were deficient in subject matter courses.

Recognition of these inadequacies, and others, has led to research on methods to improve instruction in programs for teachers. Matthews (102), McLeod (111), and Yulo (183), in separate studies, used Flanders' interaction analysis techniques in teacher training. Yulo used data collected by the Flanders system to help interns study their teaching. Using the Flanders technique, Matthews identified changes in interns toward indirect teacher influence. McLeod trained science teaching interns in Flanders techniques. These interns showed a more rapid change toward indirect teaching than did a control group.

Van Houten (160) developed a checklist of essential laboratory skills needed to teach physics and chemistry. He recommended that self-instruction techniques for developing these skills be investigated.

In a study in which conventional pre-service preparation of secondary school teachers was compared with a training program that integrated professional content with laboratory experiences, Sandefur (134) found highly significant differences in teaching behaviors in favor of the experimental group.

Yager (180), in a detailed study involving eight teachers and their classes, concluded that differential teacher personalities had definite effects upon science content learning, critical thinking ability, understanding of science, and student attitude toward given science courses.

Hoffart (73) found that high school teachers profited from exposure to new science curriculum materials, including elementary school materials. In some cases this exposure resulted in the high school teachers serving as catalysts to bring about science workshops for elementary and junior high school teachers.

One impact of federal funds has been to give rise to many institutes and other projects in in-service teacher education. As a result, many studies related to the effectiveness of institutes for science teachers have been conducted.

Jorgensen (84), Irby (77), Horner (74), Bradberry (23), and Martinen (101), did separate regional studies of academic year and summer institutes. Jorgensen was concerned with the qualifications of applicants. He found that, in general, acceptees had higher qualifications than rejectees. The rest of the studies indicated that institutes apparently do upgrade the subject matter competency of teachers. Welch and Walberg (169), in a national study, noted that gains in knowledge of subject matter and in general understanding of science and its processes occurred as a result of participation in physics summer institutes. Piltz and Steidle (122) found that in the opinion of state science supervisors, Title III NDEA projects improved science instruction.

TEACHER AND STUDENT CHARACTERISTICS

The establishment of effective procedures in science teacher education is in large measure dependent upon the identification of the characteristics of teachers and pupils, and assessment of the effects of pupil-teacher interactions. For the most part, research efforts reported in this area have been unrelated to each other.

Mitias (105) studied problem solving behavior among prospective science teachers and found differences in problem solving patterns in a group of homogeneous subjects. He also found patterns of problem solving differing from one problem to another with the same subjects.

Lee and Cooley (97) used stored data from Project Talent to identify factors in the career development of science teachers. Physical science interest was found to be high in science teachers and low in other teachers. Social service interest showed a reverse trend; science teachers were low, other teachers were high. Mathematics information and physical science information were found to be high in scientists, moderate in science teachers, and low in other teachers.

Blankenship (19) measured the attitude changes of 55 teachers in BSCS summer institutes. He found that approximately 50 per cent of these teachers developed unfavorable attitudes toward BSCS laboratory activities. Further study is needed to find the genesis of these unfavorable attitudes.

Walberg (164) used the Reed Science Activity Inventory to characterize 725 boys and 332 girls in the twelfth grade from all parts of the U. S. It was found that the girls scored higher on academic, nature study, and applied life factors (animate aspects of science), whereas the boys scored higher on tinkering and cosmology factors (inanimate aspects of science).

Edgerton (50) sent questionnaires to 5330 Science Talent Search winners. He received replies from 1550 and had personal interviews with 136. He found that the selection procedures of the Science Talent Search, especially the anecdotal performance record, added significantly in the quality of the selection. There was substantial correspondence between choice of field as high school senior and actual occupation 15 years later. He also found that students who stayed in science came from larger high schools. Professors and teachers were a major influence on the career decisions of all occupational groups except physicians. Generally, this influence resulted from the teacher's attitude more than from his subject matter competence.

Welch (168) developed an instrument to inventory knowledge of processes of science. This instrument included 150 statements pertaining to the assumptions, activities, products, and ethics of science.

Brakken (25) studied intellectual factors among conventional and PSSC high school physics students to determine relationships between varying curricular designs and student aptitudes and aptitudinal patterns. The PSSC approach was found to be related to greater development of critical thinking ability, while a conventional approach was related to greater reasoning ability.

Smeltz (143) studied retention of learning in high school CHEM Study classes over a period of one year. He found that approximately 68 per cent of the knowledge was retained over the year. He also found that retention was more closely related to achievement than to intelligence. This finding is in sharp contrast to the usual "curve of forgetting."

The most concentrated effort in research related to teacher-pupil behaviors has been in the area of classroom verbal interaction.

LaShier (95), using Flanders' interaction analysis, examined the verbal behavior of ten student teachers and their eighth grade students. He examined the effect of teacher behaviors on student achievement in a BSCS laboratory block on animal behavior and on student attitudes. Student achievement gains and increase in favorable attitudes were found significantly related to indirect teacher influence.

In a study of seventeen high school physics teachers and their classes, Snider (147) noted that the verbal behavior of each of the teachers was quite consistent over a period of time, providing that all observations were taken during a particular type of activity, such as lecture, laboratory, or recitation-discussion. The study by Snider emphasized the need for further study of teacher verbal behavior during such periods as laboratory investigations.

Parakh (120) studied pupil-teacher interactions in high school biology classes. Eight biology teachers were studied and findings were (1) lecture classes had about 75 per cent teacher talk and 10 per cent pupil talk and (2) teacher-operations, in decreasing order, were stating facts, explaining, defining, and evaluating.

Kleinman (88) studied the effects of teacher questions on student gains in understanding science. Using an observation form for classifying teacher questions, the TOUS, and a questionnaire to determine teacher education and experience, she found that (1) approximately 50 per cent of the questions asked by teachers were memory questions, (2) teachers who ask more critical-thinking questions tend to ask fewer total questions, and (3) teachers who ask critical-thinking questions impart a better understanding of science to students.

Snyder (148) employed a three-dimensional category scheme in the analysis of the questioning behavior of gifted junior high school students and their teachers. Under controlled curriculum conditions, he found significant differences in the questioning behaviors of students and their teachers. He also found certain similarities and obvious differences between different classes of students and between different teachers. Both students and teachers demonstrated changes with time in the kinds of questions (both written and oral) they asked. The style of questioning appeared to be related to alterations in instructional modes and course content.

It seems evident that we know considerably more about teachers and teaching than we are making use of in our science teacher preparation programs.

EVALUATION AND EDUCATIONAL OBJECTIVES

Most of the reports in this area are concerned with the use of course objectives as criteria for evaluation. The reports may be considered in two parts: testing and curriculum evaluation.

Easley, Kendzior, and Wallace (49) studied changes in biology tests from 1948 to 1967. By using item analysis techniques they classified test questions by content, type of knowledge needed to answer, and processes used in arriving at the answer. They found that the older tests emphasized recall of facts whereas the newer tests emphasized interpretation of data, at least in a greater variety of areas than did the older tests.

Most of the research on testing, however, was concerned with the development of tests. Drumm (46), using science as a vehicle, developed a test to measure the ability of junior high school students to infer information using inductive and deductive processes. Krabill (92) constructed a test to measure the ability of students to apply biological principles in verbalized problem situations. Jeffrey (78) classified the objectives of chemistry laboratory instruction into six categories and developed tests, using a multi-media presentation mode, to measure objective attainment in three of the six categories.

The remaining studies involved summative curriculum evaluations.

Herron (69) compared the cognitive abilities (referring to Bloom's categories) of CHEM Study students with those of students in conventional chemistry classes using the Watson-Glaser test and a test which he constructed. He concluded that CHEM Study students were better able to make application of their knowledge than were conventional students.

Uricheck (158) proposed a research scheme for evaluating CBA and CHEM Study. The scheme called for the testing of four common objectives of CBA and CHEM Study by batteries of tests and long term follow-up studies.

Hutchinson (76) reported an approach to individualization of instruction known as STAC (the Science Teachers' Adaptable Curriculum) which utilized a broad selection of science investigations printed on Keysort cards. Teachers were given the opportunity to select the content and sequence of the courses taught to fit whatever criteria they wished. No significant differences were noted between the achievement of the experimental group and that of the control group which had been conventionally taught the previous year by the experimental teachers.

Wachs (163) utilized science source papers for supplementary home reading and class discussions to achieve significant gains in the understanding of science and scientists when compared with a conventional textbook-only course.

Similar gains were reported through the use of supplementary materials designed to be used with the BSCS Blue Version biology. Duke (47) found that classes using Springboards for Discussion, a set of materials using the overhead projector, magnetic audio tape, or both, experienced significant gains in the understanding of biology processes and procedures. Also noted was a slight decrease in the scores of the experimental group on the BSCS Comprehensive Final Examination, apparently as a result of using class time for the supplementary materials that otherwise would have been spent working on the regular BSCS content.

In the field of biology, Kochendorfer (93) and Barnes (10) developed checklists to evaluate BSCS classroom and laboratory activities. Using these checklists and selected tests, it was shown in both studies that there was a significant relationship between teacher behaviors and acceptance of BSCS objectives.

National secondary school science curriculum projects have been a major concern since 1959. In view of this, it is surprising that there has not been more research on curriculum evaluation. Especially disappointing is the lack of research on formative evaluation techniques which might be used in writing new programs.

At the junior high school level, six studies are of special interest. Quantitative aspects of physical science stressed in the FUNEPS (Fundamental Experimental Physical Science) curriculum reported by Smith (146) resulted in significant gains in I.Q., understanding about scientists, mathematical reasoning, quantitative physical science literacy, and teacher acceptance of a new program as compared with conventional classrooms.

Remick (129) found that a novel pairing of industrial arts and physical science yielded significant gains over a traditional science course.

Direct involvement in the learning process on the part of California students in the Montclair Science Project yielded significant gains over the conventional instructional techniques. Riner (131) reported that the southern California students in the study were judged on critical thinking and in subject matter knowledge in physical science.

DeVito (44) reported that students working with three units developed to aid in the understanding of scientific model-building showed an increase in understanding that was independent of either general ability or of the order of presentation of the units.

Fiasca (53) studied combinations of CBA Chemistry and CHEM Study Chemistry with PSSC physics in two-year integrated courses as opposed to their instruction as separate courses. No combination of chemistry and physics was found to produce differences related to any of three criteria (critical thinking, subject matter knowledge, and attitudes toward science and scientists) from the courses taught separately.

Hedly (68) evaluated the effectiveness of three 10th-grade science programs being used in the Manitoba secondary schools. One was an integrated PSSC-CHEM Study program, the other two were one-text courses. The PSSC-CHEM Study program resulted in the greatest student gains in understanding science, in content knowledge, and in favorable attitudes toward science and science classes. The PSSC-CHEM Study students did not show as significant a gain in understanding the role of scientists as did one of the other groups.

Most of the studies reported involved evaluation based either upon outside criteria, such as pre-determined "favorable attitudes," or upon conventional criteria, such as standardized tests. A more appropriate method of evaluation would be to determine how effective a course was in achieving its stated behavioral objectives. Thus far behavioral objectives have not been stated for secondary school science curricula.

INSTRUCTIONAL PROCEDURES AND CLASSROOM ORGANIZATION

An important trend in laboratory instruction is the teaching of inquiry by the use of open-ended investigations. However, there is not yet a firm basis of concrete evidence supporting the effectiveness of this practice. In attempts to evaluate different modes of laboratory instruction, several investigators have compared learning outcomes of open-ended inductive laboratory instruction with the learning outcomes of more deductive laboratory instruction.

Studying the effects of directed versus non-directed laboratory work on high school chemistry achievement, Rainey (127) found no significant differences between the performance of the two groups on tests of facts and principles of chemistry. However, on a performance test which consisted of giving each student a problem which could be solved only through using laboratory procedures and apparatus, a group of non-directed students performed significantly better than did the directed group.

Coulter (38), in an investigation comparing the amount of learning of students taught by inductive laboratory, inductive demonstration, and deductive laboratory in biology, found that there were no significant differences among the three groups in factual knowledge, application of principles, and critical thinking.

Brem (27) studied the appraisal of high school biology courses by Metropolitan Detroit students. In this study it was found that students had assigned a functional value to laboratory instruction and that they had an intense interest in the genetics and evolution of man.

Ledbetter (96), investigating student-centered teaching in high school chemistry, found that students learned as much subject matter in student-centered classes as in traditional classes. There was evidence that some students felt insecure in the student-centered classes and it was implied that this may have been due to their earlier conditioning in teacher-dominated classes.

Yager and Wick (181) made a statistical comparison of three groups of biology students in which the instructional emphases were on textbook-laboratory, multi-reference-laboratory, and multi-reference-laboratory with idea discussions. These instructional emphases produced different outcomes among the groups of students as measured by TOUS, the Watson-Glaser critical thinking appraisal, and mastery or achievement tests.

Olstad (118), in a study to determine if there were any differences in the effectiveness of biology instruction conducted in two-hour class periods and one-hour class periods, found that class period length and teaching method had no significant effect of mean student achievement in biology. However, two-hour class periods, with appropriate variation in instruction, produced greater achievement in those behaviors measured by a test of laboratory and problem solving skills. In addition, the two-hour groups reacted more positively to instruction than did the other groups.

Williams (173) compared two patterns of classroom organization: (1) a conventional class meeting five 50-minute periods per week with a class size of approximately 25, and (2) a varied class organization with five 50-minute periods per week and with provisions for students to work in large (50 students), medium (25 students), and small (12-15 students) groups, and to study independently. The results of the study indicated no significant differences in achievement between the two groups as measured by a conventional chemistry examination. The experimental group demonstrated significantly greater gains in interest in physical science as measured by the physical science sub-scale of the Thurstone Interest Schedule.

Winter, et. al. (175) found that achievement of students in experimental large group-small group (experimental classes ranged in size from 78 to 153 students for large group instruction and from 7 to 32 for small group activities) chemistry classes was significantly higher than achievement of students in conventional groups on the New York State Regents' examination and unit tests. Meiller (104) found no difference in the achievement of academic knowledge in biology and physical science between large and small groups, and no difference in retention of such knowledge. He also found no difference in attitudinal changes as measured by the Purdue Attitude Test.

Platz (123) indicated that ability grouping for below average students was more effective than ungrouped classroom organization for academic achievement on content exams. He found no relationship between students being grouped or ungrouped and teacher ratings of students' classroom performance. There appeared to be no significant relationship between the grouped and ungrouped students with respect to academic grades, interests, and understanding of the broad objectives of general science.

Hurd and Rowe (75), in a study of the relationship between small group compatibility and achievement in the BSCS Laboratory Block program, found that the performance of college-bound students in incompatible groups tended to be higher than the performance of college-bound students who were members of compatible groups. Performance of non college-bound students tended to increase directly with group compatibility.

Knorr (91) and Walker (165) reported studies of the effects of varying instruction in certain specific areas of science courses. An eighth grade unit using a charge-cloud model was prepared by Knorr and used in experimental classes to allow students to relate atomic structure to a set of concrete objects rather than to a set of abstractions to be memorized. The results indicated a significant difference in achievement between the groups on an atomic structure test constructed by the investigator, with the experimental group achieving the higher. Walker provided a procedure for predicting students' difficulty in balancing chemical equations on a mathematical basis.

An investigation by Kleppinger (89) involved constructing and evaluating a unit about atomic structure based on an historical and experimental approach. Significant differences in achievement were found favoring the experimental group over a control which did not use the special unit.

In a more general study of a specific aspect of science teaching, Schirner (137) analyzed the teacher-responses to student-questions and characterized them as positive or negative. He found that either type of response generally led to teacher action (rather than student action) and he, therefore, called both types of teacher response "terminal responses". He concluded that the use of such terminal responses is not an effective way to stimulate classroom discussion.

In another general study, Nasca (113) attempted to determine if science instruction by means of closed-circuit television had any effect on the recall of content by students. The results of the study indicated that the difference in student ability to recall factual information could apparently be narrowed down to a significant difference between "forced" and "voluntary" attention in favor of the "forced" or active student participation method. Verbal presentation of material by television was the least effective method in terms of stimulating factual recall.

Brandou (26) investigated the feasibility of making short film clips from existing longer films (the CHEM Study films) by having a group of experienced teachers evaluate the regular films for overall and segmented usefulness. He concluded that many existing films could be readily made into usable short clips.

PROGRAMED INSTRUCTION

Little research has been done to evaluate the effectiveness of programed instruction in science education. With the attention that is being given to various methods of individualization of instruction, however, it is clear that much more research should be undertaken in this area. Research methods range from careful statistical studies to opinion surveys. For the most part, the results are far from definitive, and in some cases, e.g. Anderson (8), are reported in such technical jargon as to be nearly incomprehensible.

Carnes (35) compared the effectiveness of programed instruction in problem-solving using open-ended laboratory experiments with non-programed problem-solving instruction employing lecture-demonstration only. The results of the study favored the non-programed instruction. However, he suggested that it is likely that differences between programing and non-programing methods may be attributable to the effects of other variables.

In a carefully controlled study, Eshleman (52) measured the effectiveness of linear programed instruction in comparison to conventional methods in the teaching of factual information in eighth grade science. The results of the study indicated that both methods of instruction produced significant gains in knowledge of the subject, both immediately and after a retention span of six weeks. However, measures of both immediate learning and retention revealed a significant difference in favor of the conventional group.

Schrag and Holland (138) used a programing approach in structuring a PSSC 16 mm film for classroom instruction. They found the programed film more effective in increasing achievement scores than the ordinary use of the PSSC film.

Smith (145) made a preliminary investigation of the use of "non-wordal" programing in the teaching of vector analysis. The programs utilized mathematical symbols, graphs, and diagrams, but no words. He compared groups of students who used the non-wordal programs with groups who used combined wordal-non-wordal programs and found little difference. However, this was reported as a pilot study and it certainly seems to merit continuation as a full-scale effort.

ACHIEVEMENT

Research in student achievement has dealt with both cognitive and affective changes. Studies in each domain have taken a variety of forms.

Studies are still being conducted in which it is found that student achievement on tests over familiar material is superior to that on tests over material not studied. Berry (17) found that although there was no significant difference between the achievement of PSSC students and that of traditional physics students, as measured by the Cooperative Physics Test, PSSC students did significantly better on the PSSC Final Examination than did the students in traditional physics. Moore (106) evaluated the effectiveness of BSCS as compared with traditional instruction of high ability ninth grade students. He found that the BSCS and traditional groups achieved equally well on the Nelson Biology Test, but the non-BSCS group did not achieve as well as the BSCS students on the BSCS Comprehensive Final Examination.

Altendorf (4) made a comparative study of student achievement in high school chemistry using CHEM Study and conventional approaches. The results of the study indicated no significant differences between the two groups as measured by a conventional chemistry test. This study stopped short, however, of answering the question of how well the CHEM Study students were reaching the unique objectives of the CHEM Study materials.

The Test on the Understanding of Science (TOUS) continued to be popular in studies comparing achievement in different curricula. Crumb (42) found evidence indicating that a significant difference in understanding science, as measured by TOUS, existed between students who studied PSSC physics and those who studied traditional physics, the difference favoring the PSSC group. Trent (155), also using the TOUS, showed that when the variables of prior science understanding and mental ability were statistically controlled there was no difference between students in PSSC physics and those in traditional physics.

One major study was done in which four types of chemistry courses were compared. Pye and Anderson (126) compared students from CHEM Study, CBA, Conventional, and Other (essentially advanced placement) courses. The test used represented what 35 research, industrial, and academic chemists felt were some important aspects of chemistry which beginning college students should know. The exam consisted of four parts: general principles, numerical calculations, special applications, and logical reasoning. The results showed that, as expected, the Other group led all groups in total achievement. The Conventional group, with one exception, showed greater achievement than the CBA group; CBA students showed greater achievement in logical reasoning. Conventional students outperformed CHEM Study students only in applications. CHEM Study students, in general, outperformed both Conventional and CBA students.

A so far relatively little-used device, a cognitive preference test, was used by Marks (100) to compare conventional chemistry students with CBA students. The CBA group showed a preference for critical questioning of information and for identification of fundamental principles. The conventional group showed a preference for recall of facts and terms. Both groups showed equal preferences for practical applications. The possibilities of differences between groups being due to ability and achievement were tested and rejected.

Numerous studies have been conducted in which the effects of various factors on achievement were investigated. Cain (34) collected data related to mathematical aptitude and achievement, achievement in biology, and verbal reasoning ability for two groups of tenth grade biology students, one in BSCS Yellow Version and one in a traditional program. Results indicated that the relationships between mathematics achievement and achievement in biology for the two groups did not differ significantly, but the relationship between mathematics aptitude and biology achievement was significantly higher for the BSCS group.

Walters (166) found that grade placement in biology (ninth versus tenth grade) was not a significant factor in student achievement, as measured by the Nelson Biology Test.

In a study related more to the affective domain, Butler and Boyce (33) investigated the influence of teacher-centered versus student-centered methods of instruction. Both kinds of instruction produced significant upward changes in achievement, but only in the student-centered class did personality factors such as intellectual efficiency and self-assurance undergo significant alterations.

Buffer (32) studied the effects of test interpretation in counseling upon the science achievement of pupils. Some pupils were counseled positively, some were counseled neutrally, and a control group was not counseled. The positively-counseled group experienced a significant increase in achievement. Counseled pupils, either positive or neutral, experienced greater achievement than non-counseled pupils. It was concluded that the achievement and self-perceptions of pupils who lack interest in a subject area can be affected by counseling.

A study by Redfield and Atwood (128) was based on the rationale that it is important for the student to acquire science knowledge through involvement as a scientist. Consistent with this rationale, an experimental group used curriculum materials which were designed specifically to teach students how to interpret data from experiments in physical science and to present a scheme that students could use to initiate other experiments on their own. Students in conventional classrooms showed low ability in stating researchable problems, proposing methods of attack, conducting experiments, and graphing results. A high percentage of those in the experimental group were able to state researchable problems, propose methods of attack, conduct experiments, and use data to make graphs.

Gunnels (64) reported a study designed to determine whether inferences that students in grades four through nine drew from science tests corresponded to the three-stage development of reasoning as postulated by Piaget in his analysis of mental development. Procedures were used that allowed evidence to be presented which compared the development levels of thought processes which were used by successful and unsuccessful problem solvers. From the data obtained it was concluded that the frequency of use of the formal level of operational thought in solving science problems increased with chronological age, mental age, and actual grade level, and was higher for successful problem solvers than for unsuccessful ones. In general, the data collected supported Piaget's findings that children go through various stages of development with each level a necessary prelude to the following level.

By this period in the history of science education we have not yet begun to effectively use specific course objectives stated in behavioral terms to assess achievement. Behavioral objectives are not the total answer to problems in student evaluation since they, so far at least, are almost exclusively related to cognitive learning. Many studies cited in this paper resulted in interesting findings in the affective area of learning. Surely we must learn to measure achievement in this area more effectively.

ATTITUDES AND INTERESTS

More and more researchers have turned to the affective domain in analyses of science teaching and science curricula.

In what was essentially a sociometric analysis, Westmeyer (170) found that when students were permitted to organize their own laboratory by selecting working partners, student choices were related to grade point average, general group work ability, and laboratory proficiency of the students chosen. Individuals also chose more often as laboratory partners those students with whom they had previously been associated. Instructor ratings of students on individual laboratory proficiency were highly correlated with choice scores.

Dyasi (48) investigated the affective behaviors of gifted students in day-to-day classroom and laboratory situations. Examination of data suggested that students showing personal involvement in the designing of experiments also tended to do so when they were engaged in laboratory investigations and in the discussion of collected data. He also reported that there was a parallel between involvement and desirable scholastic habits of the gifted students in general.

In an analysis of attitude predictors, Wick and Yager (171) found that a portion of students showed a severe decline in favorableness of their attitudes during the course of their science instruction. This group was not balanced by a comparable group which exhibited a gain in attitude. The students' attitudes were found to be greatly dependent upon the teacher, but not influenced greatly by grades. They also found that no group was consistently pro or con in attitude toward science throughout the secondary school science sequence.

Jensen (79) attempted to find to what extent the interests and attitudes of students were related to achievement in high school chemistry. Wynn and Bledsoe (179) found that interest change is unique and independent of such factors as intelligence, academic achievement, and home background. They suggested that if one desires to measure interest or interest change he must specifically use interest measures.

In separate studies of the science interests of high school students, Weaver and Derico (167) and Wynn and Bledsoe (179) found a high degree of stability, which seems to warrant the use of interest measures in selecting materials for courses and in the guidance of high school students.

An attitude scale developed by comparing the responses to a questionnaire by two groups of students was reported by Vitrogan (162). This scale was administered to a third group and statistically significant correlations were found between the attitude scale and the criterion measures.

The superiority of the Manufacturing Chemists Association experiments in regard to developing favorable attitudes was reported by Charen (36) in a comparison study of the relative effectiveness of the deductive process used in traditional laboratory materials with the inductive techniques employed in the MCA materials.

Cossman (37) found it possible to design and teach material which brought about broad changes in the literacy of students with regard to science and which also fostered the development of important scientific attitudes. Another successful effort involved the development of an interrelated course involving concepts of science, technology, and the social sciences which was reported by Crumb and Douglas (41). Also supporting Cossman's hypothesis was a study by Kimball(86) which measured the changes in opinions of Harvard Project Physics students concerning the nature of science.

CULTURALLY DISADVANTAGED

In an area of such great importance it is surprising that so few research studies were reported. Only two studies were noted which dealt with the disadvantaged child. Giddings (59) proposed to identify factors associated with different levels of science achievement among disadvantaged ninth graders of high intellectual ability. The unsuccessful students were from large families but with little difference from successful students in parental educational background or socioeconomic level. The successful students had more reading materials and study areas, devoted more time to assignments, had a more favorable attitude toward science, and made better scores on objective tests in other subjects.

The effects of cultural disadvantage on the ability of ninth grade general science students to demonstrate six problem-solving skills were studied, a· compared to non-culturally disadvantaged students, by Vaughn (161). The culturally disadvantaged students scored significantly better on four of the six problems and it was concluded that the disadvantaged students were not typical or that they were intellectually superior.

ADMINISTRATION OF SCIENCE PROGRAMS

Moritz (107) conducted a study to ascertain the levels of responsibility that are operative in the making of decisions in science education and to isolate those factors which influence decisions. The results showed that administrators and science teachers were in comparatively close agreement about where the responsibility for various decisions in science education lies. Moritz found that certain duties of administration were assumed by persons at each of the four administration levels established in the study.

Apparently, then, according to the one study reported in this area, the frequently heard complaints by science teachers about their school administrative arrangements have no basis in misunderstandings of levels of responsibility. There seems to be agreement on <u>who</u> should make decisions, though perhaps not on <u>what</u> decisions should be made.

SCIENCE AND SOCIETY

Two research studies concerning attitudes about science and the science teacher were reported. Highsmith (71) used an opinion questionnaire to find what image of the high school science teacher was held by high school students, parents of high school students, non-science teachers, principles, and scientists. For all groups except students the image was predominantly male. The scientist group held a more negative image while the student groups were more positive. The image held by each group was more negative than each group desired. While geographical location and parental occupation did not seem to affect the image of the science teacher, grade, sex, and socioeconomic factors did seem to affect the image to a small extent.

Kimball (87) studied the question of whether qualified science teachers understand science in the same way that scientists do. Controlling for amount of college education, he found that teachers and scientists demonstrated a comparable understanding of the nature of science. Philosophy majors showed closer agreement with a model for science understanding than did science majors or scientists, especially in regard to science methodology. Science teachers and philosophy majors did not differ significantly in agreement with the model.

Political science was the source of the conceptual framework for a study of the factors influencing the adoption of PSSC Physics by four high schools. Dionne (45) reported that the four categories of change process described by Gordon Mackenzie's Curriculum Change: Participants, Power, and Process were present in every school. Of special note was the role played by individuals, the complete lack of systematic evaluation of the innovation, and the lack of policies designed to facilitate innovation.

The drop in physics enrollment in the secondary school was surveyed by Abegg and Crumb (2). Their findings seemed to indicate that many of the reasons commonly given for students' not taking high school physics might well be discounted. Such reasons as low intelligence, lack of success in chemistry, and the reputation of PSSC Physics were not substantiated. Lack of interest and no relevance to the students' planned vocation were the reasons given most often by the students themselves.

CLOSING

If this summary of research has provided investigators with:

1) background information for their own studies,
2) sources of material,
3) ideas for aspects of science education which should be investigated, or
4) opinions which might be relevant in their professional efforts it has been successful.

The one thing, at least, that should be apparent from this effort is that such summaries must be prepared more frequently. The effective researcher needs to be at the forefront of activity and this requires that he have access to summaries of completed research and, if possible, even of on-going research.

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