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ABSTRACT

The review of science education research for 1981 includes individual analyses of approximately 400 dissertation abstracts, journal articles, research reports, and papers presented at conferences. The organization of the review is topical. Topics include: (1) status studies of science education; (2) cognitive style; (3) Piagetian studies; (4) student characteristics, attitudes, and interests; (5) teaching strategies and learning; (6) teacher use of instructional materials and learning; (7) instructional technology; (8) evaluation instrumentation and methodology; (9) curriculum research; (10) teacher education; and (11) science supervision. A rationale is provided at the beginning of each section for the particular studies clustered into it. A summary is provided at the end of each section. It is noted that 1981 was the beginning of publication of many meta-analyses on specific subjects in science education. Since these studies have the potential of "clouding" the summary of findings of a particular year, most of these meta-analyses were placed in the summary of each section. (Author/JN)

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION--1981

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PREFACE

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a one year period of time. These reviews are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Clearinghouse for Science, Mathematics, and Environmental 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.

Readers' comments and suggestions for the series are invited.

Stanley L. Helgeson
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FOREWORD

The review of science education research for 1981 includes individual analyses of approximately 400 dissertation abstracts, journal articles, research reports, and papers presented at conferences. The articles have come primarily from journals such as <u>The Journal of Research in Science Teaching</u>, <u>Science Education</u>, <u>School Science and Mathematics</u>, <u>The Journal of College Science Teaching</u>, <u>The Science Teacher</u>, <u>Science and Children</u>, and some foreign journals. Other papers came from the ERIC Clearinghouse for Science, Mathematics and Environmental Education at The Ohio State University, Columbus, Ohio.

The organization of this year's review is topical. The topics include status studies of science education, cognitive style, Piagetian studies, student characteristics and learning, teaching strategies and learning, teacher use of instructional materials and learning, instructional technology, evaluation, curriculum research, teacher education, and science supervision. A rationale is provided at the beginning of each section for the particular studies clustered into it. A summary is provided at the end of each section.

This year was the beginning of publication of many meta-analyses on specific subjects in science education. The studies have the potential of "clouding" the summary of findings for a particular year. Most of these meta-analyses were placed in the <u>summary</u> of the section. The individual, creative, studies are still a <u>must</u> in science education research, however. Without them there could be no meta-analysis.

This review has been a monumental task and special thanks have to go to the people at the ERIC Clearinghouse at The Ohio State University for providing the materials for review and their many helpful suggestions; Dr. John Novak, at ERIC, who supplied me with details instantly when necessary; and my secretary Deb Maye for her invaluable assistance in typing the manuscript.

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION--1981

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STATUS OF SCIENCE EDUCATION - RESEARCH - ANALYSIS - NEEDS

This year, 1981, there were initiated several syntheses studies of research in science education. Meta-analyses of science education research were proposed by Anderson et al. (1981) and major research questions were identified and organized to provide a conceptual framework for the analyses. These meta-analyses have been completed, and further information has to be obtained by the reader through the published reports which should be available soon.

A significant question for the science education community is one of surveying researchers about priorities for research. Renner (1981) did just that and reported the following research areas in order of priority as given by NARST members: (1) learning strategies, (2) learning and development not related to Piaget's model, (3) student attitudes and values concerning science, (4) learning and development according to Piaget's model, (5) identification of content (concepts and processes), (6) goals of science education, (7) placement and sequence of content, (8) content of teacher education programs in science and education, (9) unified or integrated curriculum, (10) student inherent and cultural characteristics, (11) implementation of research, and (12) instructional technology. Robinson (1981a) also compiled papers presented at a BSCS conference focusing on research needs in science education.

Good and Fletcher (1981), after examining a series of research studies in science education, recommended that researchers report explained variance. They described methods that could be used to obtain estimates and indicated that they believed that these techniques would improve research in science education.

Yager (1980a), Yager (1980b), and Gallagher and Yager (1981) reported studies that provided in-depth analyses of overall needs in science education. The papers by Yager clearly lead to the conclusion that there is a crisis in science education. The paper on current accomplishments and needs in science education highlighted findings on the aims of science teaching, conditions of science teaching, and recommendations for the future (Yager, 1980a). As far as science education research was concerned, the paper called for new philosophical bases for research in order to test the validity of new conceptualizations and new directions. The paper on the crisis in science education presented results of an open forum in which 28 science educators discussed problems in science education and highlighted needed actions in both policy and research (Yager, 1980b).

Gallagher and Yager reviewed five research surveys on science educators' perceptions of problems facing science education and identified the following: (1) confusion and uncertainty in goals and objectives, (2) lack of vision and leadership in schools and universities, (3) absence of a theoretical base in science education, (4) poor quality teacher education programs, (5) inappropriate avenues for continuing education of teachers, (6) limited dialogue between researchers and practitioners, (7) declining enrollments, (8) poor quality teaching and counseling, (9) insufficient programs in science for the wide spectrum of students, and (10) public and parental apathy toward science.

The major synthesis of the large-scale surveys of science education that were done in the 70s was Project Synthesis, published as What Research Says to the Teacher, Volume III, edited by Harms and Yager (1980). Project Synthesis was designed to study and analyze the following major funded studies of science education:

Helgeson, S.L., P.E. Blosser, and R.W. Howe. The Status of Pre-college Science, Mathematics, and Social Science Education: 1955-1975. Volume I: Science Education. Center for Science and Mathematics Education, The Ohio State University, Columbus, 1977.

National Assessment of Educational Progress. Science: 2nd assessment 1972-73): Changes in science performance, 1969-73, with Exercise volume and Appendix (April 1977); 04-S-21, Science technical report: Summary Volume (May 1977). Science: 3rd assessment (1976-77): 08-S-04, Three national assessments of Science: Changes in achievement, 1969-77 (June 1978); 08-S-08, The third assessment of science, 1976-77, Released exercise set (May 1978). Also some unpublished data from the 1976-77 Science Assessment, Denver, CO: 1860 Lincoln Street.

Stake, R.E., J.A. Easley, et al. Case Studies in Science Education. Center for Instructional Research and Curriculum Evaluation, University of Illinois, Urbana, 1978.

Weiss, I.R. Report of the 1977 National Survey of Science, Mathematics and Social Studies Education. Center for Educational Research and Evaluation, Research Triangle Institute, Research Triangle Park, North Carolina, March, 1978.

Teams of science educators were selected to analyze the findings of the studies in terms of elementary science, biological science, physical sciences, inquiry, and science-technology and society. Major discrepancies in science teaching were found between what the evaluators established as the actual state and the desired state. Positive directions for science education were presented based upon the descriptions of the desired state of each area studied. Dramatic changes in directions for science education in the future were proposed, such as greater emphasis on technology, more and better teacher education, new curricular materials, translating research findings into action programs, better assessment techniques, and more support for exemplary programs in science education.

Mahmoud (1981) compared data on changes in the status of science education in 100 schools between 1970 and 1980. There were substantial decreases in total student enrollment in high schools, but only a slight decrease in students enrolled in the science classes. A greater variety of courses was offered in 1980; in particular, advanced placement or second year classes were more common. Emphasis on laboratory instruction decreased between 1971 and 1980.

Hodes and Morsch (1980) made a comprehensive study of science education in 183 two-year colleges and made recommendations for change.

Heyneman and Loxley (1981) re-analyzed International Educational Achievement in terms of evaluating each country separately instead of "averaging in" all countries. By using variables that were significant for the particular country, different results were obtained which significantly increased the variance explained by school effects. This variance tended to be greater in "poorer" countries.

White and Novak (1981) assembled the abstracts of research papers presented at the National Association for Research in Science Teaching Annual meeting at Grossingers in the Catskills, NY, into a monograph available from ERIC. The Summary of Research in Science Education for 1979 was done by

Butts (1981). The summary describes trends, new knowledge from research, and some tentative answers to persistent problems in science education. Research and trends in science education in Australia were reported by Power (1980) and the Western Australia Science Education Association (Proceedings..., 1981), covering a broad spectrum of activities and research in science education.

Olstad and Beal (1980) studied secondary science and mathematics teacher supply and demand in Washington State and predicted that the state faces a serious shortage of science and mathematics teachers in the immediate future.

Summary

The studies indicate that science education is at the crisis stage. Many people are involved in meta-analysis attempting to determine those teaching practices that lead to effective learning and positive attitude development. The science education community is examining itself! It is to be hoped that new goals, direction, and support will become available.

COGNITIVE STYLE

Cognitive styles have been described as unconscious habits by which a person perceives, solves problems, thinks, or remembers. The rationale for studies relating to cognitive style is centered around the concept of determining individual differences in students and then attempting to optimize learning. The kinds of problems that have been studied are those which examine how cognitive style interacts with instructional methods and materials, personality factors, intelligence, and attitudes.

K-12 Studies

Wareing (1981) studied the relationship between field-dependence-independence and scientific attitudes of 353 sixth grade students in SCIS. The test instruments were the Group Embedded Figures Test (GEFT) and the Motz Scale of Attitudes Toward Science and Scientists. There was no significant relationship between field-dependent and field-independent cognitive styles and attitudes toward science and scientists.

Jolly (1981) designed a study to determine whether biology students who were matched with their teachers in cognitive style achieved significantly higher mean scores on a cognitive test in biology than did biology students who were mismatched with their teachers in cognitive style. The GEFT was used to measure cognitive style of students and teachers. There was a significant difference between the mean achievement scores of students of field-independent and field-dependent teachers in favor of field-dependent teachers. Field-independent students also achieved significantly higher mean achievement scores than did field-dependent students, whether they were taught by a field-independent or a field-dependent teacher. Field-dependent students, however, taught by field-independent teachers achieved significantly higher mean achievement scores than did field-dependent students taught by field-dependent teachers. Jolly concluded that a teacher-student cognitive style match may not bring about the highest achievement in students.

Ridgeway (1981) determined variation in chemistry achievement in relation to cognitive style, sex, and mathematics anxiety of high school students. The instruments given to 467 chemistry students were Suenn's Mathematics Rating Scale, Hill's Cognitive Style Interest Inventory, and the ACS-NSTA Examination in High School Chemistry Form 1977. Findings included: no significant differences between sexes on chemistry achievement; a small but significant negative correlation between mathematics anxiety and chemistry achievement; significant differences between the sexes on cognitive style, but no significant differences between the sexes in mathematics anxiety. When chemistry achievement was regressed on mathematics anxiety, sex, and cognitive style, the proportion of variance accounted for was 10 percent. She concluded that chemistry achievement was conditional on the degree to which some cognitive style elements were present and on the degree of mathematics anxiety.

College Level Studies

Isham (1981) explored the relationship between cognitive style and mode of feedback in learning theory. The GEFT was given to 248 community college students who were then placed in an experimental design in which the dependent variable was the determination of the color of an object when viewed under various conditions of lighting. It was found that students receiving feedback scored significantly higher on achievement than did the nonfeedback group and field-independent students scored significantly higher than did field-dependent. A mathematical model was developed which was related to academic performance, cognitive style, mode of feedback, level of confidence, time spent on feedback, and number of practice problems completed. This model improved the explained variance by nine percent over the original independent variables.

Lycon (1981) explored the feasibility of predicting academic achievement in prerequisite Anatomy-Physiology classes for prospective nursing students and the medical surgical nursing classes for students enrolled in a diploma program. All of the students were given the Cognitive Style Map, the Nurse Attitudes Inventory, and the Interest-Preference Test. The criterion variable was a test score derived from each area of study. Results were: (1) a correlation coefficient of .541 between the Medical-Surgical Nursing Class and the Cognitive Style Map; (2) a negative correlation between the learning test score and the Nurse Attitudes Inventory; (3) a correlation of .951 between learning test scores of the Medical-Surgical Nursing Class and attitudes and interests toward nursing; and (4) no significant difference between teaching style (lecture, or audio tutorial) and attitude and interest. The researcher concluded that additional tests should be used to find better predictors.

The relationship of the black student's field-dependence/independence and achievement in science was examined by Henderson (1981). High achieving black students in science and high achieving black students in nonscience courses, plus their instructors in biology courses, at a predominantly black university were given the GEFT. The results indicated that most of the participants were field-dependent and that there was no relationship between either the field-dependence/field-independence of the student or the mismatch between the cognitive styles of the student/instructor and science achievement.

The influence of redundancy, analogies, and field dependency upon learning of scientific material from audiotapes was investigated by Wyllie Wydra (1981). The population studied consisted of undergraduate education students enrolled in six sections of two media courses. Test materials used were the Hidden Figures Test (HFT) to measure whether students were field independent (FI), intermediate cognitive style (ICS), or field dependent (FD); a slide tape to identify sense recall and preference; and two multiple choice tests to measure concept acquisition. Three testing periods were necessary: one to measure field dependency and aural vs. visual recall and preference; a second, to present an audiotape using redundancy and a nine-question list; and a third, (one week later) to present an audiotape using analogies and a nine-question test. Results of the analyses showed no significant differences in: (1) information acquisition by FI, ICS, and FD subjects when redundancy was used in instruction; (2) information acquisition by FI, ICS, and FD subjects when analogies were used in instruction; (3) aural recall of the FI, ICS, and FD subjects; (4) visual recall of the FI, ICS, and FD subjects; and (5) preferred sense recall of the FI, ICS, and FD subjects. Conclusions were that the use of redundancy and analogies assisted all learners in identifying relevant aspects of the material.

Griffin (1981) developed a multidimensional model of three cognitive styles and 16 personality types and related the model to the analysis of an electronic response, audio-tutorial system. Descriptive results indicated that the conversational tones, logical sequential organizations, and verbal reinforcement of the audio tapes appealed to the students with field-dependent, impulsive, leveling cognitive styles; the audiotapes alone appealed to the field-independent, reflective, and sharpening individuals; the self-instruction and learning guide questions related more to the field-independent, sharpener, reflective person; and the slides that were integrated with the audio tape in the electronic system were found to appeal to the field-dependent, impulsive, leveler cognitive style.

An interesting study on the relationship between cognitive style, intelligence, and instructional mode and achievement in college science students was done by Ritchey and LaShier (1981). Students in a community college biology course were given the <u>GEFT</u> and the <u>Otis IQ</u> test. Laboratory content was dissection of the fetal pig. Students in experimental laboratory sections received organizational schema for the memorization of anatomical information and practice in the identificatiom of structures by relative position. Students in control sections received no schema. Results of the study showed no direct relation between field dependence/independence and student performance on an anatomy practical when intelligence was controlled. The authors cautioned that a test of cognitive style may not substitute for a test of intelligence.

Teachers

Daloisio (1981) made an analysis of the relationship between cognitive style and the subject area specialization of secondary teachers in Connecticut. He gave the Hill Cognitive Style Interest Inventory to a random sample of 300 secondary school teachers. Results indicated that there were significant differences between English, science, mathematics, social studies, and art teachers, with mathematics and science being most distinctively different from the others. The author suggests that there are important implications for instructional methodology because of these differences.

Summary

The research demonstrates that a field-independent student has a slight edge over the field-dependent student in learning. More research needs to be done, however, on matching cognitive styles for teaching/learning situations.

PIAGETIAN STUDIES

A great number of studies were reported that added to the already rich assortment of science education research related to Piagetian cognitive development theory. While it is difficult to isolate developmental level from most learning studies, this reviewer attempted to do so because of the many studies that dealt with some type of student attribute and its relation to learning. Special categories receiving attention in this section are development and spatial ability; developmental level and science achievement; developmental level and student characteristics (other than content achievement); and developmental level, intervention techniques, and change in student performance.

Development and Spatial Ability

This was reviewed as a special category since several reports clustered around this concept. Elementary school children studying SCIS received special manipulative experiences and benefitted in the development of their projective spatial abilities (Cohen, 1981). Doody (1981) gave the GEFT and several Piagetian tasks to high school biology students and concluded that the poorer performance of females in spatial ability and science was due to a deficit in cognitive operational ability, rather than in perceptual or imagery abilities. Brendzel (1981) concluded from the results of spatial tests and proportional reasoning tests given to high school ninth and eleventh graders that there was a strong relationship between visual spatial ability and proportional thinking. Wilborn (1981) also found that eighth grade ISCS students classified as formal operational were field-independent in cognitive style.

At the college level, Seeber (1981) found that students who received special spatial skill training made significant gains in college physics scores. Bradley (1981) reported significant differences favoring students having slides and raised diagrams over those students receiving transparencies or DNA models in spatial visualization ability and level of cognitive development.

Developmental Level and Science Achievement

Piagetian studies continue to show results that have been consistent over the years. A study by Kargbo (1981) indicated that children could not understand the predator-prey relationship until they were, on the average, 12 years old. Davidson (1981) showed identifiable concept development about the human body which changed as children grew older, and which was consistent with Piagetian stage development. Shayer and Wylam (1981) learned that nine- and twelve-year-old students' understanding of concepts of heat and temperature were also directly related to their levels of development. Rowell and Dawson (1981) found that conflict instruction was effective in assisting eighth graders to conserve volume of noncompressible matter and to apply that knowledge to gas volume.

Contessa (1980) found that certain personality factors (Meyers-Briggs categories) were related to cognitive development. Contessa (1980), S.A.S. Smith (1981), W. B. Miller (1981), and Viravaidhaya (1981) provided data to show significant relationships between student developmental level and achievement in secondary school science. Further support for these findings was provided by Glass (1981a) who reported that formal cognitive skills were essential for the successful understanding of the heterotroph hypothesis in the Blue Version of BSCS.

At the college level, Wiseman (1981), Thornton and Fuller (1981), and Za'rour and Gholam (1981) reported significant relationships between level of cognitive development and student success in science courses or problem solving.

Developmental Level and Student Characteristics

Studies that involved characteristics such as sex, IQ, creativity, etc., in relation to developmental level, made up a large cluster.

Elementary School Level

Links between creativity and conservation tasks in elementary school children were found by Novik (1981).

Secondary School Level

Davis (1981) found no significant differences between developmental level and anxiety toward science in students in grades 9, 11, and 12. Padiila _et al_. (1981) obtained data from secondary science students showing that formal thinking and process skills were highly interrelated. McKenzie and Padilla (1981) reported that response patterns to correlational reasoning problems were more predictable and stable across developmental level than educational level. Tobin _et al_. (1981) found a linear relationship between the students' formal reasoning ability and scores on the Test of Logical Reasoning, but Newton _et al_. (1981) found no relationship between proportional reasoning and developmental level. Further investigations into reasoning of ninth and tenth grade students were made by Farmer _et al_. (1981) who studied their reasoning abilities by using the Inhelder tasks classification. They suggested tentative hypotheses as to why there are intellectual stages. Linn _et al_. (1981) found that content and problem effects contributed to variance on formal reasoning problems.

The notion of the impact that intellectual development has on students' abilities was reinforced by Marek (1981), who found strong relationships between Piagetian stage and IQ, content achievement, and inquiry skills in ninth and tenth graders; by Lazarowitz (1981), who found significant correlations between classification ability and intelligence; and by Lehman _et al_. (1981), who found significant correlations between cognitive development and creativity. A study by Darion (1981) related to a concept he called "learned helplessness," defined as the withdrawal from a task after an initial failure to do the task. His research with high school students indicated a significant correlation between intellectual development and "learned helplessness."

Milakofsky and Bender (1981) developed a cognitive performance test called "An Inventory of Piaget's Developmental Tasks" and found significant correlations between it and the Scholastic Aptitude Test.

Cross-age studies were reported by DeLuca (1981) and Juraschek and Grady (1981). The results of DeLuca's study indicated that, across ages 9 to 18, deviation from Piagetian stages was influenced by gender and type of task. The Juraschek and Grady research investigated how format variations in Inhelder's and Piaget's equilibrium in the Balance Task might have had an effect on how undergraduate students and ninth graders were classified. About 30 percent of the college students and 25 percent of the ninth graders could do the task without manipulating equipment. A few were able to arrive at a right answer by trial and error, but about one-half to two-thirds could not do the task and thus no comparisons were made about the two theories.

Violino and DiGiacomo (1981) compared Italian, U. S., and British students on their Piagetian levels. Maloney (1981) gathered data on the Piagetian level of physics students in a large liberal arts university and found that most were at the formal level of development. Tschopp and Kurdek (1981) compared paper and pencil types of Piagetian tests against task testing with high school students and found low correlations between the two.

Developmental Level - Intervention - Student Performance Change

Studies were grouped into this category if the researcher had tested the Piagetian developmental level of the subjects, had provided some type of intervention, and then tested for results.

Elementary School Level

Clark (1980) used an intervention strategy with kindergarten and first grade children which consisted of giving children problems requiring concrete operational thought. Children who failed in operations seriation improved significantly after the intervention, but failed to do so on transitivity problems. Smith et al. (1981) used manipulative, or graphic, or abstract interventions with second grade children and found no significant differences between their length conservation and ability to acquire specific length measurement skills. Gann and Fowler (1981) provided an intervention consisting of classroom teaching about the cause of floating and teaching the definition of "living." They found significant differences between groups that received the intervention and the control groups. They concluded that animism and dynamism could be taught to fourth grade children who were classified as concrete operational. Howe and Shayer (1981) provided manipulative activities for 10 and 11 year old children on tasks involving volume and density and found gains in achievement. Black (1981) provided a special type of learning approach, based upon Gagne's theory, to sixth and seventh grade students who were not yet at the formal operational level. The intervention produced significant gains to formal levels for the short term, but the gains were lost when students were reexamined after a retention interval.

Peterson (1981) provided information on how children learn science and mathematics concepts at different levels by using clinical methods and group task approaches.

Secondary School Level

Gabel and Sherwood (1981b) used four instructional interventions for teaching problem-solving to chemistry students of various proportional reasoning abilities, verbal and visual preference, and mathematics anxiety. Results indicated that mathematics anxiety was negatively correlated with science achievement, and problem-solving in chemistry was dependent on students' proportional reasoning ability. Roper (1981) designed a special advance organizer intervention to improve developmental level, but it produced no significant differences when tested with high school physics students.

College Level

Several kinds of instructional interventions were imposed on students at the college level to determine changes in developmental level, achievement, etc. Alvarez (1981) found no significant differences in the cognitive levels of college biology students as a result of a cognitive process instructional intervention. An intervention which was centered around mandatory and voluntary diagnostic-prescriptive instruction was utilized by Benefield (1981). Results indicated that level of cognitive development was consistently related to achievement and retention and that the more often an individual volunteered for diagnosis, the higher the achievement.

A university introductory logic course served as an intervention for students in a research study conducted by Enyeart (1981). Findings indicated that sentence logic and analogical reasoning were related to formal thought and that cognitive development could be induced. An intervention using a projection of shadows problem, with relevant or irrelevant information, demonstrated that students receiving only relevant information improved significantly in proportional thinking (Nummedal and Collea, 1981). Robbins (1981) reported on different kinds of instructional techniques that could facilitate cognitive change in college astronomy students.

Summary

Studies reported for 1981 show strong relationships between developmental level (Piaget) and science achievement, but a review of studies relating age (or grade) and developmental level to science learning with children ages 6-12 showed that measures of student ability were better predictors of cognitive achievement than were developmental measures, and that age and grade level were weakly related to developmental level and cognitive achievement (Boulanger and Kremer 1981). This report still does not negate the fact that Piagetian developmental is a good predictor, however.

The research on spatial relationships is exciting, particularly with respect to differences between males and females in science. Also of note was that gains in cognitive development were being made through special intervention techniques.

STUDENT CHARACTERISTICS AND LEARNING

Studies that were reviewed for this section fall into a category in which some student characteristic, such as background knowledge in a subject, age, sex, GPA, personality type, cultural background, attitude, or interest was studied in relation to "learning." A few studies were included that involved student characteristic(s), a teaching intervention, and in which learning was measured, but the major emphasis was on the student characteristic(s). Some of the studies also reported student characteristics that predicted success in learning and some simply reported attitudes and interests of students.

Prior Knowledge - Instructional Intervention - Learning

Hewson and Hewson (1981) and Hewson (1981) developed a concept teaching technique that emphasized the importance and use of students' existing knowledge in influencing their subsequent achievement. An experimental group of 46 South African students was taught a series of concepts involving mass, volume, and density using the special instructional strategy and materials. Significant knowledge gains were made by the experimental group over a control group of students taught by a traditional strategy.

West and Kellett (1981) applied Ausubel's subsumption theory to the domain of intellectual skills learning. They found that advance organizers enhanced high school students' skills in solving solubility product problems, but the effect was removed if prior teaching in relevant background material was included.

Champagne et al. (1981) examined the structural representations of students' knowledge before and after science instruction. The purposes of the study were to (1) examine the congruence between the science content structure of instructional materials and students' structural representations of that content, and (2) to compare students' representations before science instruction with their representations after instruction. The study was carried out with a class of eighth grade science students. The concept structuring task yielded information about the way students related pairs of concepts and ordered concepts into larger structures. The students' representations were obtained by a procedure designed by the authors called Concept Structure Analysis Technique (ConSAT). Students were pretested, then spent four weeks studying geology under the special instructional intervention, then were posttested. Results showed that changes were detected between pre- and post-test scores on representations of geology concepts. Changes were found in 20 of 30 students on a rock structuring task, and in 17 of 30 students on a mineral structuring task. The authors do not state that their findings were significant, but the results indicate how the concept of discipline structure can be used by the classroom teacher.

In what appears to be a subproblem of the previous study, Champagne and Klopfer (1981) also examined the relationship of student structuring process skills and the solution of verbal problems involving science concepts. The types of verbal problems were analogies and set membership problems.

These two were selected because set membership problems require greater processing skills in structuring tasks. Students were pretested using the Concept Structuring Analysis Technique (ConSAT), the analogies, set membership problems, and a science knowledge test. A four-week instructional module was then taught by the special intervention technique that emphasized structuring processes and verbal problems. Results after posttesting indicated that students who rated high on structuring process skills were not significantly different on analogies problem-solving performance from those students who rated low on the same skills and that students who rated high on structuring process skills were significantly different on set membership problem-solving performance than those students who rated low on the same skills. Residual effects were not maintained, however, as the students rated high in structuring process skills did not retain the skill after one year any better than did students rated low. Both of these studies should be thoughtfully analyzed by all readers since structuring learning, concept formation, and processing skills related to problem-solving are important areas of study in science education.

A valuable study for science education was done by McVey (1981). She designed a study to explore the role that prior knowledge plays in the comprehension of scientific text, the influence of reading and retelling on students' understanding of a concept, and the differences in the oral language of students who understand a concept as opposed to those who have only a partial understanding. A subproblem was related to the question of what students learn about a concept from listening to an explanation of it. The research design randomly assigned the all male 13- to 15-year-olds with no reading problems into groups in which (1) students read and retold material concerning the discovery of Archimede's principle and applied their understanding to another problem, or (2) students formed a listening group, or (3) students composed a control group. The investigation revealed a positive relationship between students' prior knowledge of the concept of density and their comprehension of a written explanation of it. Formal operational thinkers performed significantly better than did concrete operational thinkers in their free recall of major concepts contained in the reading selection, although not in their recall of generalizations or specific details. There were no significant differences between groups in their application of concepts to a new but analogous problem. Reading and retelling did improve students' understanding of the concept of density, but listening alone provided no improvement. The author recommended that a variety of instructional techniques that take into consideration prior knowledge of a concept would be most beneficial to learning.

Student Characteristics and Learning - Predictive Studies

Two studies were reported concerning background characteristics and achievement in college biology. These studies were done by Yeany et al. (1981b) who found that grade point average (GPA) followed by the SAT, were the two best predictors of achievement; and Helseth et al. (1981), who found that the SAT, followed by level of cognitive development were the best predictors.

Soucheck (1981) found that: (1) students, regardless of being freshmen, sophomores, or juniors, entered biology at the same competency levels; (2) the number of chemistry courses students had had made no significant difference on pretest scores; and (3) students who had enjoyed high school biology received higher scores on the biology pretest. A study by Pridmore and Halyard (1980) at a community college showed that GPA and SAT scores were the best predictors of achievement in chemistry, physics, and biology.

Hudson and Rottman (1981) and Van Harlingen (1981) studied predictors of success in college physics. Hudson and Rottman found that mathematics ability was of primary importance for achieving success in college physics. Van Harlingen gave 500 physics students a battery of pretests, including mathematics, SAT, spatial rotation, deductive reasoning, inductive reasoning, and spatial visualization. The dependent variable was the course grade in physics. Factor analysis indicated that logical/verbal, spatial, and mathematical ability explained 31 percent of the achievement variance. He also found that physics achievement favored males to the extent of 1/6 of a letter grade. He concluded that sophistication in mathematics is a virtual necessity for success in physics.

Alraegi (1981) reported that the best combination of twelfth grade transcript data for the prediction of college freshman GPA for male science majors in colleges of education in Saudi Arabia was twelfth grade total score. It explained 24 percent of the variance. Combining twelfth grade total score with the mathematics average, Arabic average, and age increased the amount of explained variation to 31 percent.

Paydarfar (1981) studied data collected from students in undergraduate colleges and universities that made up the National Longitudinal Study. He found that mental ability and the number of mathematics courses taken in high school were the most important factors related to attainment in science in college.

Riblett (1981) studied 366 graduates of a high school in Kansas to determine science program components in relation to their success in science. The results indicated that the five most significant predictors for success in science were having taken physics and chemistry, independent study in science, involvement in high school activities, and high school rank in class.

Thompson (1981) reported on a study in which he investigated several background factors of students who were winners in the ninth Westinghouse Science Talent Search. Forty students were selected and information about them was determined from a questionnaire. Interesting data were: (1) about half of them had at least one parent whose occupation was science or mathematics related, (2) their teachers had nine or more years of experience, (3) they came from high schools with enrollments of 1000 or more, (4) nearly all of them came from public schools, and (5) most of them used resource persons other than their teachers to assist them with their research.

Student Characteristics - Instructional Intervention - Learning

Adams (1981) and Yeany et al. (1981a) conducted similar studies that investigated the effects of student entry characteristics, instructional methods, and learning on the voluntary participation in diagnostic-prescriptive testing in college biology. Measures used were a locus of control test, SAT scores, teacher-made summative evaluations and, in the Yeany study, a test of logical thinking. Results indicated that: (1) the number of diagnostic/prescriptive tests voluntarily taken significantly influenced achievement and was the single best predictor of achievement, (2) there was no difference in the number of diagnostic/predictive tests voluntarily taken by students of varying levels of achievement motivation, and (3) the number of diagnostic/prescriptive tests that students of low academic aptitude volunteered to take was significantly greater than the number taken by students of middle or high aptitude.

A community college study that investigated student characteristics and success in an independent, open laboratory program was accomplished by

Halyard et al. (1981). They studied the effects of age, sex, laboratory preparedness, lecture achievement, GPA, and time spent in laboratory on success in the laboratory. The best predictors of success, in order of importance, were (1) achievement in the lecture portion of the course, (2) time spent in laboratory, (3) age, (4) sex, (5) majoring in science, and (6) college GPA.

Haukoos (1981) also studied community college biology students. He examined the effects of two different classroom climates (discovery and non-discovery) on learning science processes and content. Measurement instruments included a Science Laboratory Interaction Categories to ensure discovery teaching, the Science Process Inventory, a Biology Achievement Test, and the Edwards Personal Preference Schedule. Results demonstrated that (1) students in the discovery treatment scored significantly higher on the Science Process Inventory; (2) there was no difference between the two groups in biology achievement; (3) personality characteristics with significant interactions with science process were achievement, order autonomy, affiliation, intraception, succorance, abasement, and heterosexuality; and (4) personality characteristics of heterosexuality and autonomy differed between the discovery and nondiscovery groups. The author made a definite point that science process skill instruction must be continuous or students soon lose the skills, and inferred that discovery teaching is a vital part of instruction.

Research input for the science program for middle schools is needed. Three studies related to the general topic of student characteristics, instructional intervention, and science achievement. Daume (1981) compared the relationship of science content achievement and science process achievement to the variables of reading achievement, mathematics achievement, attitude toward science, and sex in two junior high school programs: ISCS and traditional. Subjects were selected who had studied in the ISCS program or in the traditional program for three years. The SRA Achievement Series was used to obtain achievement in science content, mathematics, and reading. Science process achievement was determined from scores on the Comprehensive Test of Basic Skills: Science, Expanded Edition, Level 3, Form S. The Attitude Toward Science Semantic Differential was used to measure attitudes. Results indicated that students in ISCS and in traditional science did not differ significantly on science content achievement, science process achievement, and attitude toward science when the variables of reading achievement, mathematics achievement, and sex were held constant. When the variables of reading and mathematics achievement were controlled, significant differences were found in favor of males in the traditional science program on science content achievement, attitude toward science, and science process achievement, but not for males in the ISCS program.

Bernreuter (1981) investigated the effect of values clarification on the self concept and science achievement of inner city black seventh graders. He also utilized the variables of reading level, mathematics score, grade point average, family size, science grades, age, sex, socio-economic level, and number of values clarification lessons missed. The experimental group was given 18 values clarification lessons over an 18-week interval. Both groups were pre- and post-tested with the Tennessee Self Concept Scale and the Bernreuter Science Achievement Test. The total sample was also tested 60 days later with the Self Concept Scale. Findings indicated that both groups gained in self concept and that the experimental group was not significantly different from the control group. The self concept dropped significantly 60 days after post-testing. Females had significantly higher self concept ratings than males had after the values clarification exercises. The conclusions were: (1) values clarification lessons did not increase self concept of black inner city students, (2) total grades and science grade made the most consistent contribution to self concept in regression models, and (3) there was no loss of achievement by using the values clarification lessons.

Personality Traits and Learning

This portion of the section on student characteristics and learning examines the relationship of students' attitudes, interests, personality traits, etc., to some aspect of learning, instruction, or affective development.

Sherris (1981) studied the relationship between degree of concept relatedness of an instructional sequence and a person's locus-of-control orientation. Locus-of-control orientation of 541 high school students was measured by the adult Nowicki-Strickland Scale. Experimental groups received treatment stressing conceptual relationships through conceptual cues and concept mapping, while control groups did not. Analysis of covariance revealed that the treatment effect was not significant. The treatment by locus-of-control interaction effect for retention test scores was statistically significant for females, but not for males. Subjects with an extreme locus-of-control orientation, exposed to the experimental treatment, performed significantly different on achievement when compared to controls.

Sellers (1981) studied 214 high school biology students to determine the relationship between students' self concepts in science, their science achievement, and mental ability. Self concept was measured by the Self Concept in Science Scale. The analysis showed that students who had the highest achievement in biology and had high mental ability had the highest self confidence in science.

A study by Hummell (1981) showed that there were several significant correlations between desired affective goals in science education and student personality types. He studied ninth grade female students in urban parochial high schools. Test instruments used were the Meyers-Briggs Type Indicator and the Test of Science Related Attitudes.

Campbell (1981) used second grade children to determine the relationship between self concept, intellectual development, and achievement. He found significant relationships between self concept and achievement measures and also between self concept and intellectual development.

Novak and Voss (1981) determined the cognitive preference orientation (measured by the Cognitive Preference Examination II) and Jungian personality types (measured by the Myers-Briggs Type Indicator, MBTI) of 283 eighth grade students. Relationships between these two variables were predicted. It was hypothesized that introverted, intuitive thinking, and perceiving MBTI personality types would exhibit an application, questioning, or application/questioning cognitive preference orientation; that is, an inquiry orientation toward learning. It was further hypothesized that extraverted, sensing, feeling, and judging MBTI personality types would exhibit a memory, memory/application, or memory/questioning cognitive preference orientation; that is, a traditional orientation toward learning. The study also attempted to determine if students differed on these measures according to sex or intelligence. The predicted relationships were not supported by the analyses in the study. Differences between the sexes were not noted. Differences in intelligence between sensing and intuitive students (in favor of intuitives), between judging and perceiving students (in favor of perceivers), and between students classified according to cognitive preferences were found.

Charlton (1981) conducted a rather complex study in order to examine the effects on biology achievement of the interaction between specific learning activities designed to correspond to the four quadrants of the Meyers Briggs Type Indicator with students whose quadrant groups were identified by the MBTI. Special quadrant-based activities were designed for a high school biology unit. Test results indicated no significant differences in achievement gains in biology by any of the special quadrant groups.

Student Characteristics - Attitudes and Interests

Ormerod (1981) reported a study done in England with 2200 high school pupils in 33 schools which was concerned with students' attitudes about the social implications of science and their science choices. He found that students had mildly favorable attitudes toward the social implications if they elected physics and chemistry, but that this was not the case for biology. In addition, sex differences were noted on some subsections of the attitude scale and there was some indication that student liking of the teacher influenced course selection. Ormerod also suggested that most students' attitudes toward the social implications are formed before age 14, implying that more teaching related to social implications should be accomplished early in schools.

Another study of science interests was reported by Bottomley and Ormerod (1981). They investigated science interests of 592 students by administering questionnaires to the students at the ages of 12, 13, and 14. Relevant data showed that, in general, 12- and 13-year-olds liked science, but that this liking was lost at age 14. Boys preferred chemistry and physics and girls preferred biology. Practical work, teacher interests, and course difficulty also showed as having strong influence on science interests. Of special note, girls preferred botany over animal study. Any first-hand dealing with animals seemed definitely detrimental to some girls' future interest in biology.

A study reported by Sharan and Yaakobi (1981) of students' perceptions of the classroom learning environment in tenth grade biology classes in Israel showed that students in Kibbutz samples scored significantly higher than did students in urban areas. A comparative study of self concept and perceptions of behavior between U. S. and Israeli science students was reported by Yaakobi and Peterson (1981). A general finding was that the U. S. students had significantly higher self concept scores than the Israeli students had. Further subproblem analyses were given which detailed the reported significant differences.

Science interests were also probed by Wright and Hounshell (1981). They gave a science interest questionnaire to 147 high school students who attended the 1979 North Carolina Junior Science and Humanities Symposium. Seventy-four percent of the students reported that their interest in science came through school. Elementary and junior high school teachers were singled out as very important because results indicated that 128 of the 147 students reported their first interest in science came before the end of ninth grade, with boys showing earlier interests in science (grade school level) than did girls. A comparative study of scientific curiosity of Israeli and American students was reported by Hofstein et al. (1981). The samples selected were not exactly the same, but a reasonable judgment of the scores led the authors to believe that the levels of curiosity were similar. Additional subproblems were reported in relation to students either in the U. S. or in Israel.

Power (1981) reported on changes in attitudes toward science in the transition between Australian elementary and secondary schools. The students were tested in grade seven and then a year later (after approximately one year in the secondary schools). There were no significant differences in attitude change as a result of the transition to a higher grade.

Schaap (1981) determined the construct of "scientific attitude," as measured by the Moore and Sutman Scientific Attitude Inventory, in relation to external variables thought to be related to science attitude. Six factors were isolated from the SAI as being constructs of the scientific attitude. Regression analysis indicated that (1) sophomore aptitude accounted for 8 percent of the explained variance; (2) parental attitude, 5.5 percent; (3) senior aptitude-achievement, 2.5 percent; and (4) attitude toward mathematics as a subject, 2.8 percent. He concluded that the instrument was reliable and that the construct of scientific attitude had some degree of cognitive nature.

Student Characteristics - Sex Differences

Baker (1981) determined factors which would discriminate between males and females in the humanities and biological and physical sciences. Special factors which he studied were spatial ability and attitude. He found that these factors were the discriminating variables between 86 science and humanities undergraduates. Baker concluded that the factors which influenced a choice of career in science, regardless of sex, were spatial ability and positive attitude toward science. For women, attitude toward science was a more important variable than was spatial ability. Once women selected science as a major it was not possible to distinguish them from men in science on the basis of spatial ability.

Camp (1981) reported on a problem-solving research investigation using ninth graders. The students were grouped by sex and spatial ability. She found significant differences between the boys and girls in spatial ability and inability to solve science problems that had spatial relations tasks in them. These studies were rather interesting when compared to an article by Mary Budd Rowe (1981) in which she reported that the correlation between mathematical ability and selection of science as a major in college was 0.05. Rowe hypothesized that the reason women do not enter science is that they do not do as well as men on spatial visualization and mechanical aptitude. Her ideas do not mesh with the findings of Baker. It is important that future studies examine attitude toward science versus mechanical reasoning, spatial relationships, abstract thinking, and mathematics ability in relation to choice of a career in science. Another related variable, however, is sex-role stereotyping. Vockell and Lobonc (1981) studied sex role stereotyping by high school females in science and found that both boys and girls viewed the biological sciences as less masculine than the physical sciences, and girls in coed high schools rated physical sciences as more masculine than did girls in noncoed schools. This finding might lead one to believe that differences in sex enrollments in classes may continue to contribute to sex role stereotyping of the biological and physical sciences.

Rudy (1981) reported on an investigation of urban children's responses to the science/technology role models on the television program "3-2-1 Contact" in relation to their gender, sex-role stereotype, and interest in science. One hundred fifty sixth-grade students participated in the study. Findings were: (1) boys saw themselves and other males as more masculine than did girls on sex-role stereotype and interest in science; (2) boys had greater interest in mechanical aspects of science; (3) following the viewing of the series, mechanical interest decreased in boys and increased in girls; and (4) when responses to role models were considered, boys preferred and remembered more about males while girls had higher opinions of females.

A study which encompassed a variety of psychological and skill factors, and especially gender differences, related to science attitude and achievement of fifth and tenth grade students was reported by Stoner (2982). Findings for fifth graders included: (1) no significant relationship between science achievement and attitude, (2) no sex differences on the tests, and (3) fifth graders had a significantly more positive attitude toward science than did tenth graders. In the tenth grade, attitude toward and achievement in science were correlated for both sexes. Significant differences in favor of boys were: (1) stereotyping of science usefulness and attitude, (2) attitude toward and achievement in language, and (3) perceptions of father's attitude toward science. The difference in favor of girls was perception of relevance to science toward a career.

Silberstein and Tamir (1981) measured Israeli students' attitudes toward the use of living animals in learning biology. Responses from 577 students in grades 5, 7, and 9 showed better attitudes toward use of animals for research over use of animals in school experiments. Boys had significantly more positive attitudes (and these increased with age) than girls had toward use of animals.

A simple, but effective, study about elementary school children's interests was reported by Jaus (1981). He asked 224 elementary school teachers and 5124 ele :entary school children the question "What do you want from school?" No teachers or students in K-2 mentioned science. In grades 3-6, 27 percent of the students mentioned science and only two of 128 teachers. The interesting point is that the girls mentioned science as often as did the boys in grades 3-6. Thirty percent of the intermediate students also mentioned career information about science. Jaus speculated that many teachers feel that students do not want to learn science and some of the data indicated that. What a challenge for science education!

Student Characteristics - International Studies

Duckrow (1981) reported on the cultural differences between Chamarro students (students native-born on Guam) and their nonChamarro teachers. He gave recommendations for the improvement of science teaching and curriculum development based on his findings.

A study that was done in Australia reported on relationships between socio-economic status and proficiency at inquiry skills. Fraser (1981) found a correlation of .35 before adjustment for ability and .27 after adjustment.

Belandria (1981) reported on a cross-national study of the multi-level effects of social background on achievement. Patterns were examined in Hungary, New Zealand, and Australia. Important differences were noted in verbal ability.

Ho (1981) did a very limited study in Hong Kong using Chinese students. There was concern about whether students would learn physics as well if they were taught in their second language: English. There were no significant differences in achievement in physics between experimental and control groups.

Students with Special Characteristics - Mainstreaming and Handicapped

Moore (1981) surveyed and compared practices of classroom teachers on the use of instructional materials with mainstreamed, moderately handicapped students in the elementary schools of Montgomery County, Maryland. She recommended that teachers use more media-centered materials and instruction, that teachers be given more time for consulting with special education teachers, and for finding and preparing instructional material.

Student Characteristics - Minorities and Success in Science

Two studies are reported which focus on problems related to Hispanic bilinguals and their success in science and engineering. Robinson et al. (1981) found in a study of bilingual Hispanics and a control group of nonminority students vast differences in their academic achievement, motivational factors, and social and economic status. A more specific study done on bilingual Hispanics at the same university was reported by Gêrace and Mestre (1981). They found several mathematics misconceptions unique to Hispanics that could have originated in linguistic factors. Possible solutions to the problem were discussed.

Atwater (1981) studied the cognitive and affective variables which influence successful and nonsuccessful black undergraduates in science and engineering at a large university. She found significant differences in SAT-M scores and in predicted university grade point averages. No significant differences were found for exposure to black role models, proportion of blacks in the high schools, size of graduating class, or high school achievement. Attitudes were found to be significantly related to achievement. Also, attitudes toward professors, blackness of students, and science teaching and achievement were significantly different between the two groups.

A very thorough study reporting relationships of classroom off- and on-task behaviors of black and white students in ISCS classes was reported by Stanback (1981a). Classroom behavior observations were made by trained observers as students worked in the laboratory. The results showed no significant differences in the classroom behaviors of the male students but the grades of the black students were lower than those of the white students.

Summary

The question asked at the end of this section is "What does it take to be successful in science?" Answers found were: a positive self concept, a good science background, a positive attitude toward science, very good mathematics skills, a good high school GPA, good SAT-M scores, spatial ability, one or more parents involved in a science or mathematics occupation, an intuitive nature, and formal reasoning ability.

Boulanger (1981a), in his study of the relationship between measured ability and measured science learning, using 34 studies from grades 6-12 reported over 16 years, found that ability and cognitive learning correlated at .48. He made the judgment that ability and past learning were the best predictors of future learning, accounting for about 23 percent of the variance in science learning.

TEACHING STRATEGIES AND LEARNING

The rationale for the selection of studies that make up this section is that the major independent variable is a kind of teaching strategy that is performed with students. A variety of student outcomes was studied: achievement, attitudes, and creativity, to name some.

Mastery Learning

Five studies investigated mastery learning; four with high school students, one at the college level. Kushner (1981) involved 450 tenth grade students in 19 classes of high school biology in which the mastery group was given the option of taking as many as three parallel quizzes for each experiment in order to try to reach an 80 percent criterion level of achievement. Students in the control group were permitted one quiz. There was no significant difference between the groups on a summative laboratory practical examination. Kushner concluded that mastery learning in a high school laboratory was no better or worse than the traditional laboratory approach. One might question, however, how carefully lecture content was separated from laboratory information.

The effects of a modified mastery learning strategy on achievement, attitudes, and task behavior of high school chemistry students were reported by Dillashaw and Okey (1981). One hundred and fifty-six high school students were divided into three treatment groups: (1) contrast (no diagnostic/remediation procedures), (2) student-managed remediation (students selected their own remediation following diagnosis), and (3) teacher-managed remediation (teachers assigned remediation based on diagnostic test results). Results showed that the modified mastery learning strategy significantly influenced on-task behavior and achievement, indicating that high school chemistry teachers may successfully employ such a strategy to increase the on-task behavior and achievement of their students. Lack of significant differences between the two experimental groups and the contrast group on locus of control and attitude suggested that assigned remediation may not be necessary to bring about achievement gains; simply having remediation available for students to use on their own may be sufficient.

Dunkleberger and Knight (1981) studied mastery learning techniques with ninth grade students in physical science classes. They established laboratory instruction for mastery techniques that included behavioral objectives, self-paced laboratory experiments, self-checking quizzes, criterion-referenced test items, and retesting opportunities to achieve at least to a 70 percent level. The control groups experienced a traditional laboratory approach. Students in the mastery program exhibited greater achievement on a comparative instrument than did those in the control group. The authors did not describe their results as significant because the reliability of the instrument was marginal and validation of items limited.

Lueckemeyer and Chiappeta (1981) reported on an investigation into the effects of a modified mastery strategy on achievement in a high school human physiology unit. They designed a modified limited prescriptive remedial period of time for their experimental groups to attain at least an 80 percent mastery level if possible. Control students received regular instruction.

After controlling for ability, there was a small, but significant, difference between the two groups on achievement in physiology. The authors found that the treatment accounted for only 3 percent of the variance in achievement and recommended that the type of approach they investigated was not practical in terms of time and effort for high school biology.

College level students were exposed to a PSI mastery-based curriculum in general studies in the University of Cabimas, Venezuela. Mastery groups made use of criterion-references objectives, self-paced modules, criterion referenced tests, and self-evaluation pages for each module, control documents, and additional resource materials. The control groups received traditional instruction. Montiel (1981) found no significant difference in time spent in learning for the two groups but did find significant differences in achievement between the groups in favor of mastery learning.

Ausubel - Meaningful Learning

Five studies were reported that investigated the use of advance organizers, conceptual cues, or links to prior knowledge and their influence on student learning. Giles (1981) investigated the effects of advance organizers and clustering as mediators of learning by high school students in lessons presented at a planetarium. Thirty-six class sections totalling 832 students participated in the investigation. Nine class sections were randomly assigned to each treatment; therefore, there were three class sections from each of the three academic track levels assigned to each treatment. The control group received no special treatment. The treatment groups included those that received clustering, or advance organizers, or a combination of these mediators of learning. Results showed that the treatment group receiving both clustering and advance organizers in the instruction performed significantly higher on the astronomy posttest than did any other treatment group. However, the clustering treatment and the advance organizer treatment each produced significantly higher performance than was found for the control group. It was also noted that lower-ability students in the treatment group were assisted in learning in that they performed as well as high-ability students in the control group.

Sherris (1981) investigated the meaningful learning theory of Ausubel in examining an instructional sequence designed to enhance meaningful learning. The essential difference in instruction between control groups and experimental groups was the use of conceptual cues and concept mapping exercises in the experimental group study guide. The study involved 541 biology students in six Indiana high schools. Results of the study indicated: (1) no significant differences in meaningful learning between control and experimental groups, and (2) meaningful learning was best predicted by level of student prior knowledge, general school ability, and the degree to which students completed concept-related instructional materials.

Tests of Ausubel's and Gagne's learning theories were undertaken by Fouda (1981) with tenth grade females in Egyptian schools. Instructional designs following Ausubel's theory and Gagne's theory were developed. It was found that students instructed following either of the two theoretical approaches performed significantly higher in concept learning than did students taught by a conventional instructional model.

McAdaragh (1981) examined Ausubel's theory from a different point of view. She studied the effects of an advance organizer and the effect of background experience in science on the attainment of science concepts. The study involved 90 students in ninth grade earth science classes. Results of the study showed that there were no significant differences in relation to (1) background experience and science achievement and (2) the use of an advance organizer and science achievement.

Two instructional programs with different emphases on linking to existing knowledge and experience were designed by Gunstone (1981). He used these strategies to present a unit on elementary dynamics to 67 students in high school physics. Propositions elicited by a modified word-association technique were used to assess linking in cognitive structure between dynamics and existing knowledge. Path analysis indicated that this effect of instruction on performance was substantially mediated by the extent to which cognitive structure was linked to existing cognitive structure. In a somewhat similar study at the college level, Moreira and Santos (1981) found that organization of the topic of thermodynamics following Ausubel's learning theory assisted students in conceptualizing the content of thermodynamics better than did a traditional organization format. They studied 58 students who made up an experimental and control group. Students were tested on a word association test analyzed through hierarchical clustering analysis. The authors concluded that the Ausubelian structure influenced the students' cognitive structure in such a way that their conceptual hierarchies were more coherent with the basic laws and conceptual structure of the subject.

Research analyses by Mayer (1981a), (1981b), related to techniques for increasing meaningfulness of technical or scientific information. These techniques were: (1) organization of prose, (2) use of concrete analogy and advance organizers, (3) use of inserted questions, (4) elaboration techniques such as note taking, and (5) discovery learning. He also made recommendations for improving science text design and text processing.

Teacher Verbal Behaviors - Inquiry and Questioning

Botti and Fowler (1981) evaluated whether congruency or incongruency between a teacher's intended discovery-inquiry laboratory instructional strategy and his/her actual behaviors used to implement that strategy had an effect on higher level learning by students. Four classes of high school biology students (N=72) were established. Results were that subjects did not differ statistically in mean score performance in the two verbal treatments, and that the congruent treatment subjects earned significantly higher mean scores in cognitive ability related to science process.

Special inquiry training was given to a group of fourth, fifth, and sixth grade teachers to determine if their students would change significantly after this type of training of teachers in inquiry. Maria (1981) reported that experimental fifth and sixth grade students taught by the inquiry trained teachers scored significantly better than did control group students on the verbal portion of the Torrance Tests of Creative Thinking. (This was a very well controlled study, as noted by observations made to validate inquiry teaching). Rodriquez (1981) reported on the effectiveness of an inquiry approach to science and language teaching with Mexican-American bilingual children in third grade. He found that students in a special inquiry treatment group scored significantly greater gains in classification skills and oral communications skills than did control group students. Wright (1981) also reported that ninth grade students who received intensive instruction in cue attendance or hypothesis generation demonstrated significant differences, compared to control students, in their capacity to explore science problems.

Reports by Russell (1981) and Ackerman (1981) provided some interesting insights into questioning techniques. Russell sought to develop and demonstrate a plausible conceptual linkage between a science teacher's use of questions to develop student understanding and, the associated provision for students to understand scientific authority. Ackerman studied the use of several forms of adjunct questions to establish encoding by visual imagery, and then tested whether such coding enhanced performance, compared to questions designed to encourage verbal encoding alone. Four hundred sixth graders participated in the study. Findings showed no significant differences on main effects, but students who scored high on visual imagery scored significantly better on the criterion test than did those students receiving verbal encoding only.

Smith and Bramblett (1981) and Land (1981) conducted studies that dealt with high school biology students in which the teacher was explicitly vague with terms. Significant differences in biology achievement and student perception of lesson effectiveness were found in the experimental and control groups, favoring control groups. Land designed high-clarity and low-clarity lessons on college level genetics. Students in the high-clarity group were able to perceive the teachers as such, but did not achieve significantly higher than students in the low-clarity group.

Diagnostic Prescriptive Treatment

Long et al. (1981) measured the effects of three variations in the use of diagnostic-prescriptive (DP) teaching on the cognitive and affective biology achievement of high school students. Students were placed in treatment groups of DP with no assistance, or teacher-managed DP, or student-managed DP. All three treatments showed significant differences at the 0.10 level compared to the control group. Attitudes toward biology and instruction were highest when students managed their own DP assistance.

Teacher directedness, academic ability, time allowed for study, and their relationship to achievement of high school students in ISIS were variables studied by Burkman et al. (1981). On the two instructional variables, the degree of teacher direction (student- versus teacher-directed) and time allowed, there were modest differences in favor of student-directed for the low allowed time condition, but the difference was reversed in favor of medium- and high-time conditions. The main effect of academic ability on achievement was positive and strong. The authors concluded that both teacher-directed and student-directed methods can be effective and that ISIS teachers using a self-directed teaching method should set time limits for the logical units of work.

Peterson and Mayes (1981) used the Peterson-Yaakobi Q-sort to examine junior and senior high school students' perceptions of ideal teacher behavior. Significant differences in perceptions were found between high- and low-ability students, particularly with those behaviors that related to "getting subject matter across," in favor of the high-ability groups.

Yandila (1981) used a controlled experiment with high school biology students to determine if they could learn particular content related to genetics. There was an apparent teacher conflict about the grade placement of the content in his country. The data indicated that experimental classes did learn the content above the 60 percent level in all cases except for the use of laws related to incomplete dominance.

A teaching strategy that utilized a case study approach to increase junior high school students' overt environmental behavior was reported by Ramsey et al. (1981). They found that the case study environmental action experimental group showed significantly more overt environmental behavior than did students who received environmental awareness or science instruction.

Teaching in Out-of-School Situations

Diamond (1981) observed parents and children interacting at science exhibits at a science center. She found that children teach in order to acquire information about the objects they manipulate, and that parents teach as a way of communicating with their children. W. W. Martin et al. (1981) found that an outdoor field trip was a poor setting for task learning when compared with learning in environments familiar to children.

Evaluation Strategies

A study to determine the effectiveness of several formative evaluation models was reported by Kirschbaum (1981). She found no conclusive results when she attempted four different versions of evaluating chemistry and weather lessons.

College Biology Methods

Downie and Maden (1981) surveyed the attitudes toward teaching of biologists at the University in England where they were teaching and found that the biologists were interested in innovation in teaching, but that little was being done to implement anything new.

Individualized Instruction

Hay (1981) reported on a study designed to investigate the effect of cooperative goal structuring on sixth grade students' ability to initiate task and maintenance group behaviors. She found no differences in the behaviors whether students worked independently, in an unstructured group, or in a cooperative group with structural goals. On content tests, however, the cooperative group performed significantly better than did the independent and the unstructured groups. After three weeks no significant differences in retention was found among the groups. Burkman et al. (1981) reported on a study they designed for high school students using the ISIS program. They studied the simultaneous effects, including interactions, of two controlled instructional management variables and two student aptitudes on student achievement. Management variables were time allocated for learning and student groupings: student-directed/group-directed, and teacher-directed. Student aptitudes were reading ability and study ability. Aptitude-treatment and aptitude-aptitude interactions were found.

Dolphin (1981) reported on the need for research in individualized instruction at the college level, particularly using multivariate methods of analysis. Two studies, Davis (1981) and Tuckman and Waheed (1981), found superior results with individualized instruction. Perry and Howe (1981), however, on the basis of the variables they studied, could not find a significant relationship between the variables and the final course grade. Regression analysis gave no significant predictors.

Problem-Solving Strategies

Pilot et al. (1981) presented a paper at AERA in which they described Galperin's instructional theory of problem-solving. Also provided were details on the theory, the systems of heuristics, teaching plans, and evaluation of experimental courses using the approach. Manteuffel and Laetsch (1981) compared the achievement of undergraduate biology students in individual investigations with and without written guidelines for problem formulation. The quality of students' problems improved significantly with the use of written guidelines.

Russell and Chiappetta (1981) and Volk and Hungerford (1981) reported useful applications for teaching problem-solving. Russell and Chiapetta found that eighth grade students who received problem-solving procedures achieved significantly higher scores on earth science content tests than did students in control classes. Volk and Hungerford trained junior high school students in investigative environmental skills and found that they outperformed students in general science courses on measures of skills in problem identification.

By means of a more traditional problem-solving procedure, dimensional analysis, Kirkland (1981) found that high school physics students who used this method outperformed control students in a physics achievement test. Students who were high in mathematics ability and received dimensional analysis training performed the best of all students.

Laboratory Instruction

Three studies were reported that examined laboratory science instruction in secondary schools. Folkomer (1981) compared experimental groups of junior high school students in earth science in lecture, or lecture-laboratory, or field trip situations and found that students in the field trip teaching group performed significantly higher on observation types of questions on achievement tests than did students following the other two methods, but on interpretation types of questions there was no significant difference. Leonard et al. (1981) compared the effectiveness of an Extended Discretion laboratory approach (exercising independent judgment) to a BSCS Green Version laboratory program in high school biology. The Extended Discretion approach was significantly better in producing biology laboratory concept learning in groups of students of three of the five teachers involved in the study.

Al-Faleh (1981) compared high school chemistry students taught by lecture-demonstration with students taught by small-group experimentation. He found that, with Saudi Arabian students, the small-group experimentation approach produced significantly greater chemistry learning and better attitudes toward science.

At the college level, four studies were reported. For students in college physical science, Schellenberg (1981) found no significant differences in science achievement, the processes of science, or science attitudes when students were taught by an experimental method called the contemporary topics approach or by a standard topics approach. Gowin's epistemological V proved to be a useful device for showing and improving the structures of knowledge of physics laboratory experiments. Concept mapping was shown to be a helpful technique for analyzing the conceptual structures of the experiments. As a result of doing the laboratory experiments, students' conceptual cognitive structures changed significantly in terms of understanding concepts and relationships among concepts in all cases except two. In a somewhat related study, Levandowski (1981) used Gowin's epistemological V to help college physics students understand the structure of knowledge of laboratory experiments. In this experiment the use of the V did not improve student understanding significantly but it did improve communication between the teacher and the students.

Hegarty (1981) described a model which course designers could (and did) use to establish a laboratory program in microbiology at the university level.

Summary

The research in 1981 showed no strong support for mastery learning, although the approach has had wide appeal. Meaningful learning approaches had strong support as well as did studies on inquiry approaches and questioning techniques. Special problem-solving techniques were also beneficial to student learning.

Included in the 1981 data were several reviews of research findings in areas related to teaching strategies and student learning; thus, it was felt they should be a part of this summary. Boulanger (1981b) reviewed 52 studies, including grades 6-12, from 1963-78 on instruction and science learning. He found significant positive cognitive outcomes due to the use of preinstructional strategies, training in scientific thinking, increased structure in the verbal content of materials, and increased realism or concreteness in adjunct materials. Capie and Tobin (1981) reviewed the research on the relationship between teacher performance and student engagement in learning tasks and found that student engagement rates were clearly related to achievement. Aiello (1981) reviewed individualized instruction (115 studies) and gave it a "somewhat more effective" rating than traditional instruction. Horton (1981) reviewed 17 studies on teacher effectiveness and student learning and reported that teachers who received special training in individualized science instruction were more effective in their science teaching. Matthews et al. (1981) reviewed the research on Student Structured Learning in Science (SSLS) and Teacher Structured Learning in Science (TSLS) and reported positive gains in student performance such as problem-solving, creativity, attentiveness to teaching, and independence in learning. Blosser (1981) made a comprehensive analysis of the use of laboratory in science instruction. Several research studies were reported that showed no significant gains in achievement between laboratory and nonlaboratory groups, but, in general, gains in science attitudes, motivation, and skills were found.

Koran and Lehman (1981) summarized research related to the role of attention in concept formation in science. They discussed cuing, manipulation of symbols, and directions for focusing attention on particular aspects of concepts. Shymansky and Penick (1981) analyzed studies of teacher behavior in acitvity-centered classrooms (grades K-9) and found that activity-centered classrooms encouraged student creativity in problem-solving, student independence, and assisted low ability students to overcome handicaps. Stallings (1980) reported, from her review of research on teaching in the 1970s, that, in general, most instructional research was directed toward identifying effective instructional strategies for low achievers. This did not seem to be the case when specifically applied to science education research.

TEACHER USE OF INSTRUCTIONAL MATERIALS AND LEARNING

A series of research studies that formed a cluster were those in which instructional materials were used as one of the variables. The materials may or may not have been linked to a particular teaching strategy, but either or both are included in this portion.

Elementary School Level

Fitzgerald (1981) analyzed the effects of a humane education program on children's attitudes toward animal life. Eight fifth grade and eight sixth grade classes were divided equally into experimental and control groups. The independent variables in the study were three treatments: (1) reading materials with no instruction, (2) reading material with instruction, and (3) reading material with instruction repeated over time. Students were pre- and post-tested on an examination over humane attitudes. Results indicated that the intensive treatment group (reading material with instruction repeated over time) was significantly different from all other treatments and from the control group.

Abdullah and Lowell (1981) reported on a procedure to develop and validate two hierarchically related measures of concept generalizability. They used a series of tests which consisted of three degrees of stimulus complexity. The concepts used were insects and animals. Pictures of each concept were organized from sets having the most critical attributes of the concept to the most general. They hypothesized that if children ranging in age from 6 to 11 years could master the general exemplars, they could also successfully identify exemplars using the more critical attributes. It was found that the measures Abdullah and Lowell developed constituted valid scales for concept generalizability of insects and animals.

Secondary School Level

The recall of past experiences by eighth grade students on their identification with abstract physical science concepts was investigated by Rowe (1981). These effects were manipulated in two ways: (1) type of reading narrative and (2) specific recall directions contained within the reading narratives. Results showed a positive relationship between the type of narrative read (contemporary historical) and the recall of science concepts as measured by the achievement test. However, simply asking students to relate their past personal experiences to the narrative read did not facilitate recall of the science concepts.

Special instructional materials were a part of a study by Porter (1981) in a program designed to facilitate student achievement of the mole concept in chemistry. She developed a synthesized instructional program in which the main effect group received twice the concrete examples, negative examples, verbal and pictoral linkages in the written material, and diagrams and charts for students to complete, plus a very strong summary. Results showed no significant differences in achievement compared with control groups. The format did assist retention of an abstract chemistry concept, thus the researcher felt that the program redesign was useful.

DeMelo (1981) investigated the effectiveness of (1) visual instruction composed of simple line drawings and printed words as compared to printed words only instruction, (2) visual tests, and (3) the interaction between mode of instruction (visual and nonvisual) and mode of testing (visual and nonvisual). The subjects were 96 biology students and the unit of instruction was the anatomy and physiology of the human heart. Results indicated that the visual version of the instruction enhanced the performance of the students significantly on the drawing test and on some subscales of the achievement test. Holliday and Benson (1981) used a chart/table medium to focus students' attention on science concepts. The study involved 299 high school biology students. The model was used to investigate the learning effects of different questioning strategies under four experimental conditions. Results showed that there were significant differences in achievement between experimental and control groups in favor of the experimental. Holliday (1981) also reported on results of a study testing a selective attention model which predicted that textbook study questions adjunct to a flow diagram would focus students' attention more upon questioned information and less upon nonquestioned information. A picture-word diagram describing biogeochemical cycles was used with 176 high school students. The population question and nonquestion treatment groups significantly out-performed the sampling question group, which in turn out-performed the placebo control group.

Special previsit instructional materials were developed and used in a study by Gennaro (1981b) to test their effect on student learning for a museum field trip experience. Ten earth science classes were assigned to experimental and control groups. It was found that students receiving previsit instructional materials significantly improved their test scores over the control group.

Winn (1981) studied whether (1) ninth grade students (N=221) receiving pictorial treatment, with critical attributes highlighted, performed better on an identification test than did those students receiving a diagram form of instruction; or (2) high verbal learners receiving a largely diagrammatic treatment performed better on a classification test than did high verbal students using a pictorial treatment. Results showed no significant differences on the main effects.

Dirks (1981) studied the effects of different learning levels of behavioral objectives and the time of their possession on relevant and incidental learning. Two hundred and four tenth grade students enrolled in high school physical science participated in the study. Three learning levels of behavioral objectives (knowledge, comprehension, and application) were distributed to learners before, during, and after instruction to determine their effects on learning. Results showed no significant differences in learning among the various treatment groups.

College Level

Four studies were reported that utilized various kinds of instructional materials with or without specific instructional strategies. Crosby (1981) found significant differences in treatment groups in achievement and in attitude of college nonscience majors by relating pertinent biological science content articles and biological science knowledge to the students' majors. Petrich and Montague (1981) reported on an investigation into the effect of organization and accuracy of detail in instructional aids on the achievement of college students (N=54) in college chemistry. They found no differences in learning whether students used scripts, outlines, or no learning aids. They concluded that aids may impede learning by decreasing students' involvement in auditory and semantic encoding during lectures.

A study concerned with learning Environmental Science from text materials aided by a diagnostic and prescriptive instructional strategy was reported by Farragher and Szabo (1981). They investigated two instructional strategies: (1) the placement of key questions in text materials and (2) the use of prescriptive feedback to direct students who missed test questions to appropriate remedial work. Learning that resulted from these two techniques was examined relative to achievement, time-on-task, and efficiency. One hundred fifty undergraduates were randomly assigned to treatment groups which varied by complexity of feedback provided. Significant differences in instructional time and learning efficiency were observed which were not linearly related to feedback complexity. Between-group and achievement differences were marginally significant.

Cartwright (1981) compared the energy environment simulator versus a lecture method on developing energy awareness and attitudes of college students. Neither treatment-cognitive level of students, nor the interaction was significant with attitude as the dependent variable. However, student cognitive level and treatment were significant in favor of the simulator with awareness as the dependent variable. Simulation seemed to assist the lower cognitive level students more than the higher level students.

Sendelbach (1981) made classroom observations in an effort to better understand activity-based teaching using existent science program materials. The observations that were made were categorized into different "frames" that would characterize teaching, such as a "materials frame," "procedural frame," "time frame," "results frame," and "learning frame." Hands-on science activities seemed to occur frequently because of the importance of frames related to materials and procedures. It seemed that the teachers' perspectives restricted instruction to one involving mostly student manipulation of equipment in elementary school science lessons.

Reading Improvement

The use of special reading materials to improve achievement was described by four studies. Esler and Anderson (1981) found no significant results in a program of SAPA activities for third and fifth grade students on their reading ability. They concluded that the activities were a valuable supplement to other activities used to teach communication skills. Two studies were reported by Britti (1981) that dealt with the effects of context on reading comprehension and information gain of fifth graders using expository materials. She found that fifth graders learned more information about pulleys when information was presented directly without the contextual support of an example. Another interesting study on reading was done by Dagostino (1981). She did an exploratory study of how ninth grade boys read short stories and science selections. Data collected on comprehension indicated that the boys remembered information from the short stories better than from the science selections. There were also data showing more interest from reading the short story than from reading science. There was little evidence that the boys were reading at the inferential level. In a study in which a guided reading approach was used in high school biology, S. A. Smith (1981) found significant results in achievement in biology for the guided approach over a traditional lecture-discussion approach.

Summary

The studies reported in this section clearly support the use of especially developed instructional materials for enriching science instruction and enhancing learning.

INSTRUCTIONAL TECHNOLOGY

Several studies dealt with instructional technology. The reviewer feels this is a rapidly expanding field and deserves a separate section. The studies have been grouped into the areas of audio-tutorial instruction, television, computer-assisted, and general media materials.

Audio-Tutorial

Two studies described specialized instructional programs utilizing AT. Singer (1981) described an AT program developed for a course in medical mycology and Waskoskie (1981) described an AT self instruction laboratory program for blind college level students.

Schafer (1981) planned an adaptation of instruction called Individualized Goal Setting (IGS-AT) and compared it to classic AT instruction. Results showed that there was no significant difference between the two methods in college students' feelings toward locus of control. Langley and Bowman (1981) also tested a portable AT program against a lecture method in presentation of ecological concepts with college biology students. Results showed no significant differences between the two groups on content achievement, but the AT group showed significantly better scores on attitudes, awareness, and appreciation of the campus environment.

A study using high school biology students was reported by Lazarowitz and Huppert (1981). Their findings indicated that students taught by special AT instructional units performed significantly better on biology achievement tests than did control groups studying the BSCS Yellow Version.

Television

A study designed to test the usefulness of "hands-on experiences" for learning by fifth grade students was reported by Harvey (1981). He found that combinations of "hands-on" experiences plus viewing a TV show on energy waves through matter, or TV only, or "hands-on" only, produced no significant differences in learning specific energy concepts. Students who viewed TV made a significant percentage of higher level Vygotsky statements than did those receiving "hands-on" only. Obviously this is a very thought-provoking study for science educators.

Sheldon and Halverson (1981a, 1981b), reported on a study in which they determined the effects of an in-service TV program on elementary school teachers' understanding of SCIS concepts and their attitudes toward science teaching. Their findings indicated that understanding of SCIS concepts improved significantly and attitude improvement was greatest for those with little science background and little prior participation in in-service programs.

Computers

An overview of how computers may be used in chemical research was presented by Delaney and Warren (1981). They developed a course at Tufts University which addressed this topic. Joncas (1981) also described the development of a project in which the computer could assist in planning of organic syntheses. No evaluation of the program was reported.

A study of computer-assisted instruction involving academically talented high school students was reported by Tauro (1981). He found that students receiving computer-assisted instruction scored higher on chemistry achievement tests and had better attitudes toward the course and instruction than did control groups. The chemistry course was a first-year college program designed for these students. Calvin et al. (1981) studied college student attitudes toward computer and chemistry. They found significant differences in attitudes toward computers and chemistry in groups receiving CAI over those who did not receive the CAI.

At the junior high school, Carter (1981) found significant differences in achievement in metric instruction in groups studying it via CAI over control groups. No significant differences were found in student attitudes toward science or toward the metric system.

Microcomputers

Cox and Berger (1981) reported that students could learn problem-solving skills through use of the microcomputer and gave recommendations on group dynamics of students working with microcomputers.

Palmer (1981) found that the microcomputer could be effectively adapted to wait-time data analysis and research procedures. The teacher training segment of the study utilizing wait-time procedures did not show significant differences in student achievement over control groups of teachers not utilizing wait-time procedures. The studies were conducted in junior high school IPS classes.

Audio-visual Materials

Meadows (1981) developed and evaluated an audio-visual tape/slide program for an undergraduate ichthyology course. Significant gains were made in student learning and the materials were rated from good to excellent by the students. Blecha (1981) also reported on the development of a series of instructional aids for teaching organic chemistry, but no evaluation was made as to their effectiveness.

Alesandrini and Rigney (1981) tested the effects of pictorial presentation and pictorial review task on science learning. Ninety-six college subjects were randomly grouped into all verbal or a verbal-pictorial presentation followed by either pictorial practice or control task. The subject matter was taken from a beginning college chemistry course. The results favored the pictorial presentation with review condition. It also produced more favorable attitudes.

A coordinated slide and audio tape about whales, whaling, and conservation was developed and field tested by Tsavaris (1981). The materials were very well received by the high school students.

Moshiri (1981) developed a set of media materials to enrich the ISCS program for junior high school students. He found no significant differences overall between experimental and control groups on attitudes, achievement, and retention, but on some subgroups there were significant differences in favor of the experimental materials.

The use of video tapes and a written assessment device were compared by Ganiel and Hofstein (1981) to assist teacher evaluation of student performance. The results showed that the written assessment instrument provided greater uniformity in assessment and better attitudes toward its use than did video tapes.

Summary

The studies that dealt with AT seemed to indicate that AT was stronger in changing attitudes, awareness, and motivation than in producing significant changes in achievement. Achievement is improving, however. More studies are needed on the use of microcomputers; it appears that students can learn from them. Of special importance in this section was the paper by Harvey on the use of "hands-on" activities in science; it deserves careful review.

EVALUATION--INSTRUMENTATION AND METHODOLOGY

Science education research studies continue to demand inventive, imaginative measurement techniques. A variety of tests is reported in this review of the research.

Formal Reasoning

Two tests were reported which evaluated formal reasoning ability and one study evaluated the Longeot Test. Texley (1981) developed a group test of formal operational logic using the content area of environmental science. She validated the test with 250 students in grades 7-12. The reliability of the instrument was 0.95 and it also showed strong validity. Shayer et al. (1981) also developed a test for assessing the ability of children to use concrete and formal reasoning strategies. (It would require about 50 minutes to test 30 children). The Longeot Test of Cognitive Development was evaluated by W- et al. (1981). He used 500 subjects for further validation of the test and found that it was reliable.

Propositional Knowledge

Caldwell (1981) described the development and assessment of procedures to derive representations of students' propositional knowledge from multiple choice items. His sample of students was a group of elementary education majors enrolled in a biological science course.

Conceptions of Scientific Theories

Cotham and Smith (1981) described the development of an instrument called the Conceptions of Scientific Theories Test. It can be used by elementary and secondary science teachers to determine student ability in understanding the tentative and revisionary conception of science.

Attitude Toward Energy Conservation

Koballa (1981) developed an instrument which could be used to determine teachers' attitudes toward energy conservation. Subscales of the instrument can be used to measure specific characteristics of the respondents' attitudes.

Physics Achievement

Al-Raieky (1981) prepared and validated a physics test for twelfth-grade-level Saudi Arabian students. Halliday (1981) made an analysis of the relationships between learning objectives and the items that were used to evaluate the Technical Education Council physics courses in Great Britain. He recommended needed improvements.

Attitudes

Munby (1981) made an analysis of the Moore-Sutman Scientific Attitude Inventory from its use in 30 research studies. He concluded that there was some uncertainty as to what was being measured by the SAI. His findings were at variance with those of Schaap.

Curriculum Assessment

Blum et al. (1981) and Landes et al. (1981) developed instruments for use in curriculum analysis. Landes reported a task features analysis system which can be used to analyze elementary school science teacher's guides and other program materials. The system gives a detailed step-by-step account of what the classroom would be like if the teacher followed the teachers' guide literally. Blum developed a Curriculum Adaptation Scheme (CAS) for curriculum developers to follow in their curriculum adaptation efforts.

Student and Teacher Observation Instruments

Four instruments were reported which describe ways of analyzing students' perception of the classroom climate or which can be used by observers to record student behavior. Fisher and Fraser (1981) did further validation on an instrument called My Class Inventory with seventh grade students in Australia. They report strong validity and reliability on the instrument which recorded students' perceptions.

Stanbeck (1981) and Ainley and Lazonby (1981) developed instruments which can be used to determine student classroom behaviors. Stanbeck developed the Science Student Observation Instrument which can be used to compare classroom behaviors of black and white students at the junior high school level. Ainley and Lazonby constructed an instrument which was used to observe low-ability 12- and 13-year-old students in a special science program. A critique of the Science Teaching Observation Schedule (STOS) by Dunkerton and Guy (1981) was responded to by the developers of the instrument, Eggleston and Galton (1981). The reliability and sampling was questioned and the authors responded by describing studies which validated the instrument.

Evaluation Methodology

A computer-assisted feedback system called CASE was designed and tested by Fisher et al. (1981). He found that college students in a genetics course who received immediate feedback from 24 quizzes significantly outperformed students who received only two midterms with delayed feedback. The multiple quiz students also had a better attitude toward the course. Another study related to retesting was reported by Deboer (1981). He was particularly interested in the effects of retesting according to ability level. He found that when high school chemistry students were given the opportunity for retesting on end-of-semester exams, there were significant gains in achievement on some units of instruction in chemistry for only the low-ability students. A subproblem of the study also indicated that retesting did not lead to procrastination on the part of the students.

Kermis (1981) studied testing cues and test anxiety and their effects on science test scores. He developed a Test Cue Identification Questionnaire to measure students' perceptions of the intensity and frequency of cue effects. This test did discriminate students into high test anxiety and low test anxiety groups. A subset of disruptive and helpful cues in an actual test did not differentially influence the test performance of high and low test-anxious students. This was an unusual study and needs further expansion.

Summary

Not a great deal was added to the collection of research tests for science education. The test to measure conceptions of scientific theories and the curriculum analysis design of Landes et al. were unusual. One would agree overall with Wilson (1981) who made a large-scale review of science education research tests. He concluded that many tests are available, but that new areas need developing.

CURRICULUM RESEARCH

Curriculum research is broadly defined to include studies on philosophy for science education, curriculum trends, curriculum innovation, student knowledge of particular concepts in science, and research reports on particular curricular programs.

Curriculum Theory

Franklin (1981) studied the philosophy of Jacob Bronowski and then described implications of that philosophy for science education. J. M. Miller (1981) discussed proposed alternatives to a mechanistic view of nature and implications of such alternative views for science education. Both researchers recommended a more humanistic view of science. Eldridge (1981) made a historical study of the relationship between the philosophy of John Dewey and the early progressive college. She discovered that, while Dewey recommended science instruction, science was largely neglected in such colleges as Bennington, Sarah Lawrence, Bard, and Goddard during their early years.

Orpwood (1981) argued in his thesis that present curriculum theory appears to be unable to provide a basis for an adequate understanding of the curriculum decision-making process. He proposed a conceptual framework for decision-making based on the analysis of rational argument and the deliberative process. This framework was tested with good results. Finley (1981) examined ways in which research of philosophies of science could be useful to curriculum developers in science and gave examples of classification schemes from earth science.

Curriculum Evaluation

Willett (1981) made an analysis of selected national elementary science curriculum projects (ESS, IS, SAPA, and SCIS) using Ralph Tyler's Basic Principles of Curriculum and Instruction as a standard of comparison. Individual projects met some of the specific criteria of Tyler, but there was no relationship between Tyler's model and the actual process of curriculum development for the projects.

A project that evaluated the acceptance of the goal of scientific literacy by science educators, supervisors, and secondary school teachers in North Carolina was reported by Mallette (1981). He found significant differences between these three groups on 15 of 45 statements related to scientific literacy. He recommended a statewide conference on objectives in order to find what would constitute the major thrust for a K-12 science program. Teacher concern about curriculum innovation was highlighted by V. M. F. Lien's (1981) summary of factors which influence the extent to which teachers are receptive to educational innovations.

Future Studies

Lane (1981) studied science students' perceptions of the future. He developed an instrument in which respondents indicated the probable time interval-of-emergence for scientific advances on developments and the most emergent opportunities for future employment. He found college science students were not very futuristic in their orientation, and found no significant differences among students in different fields of science study.

Curriculum - Other Countries

Searles (1981) studied curricula and found that different value positions claimed to be inherent in models proposed by MacDonald resulted in differences in content and/or the organization of the content. Mugiri (1981) studied factors affecting the implementation of secondary science curricula programs in Kenya and made recommendations for improvement. Pinango (1981) developed perspectives on growth of scientific knowledge and alternatives for organizing science education and then applied the theory to the Venezuelan system for science education. Azeke (1981) compared the attitudes toward science and science teaching held by administrators and primary school teachers in Bendel state of Nigeria. There were differences in their beliefs and recommendations for change were made.

Curriculum Surveys and Assessments

This particular set of papers describes research studies or surveys that extend beyond a single course in science. They usually have general curriculum implications.

McNeill and Butts (1981) surveyed samples of Georgia students in grades 4, 8, and 11 on an abbreviated form of the National Assessment of Educational Progress Science Test and found significant differences on most variables between scores of Georgia children and national scores, with the Georgia children scoring lower. Swami et al. (1981) also conducted a state-wide science needs assessment in Ohio. Students at the grade eight level were tested and results showed good achievement in science processes and earth science. Physical sciences and life sciences seemed to be weaker areas. Another state level survey by Thornley (1981) concerning the status of marine education in California public schools K-12 showed that there was a general lack of awareness, staff, and courses and textbooks for marine education.

At the district level, Buckner (1981) developed a science resource guide for grades 1-6 in Autauga County, Alabama. Included in the guide were lists of available science materials, readability estimates of materials, and supplemental reading booklets. A study of goals and objectives for teaching science in junior high schools in Kalamazoo, Michigan, was accomplished by Wester (1981). He found discrepancies on how teachers viewed objectives, on what Metropolitan Achievement Tests stressed, and what the Michigan assessment test in science stressed. Four large school districts in Texas were surveyed by Anderson (1981) to determine what science teachers in grades seven and eight were accomplishing in metric education. She found that 85 percent of the teachers were involved in metric education, even though in-service education and materials and supplies were minimal.

Loucks and Melle (1981) described a district-wide revision of a science curriculum, grades 3-6, for Jefferson County, Colorado. A large amount of data was collected on this science implementation effort.

A study that has curriculum implications was reported by Hopkins (1981). She studied the readability of science and social studies textbooks of 607 ninth grade students in an urban public school district in Texas. The Fry Readability Graph indicated that three of four textbooks were below grade level and one was at grade level, yet 80 percent of the students who were Cloze-tested found the books too difficult. She recommended that science textbook companies should examine carefully the readability of their texts and that care should be used in selecting texts for students from low socio-economic and certain ethnic backgrounds.

Blum (1981b) surveyed environmental education projects before and after 1974 and found that the environmental education curricula used methods typical of science instruction methods. The Energy Assistance Office of the Ohio Department of Education surveyed Ohio teachers on energy education (Teacher Energy Education Survey, 1981). The teachers overwhelmingly agreed that energy education is important, and 74 percent indicated the need for energy education materials.

Science - Special Subjects

Rouse (1981) prepared a list of objectives drawn from results of a questionnaire sent to secondary and college chemistry teachers to indicate which ideas or concepts would be required of every student completing a secondary-level chemistry course. Chemical and Engineering News (Chemistry Texts...., 1981) described the results of a study in which a philosopher and a chemist reviewed current introductory-level college chemistry books for nonmajors and found them to be quite uniform in factual content, and to contain an abundance of value judgments on social, political, and economic issues.

Lunetta and Tamir (1981) conducted an investigation in which they analyzed and compared laboratory activities from PSSC and Project Physics. Six major deficiencies in the two laboratory handbooks were identified. In a somewhat similar study, Tamir and Lunetta (1981) studied selected high school laboratory handbooks using the Laboratory Structure and Task Analysis Inventory (LAI). Findings from two biology, two chemistry, and two physics handbooks indicated that they contained highly structured investigations in which students perform manipulative and observational procedures and interpret their results.

Bastian (1981) studied students enrolled in experimental sections of Harvard Project Physics with respect to their attitudes toward science in 1968 and followed up with a similar study of the same students in 1972. He found no significant differences in attitude change over the four-year period. Jack (1981) collected data from 20 Nebraska secondary school biology teachers to analyze factors that moderate instruction and topics in the biology classroom. Classroom observations and teacher interviews revealed that biology instructors did not place high priority upon topics relating to ecology, environment, or interdisciplinary concepts; did not depart from basic text and laboratory manuals; and did not use much individualized biology instruction.

Curriculum implications for environmental education were brought out in a study by Wilson-Giordano (1981). She found that environmental knowledge and locus of control were important in predicting consumer behavior. These effects were determined by persons selecting products which cause few adverse effects on the environment.

Teacher knowledge, attitudes, and practices about nutrition were measured by Penner (1981). She studied health/physical education, home economics, science, and social science teachers at the secondary school level and found significant differences in knowledge and attitudes between home economics and other teachers. In general, most teachers lacked preparation in nutrition education, which has curriculum implications because many science teachers are asked to teach health and nutrition.

Robinson (1981b) and Robinson and Tolman (1981a, b, c, d, e) have prepared data tapes and machine readable users' guides for research information on many variables that were measured in evaluating the Human Science Project of the BSCS project center in Boulder, Colorado. There is a wealth of information available for researchers.

International Curriculum Development

The School Science Review (Science Education Notes, 1981a, b) has prepared summaries of papers, research findings, and program descriptions related to curriculum and instruction in Great Britain. Bajah (1981) described problems in implementing elementary science curricula in Africa. Torres-Hernandez (1981) described the need to update junior high school science teachers concerning the science curriculum in Puerto Rican public schools. Lichtenstein (1981) described the implementation of the Swaziland integrated science program. Development of an integrated science program for Nigeria was described by Urevbu (1981). None of the studies indicates that curriculum innovation is a simple process.

An interesting, and yet controversial, area for study is sex education. Goldman and Goldman (1981) interviewed 838 children, ages 5-15, in Australia, the United States, England, and Sweden on what they wanted to know about sex. More sex education is offered at earlier ages in Sweden compared to the other countries. The most important topics, in terms of frequencies of questions, were about menstruation by girls and coitus by boys. Few expressed the need for information on venereal disease.

Curriculum - Innovation and Research in Specific Subjects

Many studies were reported that could be combined into a group that could be described as evaluation and research on specific course development, contrasted to broader curriculum surveys reviewed in the previous section.

Elementary School Level

Iatridis (1981) described the development of a pre-school science-based program on water, small creatures, gadgetry, and environmental terraria. Qualitative observation data indicated that children in this curriculum increased their self-directed discovery and verbalized curiosity over children in a control group. Reading and science were studied by Simmons (1981) at the first grade level. She made a comparative study of reading skills and science processes and eliminated developmental reading classes using the basal readers. Thirty-four first-grade teachers were used in the research study and results showed that the teachers recognized that reading comprehension skills and science processes were similar in many areas and should be part of the reading/ science curriculum. Brunk (1981) studied the effects of an integrated socio-music curriculum on kindergarten, first, and second grade children. He found that children in the integrated classes learned significantly more than did children in separate classes in science, music, and social studies over a semester's time span. Walrich (1981) contributed to the education of educable mentally handicapped (EMH) children by developing a <u>Science Handbook for Teachers</u> of EMH. The formative research design that Walrich followed was effective and the activities useful to the elementary school students.

Hall (1981) selected a particular learning environment--a wilderness setting--to determine its effects on the ecological thinking, feeling, and perceiving of 12-year-old males. He found that the wilderness setting produced higher ecological thinking, feeling, and perceiving scores over those of control group students who were in a classroom-guided discovery or a didactic approach.

Blum (1981a) studied the effect of an environmental science curriculum on seventh grade students' selection of leisure time activities. He found that students in an inquiry-oriented experimental environmental curriculum significantly increased their leisure time activities in environmental science over those of students in traditional classrooms.

Secondary School Level

Two studies were reported that dealt with earth science. Rollins <u>et al</u>. (1981) found in their study of 492 high school seniors that there was no uniformity in their learning of five earth science concepts and that this was probably influenced by the number of science courses the students had taken. Lene (1981) investigated textbook illustrations in secondary earth science. He selected illustrations from earth science texts and tested students over information in the illustrations. He found that there were errors in the illustrations, but that it was difficult to improve their designs to improve student learning.

There were six studies that related to the field of biology. Dresser and Butzow (1981) and D. L. Wilson (1981) reported on marine education research. Dresser and Butzow identified differences in schools (N=64) which accepted, rejected, or made exploratory use of an innovative marine curriculum. Significant variables included (1) more interest if school was near the coast, (2) socioeconomic status of community, and (3) science and mathematics background of the teacher. D. L. Wilson (1981) found that high school students who attended a special four-week program in marine science developed significant and positive attitudes toward science and the marine environment. Lahde (1981) studied the effect of an educational land planning strategy on students' cognitive and affective development. Lahde wrote a textbook, <u>Planning for Change</u>, and evaluated high school students on land use orientation and critical thinking in a pre- and post-test situation. Significant gains in achievement, attitudes, and critical thinking were made by students who studied the course. Madden (1981) also evaluated an approach to teaching environmental education through science and urban planning. She found that high school students who participated in the 12-week program made significant gains in both the cognitive and affective domain on a pre- and post-test research design.

Wiredu (1981) developed a handbook on population education for secondary schools and training college educators in Ghana.

Roadrangka (1981) made a comparative content analysis of Texas and Thai high school biology textbooks. Significant differences in emphasis were found in the texts and recommendations for change were made.

Taitt (1981) proposed hobby-oriented physics (HOPE) as a supplement to high school physics. In addition, he recommended individualized experiences in physics which would help students become more independent in their learning.

College Level

A variety of studies was reported on curriculum innovation at the college level. A fine review of changes in introductory chemistry courses at American colleges and universities from 1950 to 1975 was made by Ryan (1981). Also, a course in biochemistry for dietetics students was analyzed by

Sirota (1981). She found great variability in what instructors in the course thought should be in the course. There was also very little input from nutritionists as to the content of the course.

Voss (1981) examined graduates' perceptions of the value of a course in science for students entering the printing profession. Former students who were surveyed indicated that electrical circuitry, electronics, organic chemistry, and hydraulics should be important facets of the course. Other recommendations were taken from the student questionnaires and changes are being made. Murphy (1981) made a similar study at Meharry Medical College to evaluate a biomedical science program for undergraduate minority students. The program had a good completion rate and 58 percent of the students had become doctors. Overall, the program was evaluated as quite successful. Dorner (1981) developed analogies portraying solid state physical science principles for teaching industrial arts electronics. Use of the analogies by an experimental group of college students showed higher achievement gain scores by experimental students than by control students. Bigelow (1981) made an analysis of tasks performed by students of machine tool technology with respect to the mathematics and physics needed to carry out problem-solving. Graduates of the program reported that mathematics was essential to program success, but did not rate physics as high. Chapman and Fleming (1981) described a continuing education course in polymer chemistry. They discussed benefits of the course to participants and made recommendations for improvement. Carpenter (1981) developed and measured the effectiveness of a college-level environmental earth science course and found that students made significant gains in their commitment to environmental issues.

Zeilik (1981) developed and evaluated a mastery-oriented, two-semester astrophysics sequence for college students. A personalized system of instruction format was used to handle students with a wide variety of backgrounds.

Two studies were reported that dealt with energy education curricula for teachers. Dunlop and Fazio (1981) conducted a one-day workshop on energy for K-8 teachers and a pre/post-test on attitudes showed significant positive shifts in participants' attitudes toward energy issues. Glass (1981b) also conducted a two-week energy education workshop for science teachers and found significant gains in their energy knowledge and attitudes on pre- and post-tests.

A study that compared student attrition and career development in a Coastal-Environment Studies Program and a Medical Laboratory Technology Program was reported by Wallace (1981). She compared students in the two programs on a number of variables and found that student-faculty and student-administrator relationship had a great deal of influence on the attrition rate.

The integration of science and mathematics has been an exciting topic and Elliot (1981) produced a framework for implementing the curriculum integration of science and mathematics in Rio De Janeiro elementary schools. The framework received favorable evaluation from science and mathematics, education, curriculum, and Brazilian education specialists.

Curriculum - Concept Attainment

The section on curriculum studies focuses on concept studies as opposed to broader curriculum evaluation issues.

Elementary School Level

Cowger (1981) conducted an interesting study in which she compared four-year-olds and seven-year-olds on their knowledge of sugar. There were noticeable differences between the two groups. There are implications for nutrition and health curriculum specialists in the data. Huggins (1981) reported that the laboratory analysis of fossil leaves he developed could be useful in elementary science curricula.

Junior High School Level

Tamir et al. (1981), Gennaro (1981a), and Rubba (1981c) reported studies conducted with junior high school students. Tamir examined students in grades 3 to 7 on "animistic notions" and the meaning of these notions. He found that 99 percent classified animals, 80 percent classified plants, and 56 percent classified embryos as living. Gennaro assessed junior high school students on their understanding of density and solubility and found that two-thirds understood a more complex problem on solubility. Rubba found that junior high science students did not adhere to myth and fables.

High School Level

Cervellati and Perugini (1981) surveyed freshman students at an Italian University on their knowledge of the atomic orbital from high school chemistry. They recommended that elementary quantum chemical concepts should be introduced in high school chemistry. In a study completed in England, Hillman et al. (1981) recommended changes in the vocabulary and the structure of examinations in electrochemistry. Dobbins (1981) studied the use of chromatography experiments to improve student attitudes toward high school chemistry. No significant differences were found between experimental and control groups.

Bartov (1981) found that the ability of tenth grade students (N=600) to distinguish between teleological or anthropomorphic explanations and causal ones was different and independent from the ability to distinguish between teleological or anthropomorphic formulations and factual ones, and that special treatment should be given to develop each of these two abilities.

Johnstone and Mahmoud (1981) developed a model designed to teach secondary school students about water transport in plants through the use of an animated film. The method was partially successful. A study which determined the prevalence of nonNewtonian views of students and the awareness of this by their teachers was reported by Watts and Zylbersztajn (1981). They found that the children answered questions about force with mostly nonNewtonian views and that teachers, in general, were aware of this prevalence. Greene (1981) developed a key and illustrations for the identification of vines growing on the campuses of teacher's colleges and schools in Jamaica. She found the materials useful for beginners in plant study.

What teachers think every high school graduate should know about computers was researched by Hansen et al. (1981). They surveyed 3,576 secondary mathematics and science teachers and listed their ideas on what students should know.

College Level

Trowbridge and McDermott (1981) investigated the understanding of college students enrolled in introductory physics courses. Conceptual difficulties of students and implications for instruction were given. In physics, also, Fredette (1981) studied student misconceptions of electric circuits. He reported that student misconceptions were due to the fact that the standard physics instructional models do not build upon existing student knowledge structures. Another physics concept was studied by Gunstone and White (1981). They investigated first year college students' knowledge of gravity and related principles of mechanics. Students seemed to know the facts, but could not apply them very well.

White (1981) studied the effect on students' attitudes and opinions toward homosexuality after studying a unit on human sexuality. She found that college students who studied the special unit showed significant changes in attitudes and opinions about homosexuality over control groups who studied anatomy and physiology only.

Trembath and Barufaldi (1981) studied the frequencies and origins of scientific misconceptions. They classified t..e misconceptions according to origin and then developed the Trembath Test of Scientific Misconceptions. The test was reported to have strong reliability and validity.

Cross-Age Studies

Bell (1981) studied concepts of "animal" held by New Zealand primary, secondary, and college students. By means of interviews and multiple choice testing she found that students of all ages had a restricted concept of "animal," compared with that of biologists. In another cross-age study, Novick and Nussbaum (1981) evaluated students in grades 5-12 and university sophomore nonscience students and found cognitive difficulties at all age levels, related to the understanding of the particulate nature of matter.

Curriculum - Minority Enrollments - Women in Science

Harris (1981) surveyed school counselor characteristics and enrollment of black female students in nonrequired science and mathematics courses. She found no demographic counselor characteristics that were statistically related to enrollment, but did find that counselors encouraged the students to enroll in courses and that this was significantly related to black enrollment in mathematics courses.

Gallagher (1981) and Styer (1981) evaluated science books in relation to the female image appearing in them. Gallagher found in her study of California elementary science texts that the female image was considerably improved in 1981 texts over those of 1970. She contended that females are still not equally represented. Styer evaluated the collection of Outstanding Trade Books for Children - 1979 exhibited at the 1979 NSTA Convention. These books were evaluated for sexist implications prior to being displayed, but Styer still found unequal treatment for females, particularly in the physical sciences.

Kyle (1981) found in her review of science textbooks that women were grossly neglected. As a result she developed a unit of study for elementary and middle grades on women in science, medicine, and technology. Biographies and bibliographies were included.

Summary

The review of curriculum research was interesting in that there were no comparisons of "new" curricula, such as BSCS, with traditional curricula. Of note, however, were the differences between teachers and science educators on the goals of science education found by Mallette. Textbooks were being carefully scrutinized for readability and sexist images. Research on integration of science and reading was exciting as well as was some work on integration of science and social studies. Overall, there were many (not-too-impressive) studies in which what students did know or what they should know was evaluated. It seemed, though, that environmental education curricula have stimulated more students to become active in issues than have science education curricula.

TEACHER EDUCATION

A large number of studies was reported that examined all phases of teacher education. Included are studies that examined teachers' intellectual characteristics, the specific skills in science teachers need to teach science, research with pre-service and in-service teachers on methods, and several studies that related to teachers' attitudes toward teaching science, particularly at the elementary school level.

Pre-service - Teacher Characteristics

Zeitoun and Fowler (1981) studied predictors of Piagetian cognitive levels of teacher education students in a large eastern university. They found that science achievement, sex, high school grade point average, SAT-verbal, SAT-mathematics score, and field independent/field dependent cognitive style accounted for 58 percent (pooled male/female sample), 53 percent (female sample), and 59 percent (male sample) of the variance, respectively, in Piagetian cognitive levels.

Pre-service - Science Skills and Techniques

Gabel and Sherwood (1981b) studied factors that might serve as predictors of success for students enrolled in a basic science skills course at the college level. They gave students a demographic data questionnaire, a fractions and decimal test, a mathematics anxiety test, a proportional reasoning test, content achievement tests, and a laboratory practical; the latter two were taken as measures of success in the course. The best predictor was the fractions and decimals test. The number of science courses taken in high school was significant for the laboratory practical, but not for the content test.

Two studies that defined laboratory teaching competencies for secondary teachers were reported by Voltmer (1981) and Cobbins (1981). Voltmer developed a final test of 55 competencies in laboratory science skills for the science area and Cobbins identified 68 laboratory and field study skills for teachers of biology.

Shrigley (1981) designed a criterion-referenced format for scoring subjective student tasks in science education courses. Uzor (1981) evaluated the total science teacher preparation program at Auburn University; the findings indicated that the program was very adequate.

Pre-service - Research Prior to Student Teaching (Methods)

Several studies were reported on teaching techniques at the pre-service level. The experiments were not accomplished during the student teaching experience, but effects were studied through video-taped, micro-teaching sessions, or short teaching episodes in elementary or high school classrooms.

An approach that prepared teachers to apply the Guilford Structure of Intellect Model to induce active response learning in science classes in Jamaica was studied by South-Guy (1981). She found significant changes in teacher behavior in experimental over the control groups. The teacher trainees who applied the new strategy used more probes and were able to elicit more spontaneous responses in higher-order cognitive levels. P. A. Miller (1981) studied the effects of behavioral model analysis and formal reasoning ability on science activity lesson behaviors of pre-service teachers and found that the model analysis strategy produced significant differences in teaching behaviors but no differences in formal reasoning ability. The influence of the amount of science knowledge on inquiry teaching behaviors was studied by Dobey (1981). No significant relationship was found between the two. Omar (1981) found that teachers who were trained in specific inquiry teaching behaviors used significantly more inquiry behaviors than did control groups, but no significant differences between experimental and control groups were found on dogmatism scales. Also, Tashkandi (1981) found Saudi Arabian teachers who were trained in higher cognitive questioning skills performed significantly better in teaching episodes than did control groups. Modeling techniques were developed and tested by Koran and Koran (1981). Experimental groups performed significantly better than did control groups on increasing student achievement, and their anxiety level was reduced to a greater extent.

Pre-service - Research During Student Teaching (Methods)

Three studies conducted with student teachers indicated positive results. Taiwo (1981) found that student attitude toward science teaching was a significant predictor of success in student teaching. Pre-laboratory teaching behaviors learned in methods classes transferred to student teaching, but divergent questioning techniques did not transfer according to Haberly (1981). MacDougall et al. (1981) developed a coding scheme which was useful in detecting individual differences among students having different kinds of handicapping conditions with their adjustment to "hands on" science activities from Science Activities for the Visually Impaired.

Additional studies provided data on variables which did not show significant differences but which raised questions of value. Jones (1981) found that secondary student teachers did not differ in pupil control ideology whether they had 8 or 16 weeks of student teaching. Beasley (1981) was concerned that 70 percent of the science student teachers in his study accomplished only 70 percent of the competencies science supervisors thought they should accomplish. Riley (1981) found no differences in achievement by groups of high school students taught by differing cognitive levels of questioning, but did find significant differences in achievement when teacher redirected questioning techniques were used. Preparation to teach elementary science was found to be poor in a sample of teachers studied by Merkle (1981) and more than half of the former students did not desire to be interviewed because of lack of confidence in their science ability. The level of cognitive development of student teachers showed no difference in teaching abilities according to Padilla (1981). Nussbaum (1981) found that teachers' competencies to evaluate students' answers for misconceptions was poor.

Results of a survey of university graduate science students and science professors by Terhune (1981) indicated that they were satisfied with their preparation for teaching. They felt that the graduate teaching assistant approach was an effective way to gain pedagogical skills.

In-service Teacher Education - Needs

Teacher in-service needs in science in Illinois schools were reported from a random survey of 4965 teachers in grades 6-12 by Rubba (1981a, b). The Concerns Based Adoption Model (CBAM) was employed by James and Hall (1981) in studying science teachers' concerns in schools that adopted the ISCS program. The model proved effective in isolating adoption concerns.

Spooner (1981) showed that teachers changed their attitudes in a more positive direction after in-service and teaching the "Beginnings" kindergarten program of SCIS. Also of significance for in-service programs were the findings of Alschuler (1981), who reported that the teacher behaviors that brought about the most academic growth in SCIS pupils were leadership, flexibility, good classroom management, and consideration. Further suggestions for in-service growth were given by Risma-Cordura (1981) who developed in-service modules on specific competencies needed for effective science teaching.

In-service - Teaching Strategies

Lombard (1981) surveyed teachers who were exposed to an in-service program on science teaching and the development of reasoning and found that they were much more aware of student developmental level and, as a result, changed their teaching behaviors. A favorable in-service program that demonstrated positive gains in teacher attitudes toward teaching strategies and gains in student achievement in science was reported by O'Sullivan et al. (1981). On the other hand, Bowie (1981) found no change in teacher questioning techniques as a result of in-service education and Stronk and Koller (1981) found no significant increase in use of science materials by elementary teachers after specific workshop training in materials usage.

International Studies

Characteristics of Liberian teachers involved in adopting the Science Education Program for Africa were described by Gbegbe (1981).

Teacher Attitudes Toward Science and Teaching Science - Pre and In-service

Ways of producing changes in attitudes of teachers toward teaching science or their attitudes toward science were rather unique. Koballa (1981) showed how a persuasive communication technique produced changes in pre-service elementary school teachers' attitudes toward energy conservation and Martin (1981) also found that communicator credibility was influential in changing pre-service teachers' attitudes toward science. In terms of teacher willingness to change to work with innovations in education, Lien (1981) suggested that the teachers' perspective of change, change agent, and teacher role were important. Sallam (1981) found that students receiving inquiry methods of instruction in elementary science improved their attitudes toward science and teaching science. On the other hand, Bajorat (1981) found no attitudinal differences toward education between teachers who favored or did not favor the SAPA science program. A more favorable variable related to teachers' enjoyment of science teaching was that of providing more time to teach science (Green, 1981).

Results of a study by Salama (1981) with Egyptian science teachers indicated that teachers' attitudes toward lecture method, self concept, and locus of control were more favorable in teachers with professional education training than in those teachers with none.

Teaching Skills - Methods of Teaching Teachers

The question is often asked, "What kinds of teacher preparation develop good teaching skills?" The work of Horak (1981) indicated that selected field experiences improved teacher beliefs, attitudes, and performance; Zeitler (1981) used microteaching and modeling and found them effective; Albert and VanDerMark (1981) found peer teaching useful and a student-structured approach designed by Stallings et al. (1981) enhanced students' desire to participate in scientific activities.

Teaching metric information by exposition, modular, or gaming methods was equally effective, but high and low mathematics achievers made similar gains in metric knowledge and attitudes toward metric education according to a study reported by Hess and Shrigley (1981).

Teacher Attitudes Toward Objectives

Australian teachers in grades 8-10 rated science cognitive objectives more important than attitude objectives (Schibeci, 1981). Attitudes of secondary school science and social studies teachers toward interdisciplinary projects were explored by Glenn and Gennaro (1981). Teachers' attitudes in general were positive, but some concerns were raised.

Summary

The research did not provide startling information on how best to prepare a teacher. It seems that the kind of science preparation, not the amount, is important to give teachers an inquiry orientation. Several instructional methodologies were useful in changing student teaching methodology prior to student teaching, but changing student teacher behavior during student teaching or transfering of the skills to student teaching on a day-in day-out basis is more difficult to accomplish. There were some useful reports that gave positive results for changing student and teacher attitudes toward science and teaching science. More research is needed in attitudes toward, and motivating elementary school teachers to teach, science. Morrisey (1981), in her survey of teacher education research concerning changing attitudes, found the same needs and recommended extended research to make use of long-range follow-up studies to determine how long the attitudes remain.

SCIENCE SUPERVISION

A very important person in science education is the science supervisor. Some studies were reported related to science facilities, safety, the nature of supervision, and supervisor characteristics. Thus, a separate section seemed appropriate.

Three studies dealt with facilities or safety practices or procedures. Ainley (1981) reviewed research on the influence of facilities on science teaching and found that good facilities helped foster activity-based science instruction and that the physical environment affected positive study behavior. Chemistry laboratory safety in Alabama schools was investigated by Ekpo (1980) and general laboratory safety practices in Nebraska secondary schools were studied by Woodburn (1981). Ekpo found a need for laboratory safety information and developed a safety module that included information for teachers and students on fume hoods and ventilation, chemical storage and waste disposal, safety equipment and devices, hazards of laboratory equipment and chemicals, and first aid procedures. Woodburn's study of laboratory safety revealed that 81 percent of the accidents in high school laboratories involved heat, glassware, and chemicals; he then identified laboratory procedures that caused 78 percent of the reported accidents. He recommended smaller enrollments for science classes; specific laboratories for all science courses; provision of safety devices, such as goggles, laboratory aprons, and face shields for students; and in-service workshops on laboratory safety for teachers.

Ritz et al. (1981) probably startled the science supervisor group when they reported on their study concerning science teacher/science supervisor relationships. They found differences in perceptions about in-service, interpersonal and support activities, and peer acceptance between the two groups. Some suggestions for these differences were discussed.

Lutz (1981) investigated personality factors that could characterize successful performance in the educational linker role of establishing linkages between research and development and the science classroom. This is a role that a science supervisor often plays. Lutz concluded there is a linker personality and that it is more related to that of engineers, school superintendents, or business executives than to researchers. The nature of scientific investigators, again related to classroom evaluation and other supervisor activities, was investigated by Williams (1981). He studied characteristics such as age, sex, personalities, experience, goals, methodologies, and other qualities of researchers who were involved in the Case Studies in Science Education. He developed a hypothesis from his study that the activities of naturalistic researchers were produced by interactions between the researchers and the cases they studied.

Summary

It is clear that more research needs to be done on science supervision. Ritz et al. pointed out some significant areas for additional studies on the nature of science supervisors and supervision. Concerns are also being expressed about the nature of student teaching supervision as well. Who should do it? How can we use media more effectively in supervision? Is a student teaching supervisor necessary or should supervision be left to the classroom teacher? These questions need answers or much supervision will be done by generalists rather than by science teaching specialists.

SUMMARY AND RECOMMENDATIONS

The review of research in science education for 1981 was highlighted by the reviews of major studies in science education that culminated in the conclusion by Yager (1980b) that science education is in a "crisis." The "crisis" is more apparent from the surveys which note discrepancies between the actual classroom teaching situation and the "desired state" of science education than from the status of science education research. It is still true that there are too many one-shot studies in science education, but there are some optimistic developments which are of note.

There are the beginnings of research at science education centers where research is directed at a theoretical construct such as concept development, or where researchers are probing a question and attacking it from different angles. Nevertheless, there is still need for continuity of research on specific problems and developmental or instructional theory.

Bright spots in the 1981 review were studies that dealt with student characteristics - teaching intervention - and testing of student performance change. The research is more refined and several studies that utilized regression analysis provided more insights into predicting those student aptitudes and teaching activities that were productive. Noteworthy were studies on problem-solving, use of prior knowledge, structuring for concept attainment, and emerging studies on instructional technology.

Science education studies in 1981 indicated a strong interest in the involvement of the handicapped, minorities, and women in science. Of note also were the many studies related to sex differences and achievement, interest, and attitude toward science. There was good evidence in 1981 that achievement of males and females in science is about even between the two; boys, K-2, are a little stronger in spatial ability, and female attitudes toward science were lower than those of males. This "attitude" problem needs much attention.

Many research priorities for science education were pointed out early in the review. A few science education centers are taking a more longitudinal and conceptual approach to problems, but a major research challenge culminating from this review is inquiry into how to translate research into practice in the classroom. What are effective techniques for communicating theory into practice? Persuasive techniques and communicator credibility were two presented in this review. Teacher education is the key for the future. The race for technological and scientific superiority that will continue the United States as a productive country cannot afford to have the scientific education of its students classified as being in a "crisis" situation.

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