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ABSTRACT

This review covers 422 studies of the following types: reports prepared for scientific organizations, dissertations, journal articles, research papers, and papers presented at journal articles, research papers, and papers presented at conferences. The studies have been organized into one of seven instruction (summarizing studies related to models and explanations of how students learn, instruction (summarizing studies related to models and explanations of how students learn, aptitudes and individualized instruction, textbooks and comprehensibility, problem-solving and thinking, prior knowledge and misconceptions, museums and field trips, computers and instruction, and other areas); (2) curriculum development and evaluation (including studies related to policies, models, textbooks, and curriculum materials); (3) cognitive development (reviewing studies on cognitive growth and development, reasoning, achievement, concepts, and process skills, attitudes, perceptions, and interests); (5) learning and achievement, reasoning and logical thinking, science process skills, attitudes, perceptions, and interests); (5) preservice teacher education (presenting studies related to attitudes, process skills and logical thinking, science anxiety, and methods courses) and inservice teacher education (presenting studies related to questioning and wait time, methods courses, and teacher behavior); (6) research completed in foreign countries (including research focusing on learning, classrooms, curriculum development/evaluation, and/or sex). A bibliography (by author) and a subject index are topics (including meta-analysis studies and studies focusing on race and/or sex). A bibliography (by author) and a subject index are included. (JN)

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION -- 1983

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Foreword

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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ERIC/SMEAC

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Introduction

This year's annual review of research in science education resulted in the production of two documents. In addition to the summary published here, Holliday and McGuire produced an annotated bibliography of all 422 citations together with an extensive subject and author index. The bibliography, A Comprehensive Description of Research in Science Education - 1983, is published by the SMEAC Information Reference Center, 1200 Chambers Road, Columbus, Ohio 43212.

In this summary, the following types of research reports were included: (1) research articles (n=116) published in the Journal of Research in Science Teaching and in Science Eucation, (2) selected articles (n=56) in other journals focusing on science education, (3) relevant papers (n=121) presented at the American Educational Research Association for Research in Science Teaching (NARST) meeting in Dallas, (4) dissertations (n=109) exploring research questions in science education, and (4) reports (n=20) prepared by such institutions and organizations as the National Science Foundation (NSF) and the American Chemical Society (ACS). Conference papers from AERA and NARST are included because these works often represent research areas of greatest current use and interest to scholars at the time this summary is published.

The 422 reports were placed into one of seven clusters for analysis and discussion: learning and instruction, curriculum development and evaluation, cognitive-development studies, test development, teacher education, science education research completed in foreign countries, and special topics.

Reports appearing in journals outside of science education, reports of local interest, and reports not subject to some form of peer review have usually not been cited in past NARST/ERIC reviews. We have followed this tradition. Readers seeking background information not contained in the present document are encouraged to explore the works cited by authors referenced in the bibliography. Readers seeking copies or summaries of papers, reports, and dissertations or wishing to communicate directly with the authors of these documents will find the names of the university or institution of origin printed after each bibliographic entry. The first names of authors are included in all entries for similar reasons. Readers unable to make contact with the researchers cited in this bibliography are invited to write to NARST, The University of Calgary, Calgary, Alberta, Canada T2N IN4, for free information regarding the addresses and telephone numbers of the authors.

Learning and Instruction

Models and Explanations

Several people in science education have described models and explanatory descriptions of how students learn and how teachers can help students. These explanations vary in origin but can be very helpful to researchers. For example, Anderson (18) describes a neuromathematical model of human information processing and its application to science content acquisition and to possible future research.

Four research studies describe explanations for misconceptions and cognitive learning. Champagne, Gunstone, and Klopfer (71) described a report which included a brief description of the broad structure of the instruction and probes used to gather information about aspects of students' cognitive structures (middle school students, n=13, and college students, n=6). The results indicated a change in the cognitive structure of the college student.

Second, Osborne and Wittrock (293) looked at learning science as a generative process. They indicated that children form ideas about nature and natural phenomena long before children come into contact with science education. The generative learning model, used as a basis for explaining cognitive processes, has many implications for teaching science, learning science, teaching science teachers, and researching science education.

Third, Griffiths, Pottle, and Whelan (164) advocated the use of learning hierarchies to identify students' misconceptions for some science concepts. The use of this model to identify misconceptions with respect to the performance of "stoichiometric calculations" and "conservation of mechanical energy" was described. A number of specific misconceptions were reported in each case.

Fourth, Gilbert and Watts (157) presented three models in which conceptual development could be examined. The meaning of concept within a framework of present and past influences on science education was examined in a survey of a wide range of studies.

Wollman and Reif were concerned with transfer and problem solving, respectively. Wollman (410) described a teaching strategy explicitly designed to promote transfer using the pendulum and balance beam procedure. This information suggested that about half of the students could acquire, in a brief time, a procedure for transferring knowledge to novel tasks. Rief (315) described several central ideas emerging from a systematic approach to teaching problem solving in the quantitative sciences (chemistry, physics, engineering).

Researchers should pay more attention to theoretical discoveries, such as the ones referenced here, especially when engaging in experimental and correlational work. These discus sions are valuable aids in articulating and defining research problems.

Aptitudes and Individualized Instruction

Aptitudes now are usually defined by researchers as any learner characteristic. Science educators are particularly interested in how aptitudes interact with instructional treatments, because such interactions suggest how students should be systematically assigned to classroom experiences.

Five studies described in a general way how selected aptitudes related to instructional experiences. Knauft (216) described the major findings of a project to evaluate the effectiveness of an audiovisual, self-instructional approach for introductory college biology teaching and to develop and evaluate instructional materials on evolutionary theory. These findings included: multi-image lectures were an effective method for introducing instructional sequences, and individualized instruction worked effectively in introductory biology courses.

Beasley (34) examined the classroom management behaviors of junior high school science teachers (n=24) within learning settings characterized by small group laboratory activities and individualized problem-solving activities. He found that teachers' whole-class presence was an important factor in keeping students on-task while working as individuals or in small groups. Several other teacher behaviors such as surveillance or "with-it-ness" were also identified as effective techniques for keeping groups on-task.

Jolly and Strawitz (201) investigated the effects of teacher-student cognitive style matches and mismatches on student achievement in biology. Tenth-grade biology students and their teachers were classified as field independent (FI) or field-dependent (FD). Students were instructed on a unit in a biology textbook. Field-independent students achieved significantly higher scores than did field-dependent students with both FI and FD teachers, but FD students achieved significantly higher scores with FI rather than FD teachers.

DeVore (98) reported a study to investigate the relationship of cognitive style and knowledge of science processes to the development of positive attitudes during an inquiry-oriented science methods course stressing the philosophies, designs, and activities of various NSF elementary science curricula. The subjects included 30 preservice and in-service elementary school teachers. The design included a pre- and post-test of attitudes toward science and science teaching with the instrument developed by Moore. Cognitive styles were assessed by use of the Embedded Figures test, the Tolerance-Intolerance of Ambiguity Scale, and the D-Scale. Knowledge of science processes was measured by the SAPA Pretest for Science Teachers. DeVore found that, for his sample, the subjects' tolerance for ambiguity and knowledge of science processes were both related to their attitudes when they began the course and when they finished the course, but these variables did not seem to affect the development of the desired attitudes during the course.

Abdenroth and Friedman (3) conducted a pilot study to incorporate anxiety reduction into chemistry laboratory sessions with the goal of reducing chemistry anxiety and increasing academic performance. The subjects were 40 students enrolled in Introduction to Chemistry during the summer of 1981. Seventeen enrolled in the first session and were the experimental group. Because the subjects could not be assigned to groups randomly, the researcher used a quasi-experimental design: a non-randomized control group, pretest/posttest design. The treatment enabled students to recognize and talk about their chemistry anxieties and to experience relaxation techniques. The results suggested that treatment lowered levels of chemistry anxiety and resulted in higher grades.

The four other studies in this area were more basic in nature and provided a base for subsequent work. A study to determine whether certain instructional strategies were superior to others in teaching high school chemistry students problem solving was conducted by Gabel and Sherwood (147). The effectiveness of four instructional strategies for teaching problem solving to students of various proportional reasoning ability, verbal and visual preference, and mathematics anxiety were compared in this aptitude by treatment interaction study. The strategies were the factor-label method, analogies, diagrams, and proportionality. Six hundred nine students in eight schools were randomly assigned to one of the four strategies within each classroom. Programmed booklets were used to study the mole concept, the gas laws, stoichiometry, and molarity. Problem-solving ability was measured by a series of immediate posttests, delayed posttests, and the ACS-NSTA Examination in High School Chemistry. They found that mathematics anxiety was negatively correlated with science achievement and that problem solving was dependent on students' proportional reasoning ability. The factor-label method was found to be the most desirable method and proportionality the least desirable method for teaching the mole concept. However, the proportionality method was the best for teaching the gas laws.

Thuman (375) investigated aptitude-treatment interaction (ATI) effects of teacher control. Two teachers taught a one-week science unit in elementary chemistry to eight classes of eighth-grade students. Each teacher taught two classes using high control teaching and two others using low control teaching.

Regression analysis on achievement showed no significant ATI with either the internality-externality x treatment interaction or the field-dependence/independence x treatment interaction. There was a significant treatment effect. Analysis of covariance showed a significant aptitude-treatment interaction with reflectivity-impulsivity x treatment interaction. Students who exhibited reflective reasoning patterns achieved higher science achievement scores, probably because they were more successful in answering classroom discussion questions and received positive feedback as a result. Students were more successful in high control classrooms.

In a pretest/posttest, randomized, two-group, experimental, factorial design study, Kremer (222) compared detailed (favoring field independence and induction) and nondetailed (favoring field dependence and deduction) assignments on biology achievement over a seven-month period. The sample comprised 95 male, tenth-grade students enrolled in first-year biology in a preparatory school. High capacity students apparently benefited from flow and block diagrams, inductions, field independence, and structure, whereas low capability students may have been hindered by these.

Howard (192) conducted a study to determine the effects of two different types of written post lab tasks on the achievement of college students in microbiology. Forty female students enrolled in two lab sections were randomly assigned to two treatment groups. A series of six written question assignments (post lab tasks) comprised the treatments. The assignments (tasks) were constituted of either summarizing (lower order) or transferring (higher order) questions. It was found that the summarizing post lab tasks were more effective in influencing microbiology achievement than were transferring tests. Students having high aptitude achieved better in microbiology lab than did lower aptitude students, and students at higher levels of cognitive development achieved better than did students at lower cognitive levels.

Two final studies examined aptitude and field independence/field dependence. Crow and Piper (88) investigated the perceptual orientation and attitudes toward science of freshman community college students (n=47) and the relationship of these characteristics to science achievement. It was found that perceptual orientation (field dependence/independence) was related to students' attitudes toward science. In addition, students who were field independent and possessed a positive attitude toward science scored significantly higher on a science achievement test than did students who were field dependent and possessed a negative attitude toward science.

Further, DeLorenzo-Rooney's study (95) investigated the relationship between cognitive style (field dependence, balanced, and field independence) and the enhancement of science knowledge and attitudes of sixth-grade middle school students engaged in learning abstract physical science concepts in an experiential mode of instruction. The results supported the theory that field independent persons did better than their more field dependent and balanced counterparts on levels of recall and application. Thus, educators may need to provide additional activities for the latter two categories to help sharpen recall and application skills.

This year's studies covered a variety of research problems, thus limiting any single conclusion. But, the reported research was of higher quality than was reported in previous years. Thus, these reviewers recommend that readers examine these foundational works closely.

Texts and Comprehensibility

Researchers using cognitive psychology as a foundational base suggest that science educators need to consider more seriously the effects of texts on students. Ulerick (379) described and examined the failure of traditional science education research to address adequately the textbook as a learning variable and, drawing on research concerned with discourse comprehension, suggested a paradigm within which content of textual instructional materials could be analyzed and evaluated.

Finley (138) reported a study to develop a description of what students recalled from reading expository science text material and to search for different groups of students who recalled the same propositions. Thirty-eight grade 11 physics students read and then recalled content related to energy transfer. Each student's recall was tape recorded and analyzed to identify the propositions recalled. Cluster analysis procedures were used to identify groups of students who recalled the same propositions. Among other things, it was found that of the 259 propositions students recalled, 73 were actually in the text. There were 19 propositions in the text that were recalled by no students. Of the 75 propositions recalled by more than 10 percent of the students, 43 were in the text. Four groups of students were identified, each organized around a different empirical event that students recalled from the text. Notably absent in all groups was the theoretical content related to the main theme of the text. The results suggested that science educators cannot assume that all students in a class will recall identical information from the assignment.

McGuire and Holliday (267), using a similar literature base, evaluated the selective attention model which was first often used to explain the effects of adjunct questions on learning from a text. Twelfth-grade physics students (n=50) in a "naturalistic" setting were randomly assigned to two different question-treatment groups and a reading-only group. Subsequently, a low-level application posttest and high-level application posttest were administered. As predicted, significant interactions were detected for each posttest, and a significant multivariate interaction (based on a regression approach) was detected after combining the posttest scores.

In a different vein, Morrison (278) investigated the extent to which ninth-grade students read to learn in six social studies, science, and English classes. Four foci were identified to facilitate the observation of reading as an assigned learning activity: out-of-class reading, in-class reading, in-class spoken questions related to assigned reading, and in-class written questions (i.e., tests) related to assigned reading. She observed reading to be a learning activity that was utilized to some extent in all six of the classrooms. In addition, teachers transmitted to the students messages about the importance of reading and the students' compliance with reading assignments.

Adair (5) explored the use of science fiction literature to teach science in elementary science programs. A random sample of 62 children's science fiction books was analyzed, representing books published before and after the launching of Sputnik. A list and frequency count of scientific terms were recorded, a sample of 216 science concepts was drawn from the books and rated for accuracy, and reliability levels were determined for each book. Adair suggested that classroom teachers may choose to use science fiction books appropriate to their science programs with the knowledge that the validity of the science and the readability levels have not changed significantly from 1940 to 1980. When teachers are concerned with the quantity of scientific terms, they should be aware of the differences between pre-Sputnik and post-Sputnik books.

In a recent assessment of needs in science teaching supported by the National Science Foundation, it was reported that school science programs can be characterized by one word--textbook. Based upon this situation, Chiappetta and Rawe (73) examined a set induction narrative as one approach to effective usage of the textbook. The population for the study was all (n=165) eighth graders in a junior high school. The two independent variables used to form the treatments: (1) familiar narrative with prompting, (2) familiar narrative with no prompting, (3) historical narrative with prompting, and (4) historical narrative with no prompting. The analysis indicated that the subjects in the familiar narrative group had significantly higher scores than did the subjects in the historical group. Prompting did not appear useful.

Sor the most promising theory and research in school instru is being produced by specialists in reading and is now be used to explore problems in science education. Unfortunately, too few teachers are capitalizing on the available guidelines produced during the past few years.

Problem Solving and Thinking

Problem-solving studies described here constituted only a portion of the work completed during the year. Other studies were reported under other categories and reflected a wide variety of orientations. This topic is becoming increasingly researched in science education and is following the trail of some work reported in mathematics education.

In elementary school, Ross and Maynes (324) described an instructional program based on expert-novice differences in experimental problem-solving performance that was taught to sixth grade students (n=265). Performance was assessed with multiple choice and open-ended measures of specific transfer. Between-group comparisons, using pretest scores as a covariate, showed that treatment condition students consistently outperformed controls; similar results were found in the within group comparisons.

In secondary school, Gabel and Sherwood (148) conducted a study to determine which skills and concepts high school students have that are prerequisites for solving mole problems through the use of analogs. Two analogous tests (with four forms of each) were prepared that corresponded to a conventional mole test. The analogs used were oranges and granules of sugar. Different forms of the two tests were randomly assigned to 332 high school chemistry students of five teachers in four schools. Comparisons resulted in some of the following conclusions: (1) the size of the object made no difference in the problem difficulty; (2) students understood the concepts of mass, volume, and particles equally well; and (3) problems requiring two steps were easier than those requiring one step.

In another secondary school study, Gauld and Ryan (153) conducted interviews in which students thought aloud about their answers after they had completed a twelve-item multiple-choice physics test. A total of 144 student-item pairs were analyzed. The findings indicated that students did use strategies in choosing answers. Furthermore, many of the questions did not provide well for an analysis strategy by which students could reason out answers.

At the college level, Moose (276) emphasized the qualitative aspects of physics in problem solving in order to determine if such an approach was as good as (or better than) the traditional quantitative method in preparing students to solve the application level problems. Students in four sections of first-semester calculus were used for the control and experimental groups. He found that instruction emphasizing the qualitative aspects of physics produced problem solvers as good as those produced by a traditional quantitative approach.

Statkiewicz and Allen (356) evaluated the effectiveness of exercises designed to develop critical and analytical reasoning skills in the biological sciences. The students (n=112) were required to write out justifications for acceptance/rejection of each solution to the practice problems. A significant improvement in practice problem performance was found. Different grade groups, however, displayed significantly different trends in performance. The higher grade groups (A, B, and C) tended to increase while the lowest grade group (D) decreased. A highly significant correlation between scores on practice problems and on course examinations was also found. In summary, the findings indicate that students' analytical skills do improve with practice and that these skills are transferrable to new and unfamiliar problems.

Eniaiyeju (122) compared the relative effectiveness of teacher-demonstration and self-paced modes of teaching concepts and problem-solving skills in college chemistry. Sixty students were randomly assigned to two treatment groups. A self-paced instructional package was used by the self-paced group. Subjects in the second group were taught by a teacher who used the same self-paced package. The results showed that the self-paced mode was significantly more effective for teaching concepts and problem-solving skills and that most students preferred the self-paced instruction to the teacher-demonstration method.

Finally, Finkel (131) examined three methods of teaching problem solving which had been adapted to group presentation in an ongoing physics course. The methods were: (1) standard, guessing a formula and substituting numbers; (2) heuristic, using stepwise planning and evaluation; and (3) information processing, based on cognitive psychologists' discoveries about strategies used by experts and novices. Students (n=113) in four sections of a high school physics course were assigned to treatment groups within classes. Each group received two periods of videotaped problem sessions using one of the three approaches. In subsequent phases each group received the other treatments. He found many significant relationships between variables, and his regression approach produced useful prediction equations. The performance criteria used here indicated that the three approaches to teaching problem solving were equally successful.

These researchers have described specific strategies useful to teachers in facilitating problem-solving skills in students. These studies will be helpful to researchers continuing this line of research.

Prior Knowledge and Misconceptions

A large number of studies described explanations for how learners' thoughts about science concepts and principles often are more harmful than helpful in the classroom. Apparently, many students lack the prior knowledge necessary to learn an idea with ease or lack a proper conceptualization or understanding of the reasons why phenomena occur as they do.

Champagne and Klopfer (72) describe some interesting explanations including: (1) the characteristics of naive conceptions, (2) the influence of naive conceptions on students' interpretations of instructional events, and (3) the implications of research for designed instruction to facilitate the reconciliation of naive conceptions with scientific theories. The authors note that investigations indicate that the persistence of naive theories which students bring with them to science classes and the distortion that these theories engender in students' comprehension of instruction are among the principal causes of their failure to achieve understanding in science.

In order to determine prior knowledge, Finley (134) met with 31 eleventh-grade physics students in clinical interviews related to heat transfer prior to instruction on that topic. Transcripts of the clinical interviews were analyzed to determine each unique proposition used by the students. The frequency with which each proposition was stated and a cluster analysis procedure was used to determine variations in the students' knowledge. The results indicated that (1) there was a set of propositions common to nearly all students, (2) there were four substantial groups of students who shared distinctive sets of propositions, and (3) there were a moderate number of propositions that were essentially idiosyncratic. He suggested that teachers and curriculum developers could consider the commonly held student knowledge of a subject and the alternative conceptions of a limited number of groups of students in designing instruction. More effective instruction is likely to result when this is done. However, accounting for the additional knowledge that is particular to individuals must be done as it has been, by teachers interacting with students in their classes.

Three studies were reported which look generally at misconceptions and their effects on science learning. Specifically, Anderson, Smith, and Slinger (16) described recent research in the field of cognitive science and found that students' understanding of a wide variety of scientific concepts was influenced by the existence of preconceptions which were in conflict with accepted scientific theories. Anderson, Slinger, and Smith conducted a two-year study during which materials were modified to deal with student preconceptions which conflicted with scientific ideas. Classroom observational data showed important changes in the teachers' behavior, and student learning was improved.

In addition, Pope and Gilbert (307), in examining alternative perspectives on the nature of knowledge and psychological development, found that learning will occur only if the learner views the knowledge as having personal relevance. If the teacher's science does not fit into the learner's previously developed constructs of the world, then the learning is merely done by rote.

Hertel and Heller (180) investigated the effects of pairing parents and their middle-school aged children as learning partners in an informal science course. Forty-eight families who volunteered to attend a Saturday class in building radios, telegraphs, and telephones were randomly divided into two groups. The first treatment group (P/C) consisted of parents and children attending the class together. The second treatment group (C/C) consisted only of children from the volunteer families. All children were also classified by their prior knowledge. It was found that the P/C group children scored significantly better on attitude toward the course; and no significant difference existed between the groups based on the cognitive posttest, the perceived skill test, or on attitude toward subject matter. Prior knowledge was a significant factor in the cognitive posttest scores and in the attitude toward subject matter.

Specific instances of misconceptions in physics were examined in three studies. Watts and Gilbert (393) examined students' conceptions of the words "force" and "energy" using the Interview-about-Instances approach. Implications for science instruction and instructional strategies are discussed, based on findings that many students have views of these concepts that are different from accepted scientific views.

Conceptions of motion held by pre-college students at four grade levels (grades 5, 9, 11, and 12) were investigated by Langford (227). Clinical interviews were conducted with 29 students, in which subjects were presented with two dynamics problems via computer simulation with videographs. He found that students faced disequilibration when their Aristotelian conceptions met Newtonian realities in science classes and that these conceptions were not readily eliminated from cognitive structure by about one-half of the students who studied physics in high school.

Jones (202), using the Interview-about-Events and Interview-about-Instances procedure, attempted to identify the concepts of speed, velocity, and acceleration held by students (n=30) in the 11-16 years old range. It was found that students' understanding of the concepts varied with schooling and maturity. Unless students had received instruction in these topics, their concepts of motion were often vague and confused.

Hewson and Hewson (182) investigated 90, Form 2 (grade 9 equivalent in USA) students' alternative conceptions and instructional strategies to effect change from alternative to scientific conceptions. An instructional strategy and materials were developed using previously determined prior student knowledge (conceptions and alternate conceptions) and incorporating principles for conceptual change. An experimental group was taught the concepts of mass, volume, and density using the special instructional strategy and materials. A control group was taught the same concepts using a traditional strategy and materials. The results indicated that significantly greater improvement in acquisition of the science concepts resulted from using strategies/ materials dealing with student alternative conceptions.

In three separate studies looking at elementary school students, misconceptions were specifically examined. Eaton et. al. (114) examined the relationship between student misconceptions and learning by focusing on six fifth-grade students as they attempted to make sense of classroom instruction in light and seeing. Pretests indictated that students held the misconception that sight was possible because light illuminates things, not understanding the role of reflected light in vision. Posttests indicated that five of the six students still did not understand how light enables seeing at the end of the instructional unit. Conceptual change did not occur because the students' misconception was not addressed in either the text or classroom instruction.

Osborne and Cosgrove (294) reported that students' (n=43) conceptions of what happens when water boils, evaporates, and condenses, and when ice melts suggests that childrens' conceptions are quite different from those of scientists. Moreover, their ideas can remain uninfluenced or can be influenced in unanticipated ways by science instruction. Knowledge was retained through the high school years. Students who had elected one or more years of science had significantly higher (p .02) adjusted SPC posttest scores than those students who had not elected science.

Symington and White (366) observed the explanations offered by two classes of sixth-grade children to see how they were acquired and retained. They found that when students were asked to explain why an explanation of a natural phenomenon (given earlier in class by another student) was correct or incorrect, the children often changed their minds as a result of this process.

Obviously, a large proportion of students have developed misunderstandings or lack important pre-knowledge about science concepts taught in our schools. This is one of the fastest growing areas of research in science education, and it promises to clarify ways of dealing with the classroom problem of preparing students to learn key concepts.

Museums and Field Trips

The Korans at the University of Florida and their associates continue to dominate the research in museum work in science education. Specifically, Koran, Longino, and Shafer (220) reviewed past studies on research in natural history museums and science centers, proposed a taxonomy of exhibits in museum settings, and focused attention on factors which should be considered when studying/learning in these informal settings. In addition, productive methods of conceptualizing research and future lines of research were described and related to learning in informal settings.

In an experiment, Koran, Lehman, Shafer, and Koran (219) evaluated the instructional effectiveness of an attention-directing-and-controlling device (an instructional wall panel) prior to entering a cave exhibit or exiting the exhibit. Twenty-eight seventh- and eighth-grade students were randomly assigned to the two treatments and a control group as they entered the museum. A 25-item criterion test was designed to measure the acquisition of conceptual and factual knowledge and specific attentional factors relative to both the cave and the instructional panel. The instructional panel was found to be more effective than having a group walk through a similar habitat and view a film. Apparently the device functioned as a forward shaping or backward review prompting adjunct in this informal learning setting.

John Falk and others working at the University of Florida followed a similar approach to museum and field study. Falk (124) reviewed six studies on school field trip learning. Among the findings reported were those indicating that students' perceptions of the novelty of the trip affected what they learned; that all children will learn about the setting in which the trip occurred, but only those in a moderately novel environment will learn much about the intended lesson; and that imposed learning was inhibited in settings where novelty was either extremely great or small

Falk (125), in the development of an asessment instrument, collected data which indicated that observable behavior and time, especially in conjunction with each other, were perhaps useful as unobstrusive indicators of cognitive learning. This technique has implications for the assessment of other types of learning as well.

In addition, Balling and Falk (31) presented fourth-grade children (n=171) with a structured lesson regarding aquatic mammals, either as part of a field trip to a zoological park or as an in-class slide-lecture. The script for the lesson was identical for both the zoo tour and the class presentation. Learning and retention were assessed by giving a pretest prior to either the zoo tour or the class presentation, a posttest four days after the experience, and a second posttest approximately 60 days later. Results indicated significant learning and retention for all subjects. However, the zoo-tour group showed much more learning than did the class presentation group.

Finally, Stronck (362), from the University of Victoria, evaluated cognitive and attitude outcomes of grades 5, 6, and 7 students (n=816) touring 31 museums in British Columbia. The students showed greater cognitive learning when they participated in a more structured tour, i.e., one led by a museum docent. However, more positive attitudes were found when students participated in less-structured tours led by their classroom teacher.

Researching instructional problems in informal settings has become an acceptable and productive line of research. Results generally support the hypothesis that effective science teaching should include instructional experiences outside of the conventional classroom and that unsystematic and unplanned trips to science museums and other destinations usually constitute unproductive and indefensible teaching strategies.

Computers and Instruction

Research dealing with computers in science instruction continues to grow. The effects of computers in the science classroom are examined in many ways. For example, Wise and Okey (409) provided an analysis of student achievement outcomes (both cognitive and affective) attributable to microcomputer-based instruction. The magnitude of effects were examined using the technique of meta-analysis for those reports that provided adequate data. Comparisons of instructional effects for microcomputers and large main-frame computers were made.

Three reports describe work being done in secondary schools. Waugh and Yeany (394) conducted a study to: (1) measure the effects of computer-managed diagnostic testing on the immediate and subsequent achievement of high school biology students, (2) assess the effects of motivation and ability on this achievement, and (3) determine if the effects of the diagnostic testing were consistent across these student characteristics. The effects were measured in three units of study of a BSCS biology course. The results of their study indicated that computer-managed diagnostic testing was an effective and efficient means of increasing immediate science achievement and that the effect was consistent across levels of motivation and ability. In regard to subsequent achievement, the earlier diagnostic-testing experience appeared to have negatively influenced achievement, posssibly because of a dependence on the diagnostic feedback. With respect to student characteristics, ability had a positive relationship with achievement while motivation level had none.

Olstad, Padilla, and Heller (288) described their quasi-experimental study in which the goal was to determine if middle-school aged children who volunteered to take a short microcomputer course with their parents differed in achievement and attitude towards computers from children who volunteered to take the same course with their peers. The 62 subjects were from two locations: Athens, Georgia, and Seattle, Washington. Analysis of extensive background questionnaires given to parents and children of both treatment groups revealed that the children from the two locations differed only in that the children from Seattle had more experience with computers in school than had the children from Athens. The children were administered a 15-item pre and post cognitive test and a 17-item pre and post attitudes-toward-computers test. It appeared that children who volunteered to take a microcomputer course with their parents were not significantly different in achievement or attitude towards computers from children who volunteered to take the same course with their peers.

Okey, Shaw, and Waugh (287) reported a project to develop and evaluate lesson plans for using computer simulations in a group setting where the teacher used one computer with a class of students. The evaluation results showed cognitive achievement to be reasonably high and student response to the computer simulations to be highly positive. The results showed that limited computer facilities could be used effectively to achieve objectives in the science curriculum with accompanying positive reactions by students and teachers.

Most investigators concluded that using computers in the classroom facilitated the goals of the designers and recommended continued use and further research.

Comparing Other Variables

The studies annotated here compare a variety of variables in areas not covered by the previous categories. Typically, an experimental method is used to investigate a research problem well-grounded in literature. The first group of studies examined adjunct learning aids, while the second group examined more general strategies.

In the first group of studies, the effects of advance organizers, study questions, and prompts with diagrams were investigated.

Lantz (228) conducted a study to determine the effects of advance organizers and subsumers on cognitive learning of solar energy concepts by 11 classes of eighth-grade physical science students (n=300). The main learning activity was a 12-hour unit on solar energy. The advance organizers were verbal/graphic and comparative. The students' posttest scores on an investigator-developed test served as the dependent variable. Two major findings were indicated. First, advance organizers benefited students of all subsumer levels on cognitive learning of solar energy concepts on both immediate and delayed tests. Second, the presence of relevant subsumers in cognitive matrix benefited students on both immediate and delayed tests.

Holliday (186) used the selective attention model to explain effects of overprompting students provided with study questions adjunct to a complex flow diagram. Tenth-grade students (n=170) were randomly assigned to an unprompted-question, a no-question, a prompted-question, or a placebo control group. Strongly prompting students to answers of questions was less effective than an unprompted-question treatment, suggesting that prompting techniques be used with extreme caution.

In addition, Allison (12) focused on the use of cognitive modeling and directed written practice to train students to ask operational questions. Fifth- and sixth- grade students (n=72) were randomly assigned to one of three treatment groups. Group One received teacher modeling of operational questions. Group Two received directed written student practice in writing operational questions in addition to the modeling treatment presented to Group One. Group Three received a treatment designed to limit exposure to operational questions through cognitive modeling and direction written practice. He found that the fifth- and sixth-grade students' ability to ask operational questions, when confronted with cognitive conflict presented in the form of discrepant science demonstrations, could be enhanced by the use of cognitive modeling. Also, the use of directed written practice in creating operational questions with cognitive modeling can significantly increase the likelihood of fifth- and sixth-grade students using operational questions.

Finally, Schollum (333) reported a study to investigate and describe how the presence of arrows in science diagrams influenced pupils' interpretations of these diagrams. Tape recorded interviews were conducted with 15 students in Form 4 classes (14 years old). He found that students interpreted diagrams to fit presently held views of nature. The presence of arrows did not alter this interpretation.

The second group of studies examined different methods of presentation examining processes, inquiry, manipulatives, and mastery techniques. Dunn (110) evaluated six different presentation techniques designed to allow a comparison of method on concepts acquisition. The participants in the study, 230 students enrolled in introductory chemistry, were randomly assigned to each of the treatments. It was found that the instructional methods that developed a prototype of the concept led to a higher level of concept attainment than did the discovery lesson or the lessons which consisted mainly of a verbally-stated definition.

Small and Morton (348) studied the effect of spatial visualization training on student performance in organic chemistry. Spatial visualization tests and SAT scores were used to form two matched groups of students (n=65). Both groups had eight weeks of special training that was independent of the classroom and laboratory assignments. The experimental group received training that emphasized the development of spatial visualization skills; the control group received training in nomenclature and chemical notation. The investigators found that the spatial training (independent of classroom, laboratories, and instructors) improved student achievement and helped to develop the skills required to use model kits effectively.

A study to determine the effectiveness of an inquiry approach to science and language teaching to further develop classification and oral communication skills of bilingual Mexican-American third graders (n=64) was reported by Rodriguez and Bethel (320). The Solomon Four-Group experimental design was used. Pre and posttesting was by the Goldstein-Sheerer Object Sorting Test (GSOST) and the Test of Oral Communication Skills (TOCS). The experimental group participated in a sequential series of science lessons requiring manipulation of objects, exploration, peer interaction, and teacher-pupil interaction. The results on the posttest scores indicated a significant improvement at the 0.01 level for the experimental group in both classification and oral communication skills.

Friend and Caifa (145) determined the effect of increased laboratory time on selected students' attitudes toward science. The sample of 42 female high school juniors enrolled in a general chemistry course in an all-girls' school was divided into two groups. Both sections were taught by the investigator. The Science Attitudes Appraisal was administered initially and then again after students' laboratory time had been increased from 20 percent to 40 percent. There was no change in the students' attitudes toward science, despite increased laboratory time.

Haukoos and Penick (176) examined the effect of two classroom climates (discovery and non-discovery) on learning of science process skills and content achievement of college students (n=78). The term discovery denotes the degree of freedom that the teacher established in classroom interactions, both verbal and nonverbal. Verbal interactions were monitored with the Science Laboratory Interactions Categories. The results indicated that students in both climates achieved equally well, but students in the discovery climate achieved higher process scores as measured by the Welch Science Process Inventory.

Edoff (115) compared a planetarium unit of study which included direct manipulation and one which excluded direct manipulation to determine which method was most effective for increasing achievement and attitude change among fifth- and eighth-grade students. The population included the entire fifth-and eighth-grade student body (N=542) of a school district. Students were randomly assigned to three groups for treatment variations. The results showed that the inclusion of student object manipulation during a planetarium unit of instruction apparently improves student retention of learned information and understanding of lunar phases and motion. Students using a manipulative were better able to recall presented information and had a slightly improved ability to apply presented knowledge and to observe astronomical locations.

Cohen (79) investigated whether examining materials from several perspectives had greater effect on development of projective spatial abilities than examining materials from a single perspective. One hundred five fifth-grade students (56 females, 49 males) were randomly assigned to one of four groups. Two teachers taught two classes apiece--one receiving instruction encouraging examining materials from a single perspective, the other from a multiple perspective. The treatment was determined to have a significant effect on the development of projective spatial abilities. Gender was found to have no direct effect on the dependent variables.

The last two studies in this category compared the effects of mastery and non-mastery learning environments. Specifically, Brooks (54) examined the effectiveness of master instruction to an equivalent time, non-mastery mode of instruction for improving students' learning and retention of selected science process skills. Ninety students from a middle class junior high school in New York were the subjects for the study. No significant differences were found in levels of achievement between mastery and non-mastery approaches for average or above-average students. Above-average students who had mastery instruction scored significantly higher than did their non-mastery counterparts on an instrument measuring retention of low level process skills; however, average mastery instructed subjects showed no significant differences in retention from average non-mastery instructed subjects. Both average and above-average mastery instructed subjects scored higher than did their non-mastery counterparts on an instrument measuring retention of higher level process skills. It was concluded that a mastery instruction strategy can produce a more permanent mastery of sequentially organized materials than can an equivalent-time, non-mastery strategy.

Dillashaw and Okey (99) reported results of a modified mastery learning strategy concerning two diagnostic cycles with high school chemistry students (n=156). The results indicated that achievement of students using mastery strategies was significantly greater than that of students using non-mastery strategies. It was also found that the on-task behavior of mastery learning students increased in a linear fashion during the study (56 days), while on-task behavior of non-mastery students decreased. Attitudes toward science and science instruction were not significantly different but were positive in both cases.

These studies compared different variables under different conditions. Thus, the studies must be examined individually.

Describing Other Variables

The studies annotated here described variables where the researcher's goal typically was to identify predictors and contribute to our understanding, after using a correlational technique. Some studies were not predictive but were ethnographic in nature.

The following six studies examined instructional variables, including attitudes. Crawley, Schmitt, Saegert, and Trout (85) investigated a "matching" hypothesis with students (n=574) enrolled in ninth-grade physical science. Instruction was designed to meet student learning needs on three variables: cognitive style, locus of control, and need level. Attitudes and achievement served to measure the effectiveness of matching. The amount of enhancement of attitudes and the nature of the relationship between attitude and degree of compatibility with the instructional strategy were found to depend upon the attitudinal object.

The relationships of students, teachers, and learning environment variables to science attitudes were explored by Haladyna, Olsen, and Shaughnessy (165). Data were collected from fourth-, seventh-, and ninth-grade students and their teachers. It was determined that the following variables were related to science attitude of all classes at the aforementioned grade levels: sense of importance of science, student fatalism, teacher quality, and numerous learning environment variables.

Heath and White (177) investigated one aspect of decision making, namely, how variances in the number of properties in an object collection influence the ability of children to identify multiple alternatives. A posttest-only design was used with second and fourth graders randomly assigned to three decision-making treatments. In the treatments the subjects were asked to make an award to two children who had tied for first in a contest; the awards were sacks of jelly beans. The treatments varied in the characteristics (color) of the jelly beans in the sacks. The number of different colors varied across treatments (treatment 1: one color; treatment 2: five colors; treatment 3: seven colors). Analysis of the data suggested that variances in object properties result in an increase in the number of alternatives a student generates in a concrete-object-centered episode. Specifically, this indicated a direct positive and significant relationship between the number of properties of an object presented to a student in second and fourth grades and the number of alternatives named for a fair distribution of the objects. In addition, it was found that second graders named more alternatives than did fourth graders.

A study to determine whether or not high school seniors enrolled in non-required college preparatory science courses had different attitudes toward science and scientists than did high school seniors not enrolled in that particular sequence of courses was reported by Squiers (355). A questionnaire and the Scientific Attitude Inventory were used to collect data. Squiers determined that curriculum continuance was a significant factor in the attitudes of high school seniors toward science and scientists. The author concluded that enrollment in a science sequence of courses may be important in preventing the loss of students from science and science-related fields.

Talton (368) examined attitude and achievement measures of the students (n=1,500) from 70 biology classes that were collected at the beginning, middle, and end of the 1980-1981 school year. The data indicated that there was a significant relationship between student attitudes and classroom climate and attitudes toward science at the middle of the year.

Baker (30) looked at the relationship of attitude, cognitive ability, and personality to science achievement in the junior high school. One hundred junior high school students were given the Scientific Attitude Inventory, Spatial Rotations, and the Myers-Briggs Type Indicator. Science and mathematics grades were used as measures of their abilities. It was found that attitudes and mathematical ability seemed to affect science grades more than did personality factors. It appeared that, although girls in junior high were not hindered by less mathematics or spatial ability than boys and outperformed them in science, girls did not like the subject and lacked an important personality characteristic associated with science.

The following eight studies used a variety of variables to predict consequences. Elementary school studies were reported by Sneider and Pulos and by Dennison. Sneider and Pulos (351) looked at the state of children's model of the earth. Interviews were conducted with 159 boys and girls from public schools in the San Francisco Bay Area. The sample included 30 third graders, 25 fourth graders, 25 fifth graders, 25 sixth graders, 26 seventh graders, and 28 eighth graders. The data suggest that mature concepts of the earth's shape and gravity are acquired gradually, through a series of distinct levels. This acquisition culminates for most (but not all) children by seventh or eighth grade. It was also found that individual differences in verbal ability were correlated with performance on the earth concept interview at all notion levels and that the general ability to use a spatial reference system may be required to advance to the higher notions.

Dennison (96) studied the strategies used by sixth-grade children (n=6) in finding relations between variables. Each child participated in a practice session and three problem sessions. The problem performances were analyzed to see if strategies existed. A strategy was said to exist if a pattern of processing steps was seen to occur more than once in a subject's performance. Dennison found that the subjects in her study were accurate in finding rules involving relations between variables. The sixth-grade children used strategies when they were asked to find relations between variables, but they differed in the number of strategies they had in their repertoire for this purpose. It appeared that the rules formulated by the subjects were meaningful since the subjects were able to use the rule to predict what would happen when two elements were tested. It was clear that the subjects were hypothesis-guided in much of their attempts to find rules.

Clasen (77), in the only secondary school study in this subcategory, investigated the variable effect of four different instructional presentations of identical content on the achievement of 72 gifted seventh-grade students. The teaching strategies were independent study and three questioning techniques: (1) 75 percent of the teacher questioning being lower level as defined by Bloom's Taxonomy, (2) 75 percent of the teacher questioning being higher level as defined by Bloom's Taxonomy, and (3) 75 percent of the teacher questioning being divergent production as defined by Guilford's structure of the intellect model. It was found that immediate posttest results revealed significant differences in favor of the lower order questioning group over the higher order and independent study group on the lower order subscale of a multiple-choice test.

Harris, Dettloff, Duroy, Johnson, and Lord reported on college and university studies. Harris (171) found that the relationship between students' (n=1,008) preparation in high school physics and chemistry and students' success in college chemistry (as measured by a final letter grade of B- or better) indicated that most well-prepared students (defined as having had previous experience in chemistry, physics, and mathematics) did well in general college chemistry.

Dettloff (97) designed a study to formulate a predictive equation to identify community college biology students (n=420) who most probably would not succeed in a science course. Background characteristics and reading/math ability accounted for 42 percent of the variance in achievement. Cognitive development accounted for 12.8 percent of the variance in achievement.

Duroy's (111) purpose was to evaluate the hypothesis testing strategy of freshmen biology students and compare it with final grades. The 49 students enrolled in a first-year experimental biology class were administered the Turtle Task. Results of the test indicated that, of the 49 students enrolled in this course,

Development and Evaluation

Studies reported in this area range from those dealing with single units to those concerned with programs. Larson (29) studied the construction and field testing of a unit of instruction on Maine rocks and minerals. Five teachers and their 226 students comprised the experimental group which received three weeks of instruction which included reading printed material, viewing slides, listening to scripts read by the teachers, and performing six activities. The control group, composed of two teachers and their 152 students, received the pretest and posttest but no instruction. The unit, "Mainely Rock Talk," was found to be appropriate for eighth-grade general science classes.

Butzow and Gregory (62) reported on a study designed as an evaluation of the impact of the Northern New England Marine Education Project infusion curricula on school principals, science department heads, and teachers in grades K-12 in the states of Maine and New Hampshire. Questionnaires were mailed to all 246 secondary school science heads and to a random 20 percent sample of principals of grade K-6 schools. Major findings indicated that Project materials were used at approximately the same percent at all grade levels represented. Approximately 33 percent of the schools were aware of the Project materials, and of those, approximately 75 percent were using them. In-service education and proximity to the sea were major predictors of use.

An assessment of the implementation of Science - A Process Approach II (SAPA II) in selected fourth, fifth, and sixth grade classrooms was reported by Franco (139). The nature and extent of SAPA II implementation was identified by assessing 42 intermediate-level teachers with the Stages of Concern (SoC), Levels of Use (LoU), and Innovation Configuration (C) components of the Concerns Based Adoption Model (CBAM). Student science process outcomes were established by the administration of the ERIE Science Process Test to students of participating teachers. It was found that higher science process outcomes were associated with those teachers who utilized suggested introduction activities and who judged student performance utilizing science process assessments. In addition, students who actively made decisions, manipulated materials, and recorded data had significantly greater science process outcomes than did their occasionally-active or passively-occupied counterparts.

Shaw (339) also used eleven modules from SAPA II in determining the effect of a process oriented science curriculum on problem solving ability. Four integrated processes (interpreting data, controlling variables, defining operationally, and formulating hypotheses) were defined as problem solving. Forty-six students in two treatment classes and 37 students in two control classes were randomly assigned from the total sixth-grade population in a university community in

Oklahoma. The treatment group was administered the eleven SAPA II modules over a period of 24 weeks. The control group was administered a set of activities which emphasized the same content as the SAPA II materials, but which were content-oriented without the emphasis on problem solving skills. A t-test was used to determine if there was a significant difference between the mean scores of the treatment and control groups on the portion of the science instrument dealing with integrated problem solving. It was found that a relationship did exist between students being involved in the SAPA II curriculum and their ability to apply problem solving skills to content not covered in the program. When the integrated processes were examined separately, it was found that students' ability improved in the specific areas of controlling and manipulating variables, interpreting data, and defining operationally in science. However, it did not improve their ability to formulate and test hypotheses.

Hoskins (190) compared the achievement and attitude of students in an individualized biology program with the achievement and attitude of students in a conventional biology class. Subjects for the study were tenth grade, first-year biology students in three high schools in a large North Central Texas city. Each of the three schools was selected to represent a particular category of high schools. The categories, based upon the mean achievement scores for students within the schools, were above average, medium low, and very low. Classes and teachers in the experimental group and control group were matched as closely as possible in each of the schools. Student performance and attitude were compared by sex, achievement level, and school category. Achievement was measured using the Nelson Biology Test; attitude was measured by the Attitude Toward Any School Subject Test. Average students in the above-average school achieved significantly better in the individualized program. In the medium-low school, students as a whole achieved higher in the control classes. There was no significant difference between the two programs in terms of achievement in the very-low school. The attitude surveys showed that students in the above-average school preferred the individualized program; those in the medium-low school preferred the control program. There was no clear preference indicated by students in the very-low school. There were no significant differences in attitude or achievement between males and females in the individualized biology program.

In another study related to biology, Leonard (242) tested a Biological Sciences Curriculum Study (BSCS) inquiry approach for university general biology laboratory against a well-established commercial program judged to be "highly directive." The sample consisted of 24 laboratory sections of General Biology at a large midwestern university. Each laboratory section consisted of approximately 20 students, and each section was randomly selected into experimental or comparison group treatments. A randomized (by section) pre/posttest control group design was created with 208 students using BSCS-style laboratory instruction as the experimental group and 218 students using the commercial program as the comparison group. Students met in the laboratory for two and one-half hours per week for a semester. The experimental approach made systematic use of science processes, development of concepts by questioning, and requirements on the student to exercise discretion. The students were given a pretest during the first meeting and the same examination on the 14th week as a posttest. Experimental group student scores were similar to comparison group student scores on the pretest but were significantly higher ($p < 0.005$) on the posttest at the end of the semester.

A series of three related studies was reported as a paper set at the 1983 annual meeting of the National Association for Research in Science Teaching (NARST). The first study by Connolly and Primavera (82) sought to determine if a horizontal enrichment program which prepares research projects for the Westinghouse Talent Search would be a viable alternative to Stanley's vertical acceleration approach. Data from 590 students who qualified as semifinalists and from 98 students who qualified as finalists were analyzed using multivariate analysis with regard to the following relationships: gender, ethnicity, SES, subject area of the research project, type of school, and professional status of the students' parents. The type of school program that allowed for consistent production of semifinalists and finalists was also reviewed. It was found that, among other things, the New York Metropolitan region accounted for 35 percent of the total nationwide finalists and that 75 percent of the finalists came from New York City public high schools. An earlier finding by Stanley of differentiated mathematics achievement by gender was confirmed. It was concluded that this horizontal program proved to be a well-developed, viable alternative to a vertical acceleration approach.

In the second study, Campbell (85) analyzed successful horizontal enrichment programs in science in 15 senior high schools. The term "successful" was defined with four criteria; two of these criteria involved the consistent production of student research, and two criteria concerned th quality of this research. One of the quality criteria involved producing at least one finalist in the Westinghouse Talent Search. The schools included in the study produced 52 finalists in seven years. The programs were analyzed by interviewing teachers, students, administrators and by conducting site visits. It was found that these programs seemed to benefit the schools as much as they benefited the gifted students. It was also found that the labs in the schools were no better than in most schools and that financial commitments to the programs were also minimal. The teachers in these programs were oriented toward one of the sciences, updated themselves by reading scientific journals, accumulated as few courses as possible in education, and did not

29 used a verification strategy in testing a hypothesis and 20 used a falsification strategy. Overall, a greater percentage of students categorized in the falsification group achieved higher grades than did those categorized in the verification group.

Lord (250) reported a study to enhance the visual-spatial aptitude of students. Eighty-four college undergraduates were randomly placed into control and experimental populations and pretested to ascertain their spatial levels. During the semester the experimental population was treated to a 30-minute interaction each week. Fourteen weeks later both populations were posttested with a second comparable version of the pretest. It was found that statistical improvement in visual-spatial cognition did occur for the experimental group in spatial visualization, spatial orientation, and flexibility of closure. Lord concluded that the results tended to support those researchers who claimed that visuo-spatial aptitude was enhanced through teaching. This study found that the cognitive capacities for spatial visualization, spatial orientation, and flexibility of closure could be improved through carefully designed interactions.

Johnson and Butts (199) investigated the relationships among college science student achievement, engaged time (observed and perceived), and personal characteristics of academic aptitude, reasoning ability, attitude toward science, and locus of control. Measures of personal characteristics were obtained from 76 liberal arts, junior college students. Student engaged time was observed at least ten times for eleven lectures. It was found that engaged time measures, observed and perceived, were significantly related to achievement, indicating that an instructor should endeavor to keep the students as engaged as possible to enhance achievement. Students who were engaged or paid attention, or who perceived that they were engaged or paying attention during lecture classes achieved more than did students who were observed as nonengaged or who perceived themselves as nonengaged.

Five reported studies dealing with issues of gender represent an area of increased activity among researchers in science education. Allen (11) examined the relationship between demographic information, mentorship data, situational factors, job satisfaction and support systems, and the productivity of male and female scientists. A 36-item survey was developed and mailed to doctoral-level scientists who had graduated in the years 1973 to 1975 and who were employed at the time of the study in a college or university setting. Data analyses were performed on 149 surveys. The results indicated that various environmental and situational factors did have an impact on the productivity of male and female scientists. The findings suggested that some variables investigated had a greater influence on one sex than they did on the other.

Information about how success and gender affect students' view of ideal and actual classroom role behavior was collected by Kauchak and Peterson (210). A 20-item double Q sort was used to measure differences in perception of high school science students according to gender and letter grades. Individual Q sort item rankings of 160 students were tested for significant differences according to letter grade received; item ratings were compared according to gender for 215 students. Differences in perception according to success were found for both ideal and actual student behavior. However, no such overall patterns of difference in view were found between boys and girls.

Brown (56) investigated selected characteristics of ability and achievement as predictors of student achievement in a multi-track science curriculum. It was found that the best predictors of success in a science class were grades in past science and mathematics classes. However, the same predictors were not equally effective for boys and girls. Contrary to the findings in much of the literature, girls achieved as well as boys in high school science and mathematics classes.

A study to determine if seventh-grade life-science students assigned to three ability groups demonstrated differences in attitude toward science, motivation in science, and levels of science achievement was reported by Cannon (67). The sample consisted of 821 ability-grouped students in 38 life-science courses taught by 11 different science teachers in four junior high schools. The results indicated that level of ability group and time of testing were significantly related to achievement, and that males achieved higher than did females at all levels. Advanced ability groups were significantly more positively motivated toward science than all other ability groups, and females were more highly motivated than males. As the school year progressed, motivation toward science decreased. Life science achievement increased significantly from the beginning to the middle of the year, after which it leveled off except for the basic grouped females who made significant gains throughout the year. Results indicated that the higher the ability group, the higher the achievement level.

Burkman, Loewe, and Wongbundhit (59) assessed differences in science achievement between males and females. Subjects for the study were 1,397 high school students enrolled in the first three-month segment of a full-year science course based on minicourses developed by the Individualized Science Instructional System (ISIS). Males outperformed females at all levels. It was suggested that variations in teaching methods and time available for study might be used to improve the performance in science courses of both males and females and/or to improve the relative performance of females.

A mastery learning study in this category was reported by Hallada and Voss (167) who examined two major areas: (1) the identification of students usually considered underprepared for university level chemistry and (2) the development and implementation of mastery principle-based instructional design in general college chemistry for these students. The sample included 63 students in the treatment group, identified by their relatively low cognitive pre-measures, and 329 students in a comparison group. The mastery strategy focused on the alterable variables: time on task, formative evaluation, and highly structured teaching. Educational gain was demonstrated for the treatment group since the two groups were found significantly different in cognitive entry level but significantly similar in educational outcomes measured in terms of course grades and student satisfaction.

Dodge (101), in an ethnographic study of the interrelationship of community college teachers and students in a laboratory setting, found that the inquiry process moved from an examination of teacher role to management patterns and finally to a teacher-student interaction. The study suggested that the teacher role is a function of the transaction between a myriad of extrinsic and intrinsic factors and that the individual instructor's perception of role not only influences the leadership-management patterns employed in the laboratory, but ultimately the amount and type of teacher-student interaction.

Beditz (35) studied the effects of class size on student achievement in high school science. Data were collected on 1,022 high school students enrolled in 50 life-science and physical-science courses. The results of the student and class-level analyses indicated that class size did interact with class ability and teacher qualifications. The author concluded that the questions of class size should be studied in a multivariate context with particular attention to interactive relationships between class size and other student and class variables.

Russell (325) reported a qualitative analysis of classroom discourse and analyzed the use of questions by science teachers and assessed them in terms of arguments used to establish scientific knowledge claims. Questions were analyzed not for form/frequency but for their function in developing arguments that establish claims rationally. The analysis revealed that, because of the teachers' failure to complete a rational argument, a traditional attitude toward authority, rather than a rational attitude, could be suggested to students by the sequence of questions used. That is, the teacher's authority might be viewed as authority of position rather than of knowledge of science. Russell postulates a possible link between pattern of argument and suggested attitude toward authority. Further inquiry is needed to determine whether students "read" arguments in teaching science for an attitude toward authority and relate the results to their attitudes toward science (p. 45).

Sanford (329) described the Junior High School Management Improvement Study (JMIS) which was a field experiment conducted to verify and extend findings of previous research in English and mathematics classes. Using student behaviors (on task, off task, and disruptive behavior) as criteria of management effectiveness, this study investigated classroom management practices in 26 classes taught by 13 middle/junior-high school teachers. It was indicated that when teachers established orderly classroom environments and maintained students' cooperation, student engagement in appropriate learning tasks was more likely to occur.

It is difficult, if not impossible, to draw conclusions about such a variety of studies. Each report must be examined independently for its contribution.

Curriculum

Curricular concerns were the basis for 23 studies reported in this section. Of these, 8 dealt with textbooks and curriculum materials, 9 with curriculum development and evaluation, and 6 with curricular policies and models.

Analyses of Textbooks and Curriculum Materials

Textbooks and curriculum materials have been found by recent reports and studies to be central to science education in K-12 classrooms. Several researchers reported analyses of textbooks and curriculum materials. Yager (413) reviewed a series of initial studies of the nature of textbooks, a review of the studies of mastery of vocabulary in foreign languages, and a review of general research in vocabulary development, especially as it pertains to reading. Twenty-five of the most commonly used textbooks in K-12 science classrooms were analyzed in terms of the occurrence of special or technical terms. He found that more new words/phrases were introduced than in a similar time frame for the study of foreign languages.

Leonard (243) reported a study to determine the relative effects of placement of questions when these questions were interspersed through the reading passage of textual materials for students in a university introductory biology course. Four hundred twenty-five students were randomly assigned to seven groups. Six of the groups read a passage with questions interspersed in the text; one group read the same passage without the questions. The criterion variable was a 20-item multiple-choice test which was given once to all student immediately after they read the passage and then again exactly four weeks later. On the test given immediately after the reading, four of the groups reading with questions at the beginning of the paragraphs scored significantly higher than did the groups which read without the questions. There were no significant differences among any of the group scores for the test given four weeks after reading. He concluded that, assuming that testing immediately after reading represents short-term retention, it could be inferred that questions in textual narrative appeared in most cases to increase short-term retention.

The development of a conceptual framework concerning the messages, both explicit and implicit, about the nature and value of science and technology embodied in secondary science tests was the basis for the analysis of four contemporary textbooks by Giddings (155). A content analysis technique was derived from a system of analysis of newspaper content, and samples from the four textbooks were coded and analyzed. The analysis suggested that the Science Textbook Analysis Scheme (STAS) was a reliable instrument to determine imbalance in textbook content. The data revealed differences among different textbooks and within individual textbooks. Differences between stated goals of science education and textbook emphases were noted.

Cho (75) also examined textbook concept emphasis. He used as a basic measure the achievement level of 17 year olds on biology exercise items as measured by National Assessment of Educational Progress (NAEP) in 1976-77. Objectives from the three most widely used biology texts were combined to form a list of objectives for a hypothetical integrated textbook. The biology exercise items were classified by a panel of 13 experts into each of ten conceptual areas. Then achievement levels were assigned into one of the four cognitive levels as classified by NAEP and into one of the ten conceptual areas on the basis of the panel's judgment. Cho found that there were significant differences among achievement levels at cognitive levels and that there were significant relationships between achievement level and concept emphasis except at the cognitive level defined as comprehension. He also found that change in concept emphasis had taken place in at least one of the recently published biology textbooks.

Vachon and Haney (381) conducted a study to determine the cognitive demand of an eighth-grade science textbook. Reasoning patterns based upon the work of Karplus and science concepts sampled from the textbook were listed and compared. Each concept fell into one of three categories: concrete, formal, or a combination of concrete and formal. It was found that concrete reasoning was required more often than was formal reasoning, but some points of difficulty for students who were not formal reasoners were noted.

Concern for the interrelationship between science and society is reflected in the literature. Walford (389) examined research related to gender roles represented in textbooks and noted that previous writers have failed to identify two separate dimensions of gender inequality--gender differentiation and gender isolation. He then devised a framework for clarifying the problem with possible affirmative action to reduce sexism in science textbooks as the goal. He contends that it is now possible to classify science textbooks with respect to the two dimensions identified and to decide how future textbooks should be classified.

Content analysis was used by Rosenthal (322) to analyze 22 high school biology textbooks for their treatments of science and society. Twelve categories of social issues and six categories of the social aspects of science were defined. The textbooks were analyzed quantitatively (percentage of total text) and qualitatively. The results showed that attention to social issues and the social aspects of science decreased between 1963 and 1983 in the textbooks studied. Three social issues (evolution, the social system of science, and human health) dominated throughout the period. She found no evidence that textbook authors/publishers have responded to the statements of science educators calling for a greater emphasis on science and society in high school biology. Rosenthal concluded that current concerns about science education are of a technological and economic nature that make it even less likely that such a response will occur in the 1980s.

The teaching of biology-related social issues was the basis for a dissertation by Anderson (22) who developed curriculum materials in the areas of biology-related social, political, legal, and ethical issues included in the term "bioethics." The theoretical framework for her materials is based upon the work of Piaget, Bruner, and Ausubel. Topics include abortion, genetic screening and counseling, political and legal aspects of organ transplants, and legal definitions of death.

Concern with textbooks and curriculum materials has a long history in science education. From the studies reported in this section, it appears that our problems are not resolved. The demands on learners are still high. Science textbooks were found to introduce more new words and phrases than would be found in a similar time frame of study for foreign languages; at least one junior high text required more concrete than formal reasoning but presented difficulty for formal reasoners; differences among achievement levels were noted for cognitive levels; inclusion of questions in text materials was found to aid short-term retention but were not significant after four weeks of time. Increased attention to social issues and concerns has been advocated; however, the research indicates mixed results at best. Differences between textbook emphases and stated goals of science education still exist; while a change in emphasis was found for one biology textbook, another study reported a decrease in attention devoted to social issues over the past 20 years.

know any of the authorities in gifted education. In all cases they developed their programs for these gifted students from their own hands-on experience.

The third study by Napolitano and Campbell (86) analyzed the six most successful senior high school horizontal enrichment programs in mathematics. The term "successful" was defined as reported for the second study. The schools in this study produced 27 Westinghouse Talent Search finalists in seven years. The programs were again analyzed by interviews of students, teachers, and administrators and by conducting site visits. The results of the study indicate that female students did not perform as well as males in the various mathematics competitions. It was also found that facilities, including the type and number of computers available, were not important factors in these programs. The teachers were all mathematics majors with very few credits in education and who kept up to date by reading mathematics journals. The programs the teachers designed focused on problems taken from these journals. The students were encouraged to make contact with <u>mathematicians</u> at the college initially and then to develop investigations on their own.

Based upon the studies described, the researchers concluded that these programs were very successful in producing the next generation of professionals.

Because of the varied nature of the studies, overall generalizations are not possible; however, some interesting points are suggested. With respect to implementation of curricula, a couple of key issues are noted. The first, awareness, would seem to be self-evident; a high percentage of teachers who are aware of a new curriculum are likely to attempt to use it. Second, teachers who use introductory activities from a new curriculum and are thus, presumably, more familiar with the underlying philosophy of the curriculum are more successful in attaining desired student outcomes than are teachers who do not use the activities. The results from comparing one kind of approach, say inquiry or individualized, with a traditional approach continue to be mixed. Such studies were termed "horse races" by one reviewer in the past who suggested that there was little to be gained from continued effort in this direction. Her advice seems as sound today as in 1974. With regard to enrichment programs, a series of studies suggested that a horizontal enrichment approach was as effective as vertical acceleration, that successful programs were not dependent upon more or better facilities and financial support and were teacher developed, and that the teachers updated themselves by reading journals in their disciplines and accumulated as few education courses as possible. While the results reported in this section cannot be generalized beyond their bases, we might do well to consider them carefully.

Policies and Models

The basis for developing science curricula was the subject of six studies. An ethnographic study, reported by Gallagher (150), was conducted of the secondary school science department in a midwestern, suburban, middle/upper middle-class school district of 1,850 students. The purposes of the study were to observe, describe, and analyze: (1) how policies and programs for secondary school science were formulated and implemented in the district, (2) the sources of new information and means used by teachers and administrators to acquire new information about science and science teaching, and (3) how teachers' values, belief systems, knowledge, attitudes, and commitments affected their selection of content, methods of teaching, standards, and classroom interactions. Discrepancies were found between potential and actual practice in science instruction.

Schoeneberger and Russell (332) reported on two case studies of science education to provide data about science instruction in the K-6 elementary setting. Observational data were collected over a five-month period with particular effort to collect observation and interview data relevant to how science is perceived by elementary school teachers and how science is actually presented to the students. Factors appearing to affect teacher attitude and behavior included background preparation in science, level of confidence, availability of materials and equipment, time constraints, school curriculum, and patterns of communication and interaction among teachers in the school.

Weil (397) reported a study to develop a model for logically sequencing high school biology curricula. The importance of structure to learning has been posited by many; the supposition of this study was that a logical sequence can provide this structure. A preliminary sequence using the concepts from a high school biology text related to the structure and function of the cell was constructed and field tested. Based upon the test, a more extensive model was developed, followed by a concept list. From this list a superordinate concept was selected and, in propositional form, analyzed for words which needed further development for fuller understanding. The definitions of these words were designated subconcepts and placed in a level below the superordinate concept. This procedure was followed until specific organelles were reached. This second sequence was reviewed by a panel of high school biology teachers who responded to a questionnaire concerning the logic of each step. It was concluded that the proposed model provided a means for developing and presenting a unit, showing the interrelationship of the parts, and providing the structure needed for learning.

Duschl (113) argues that science curricula as described by research can be said to rest in the camp of the oldest, rejected views about the structure of scientific theories which were developed during the twentieth century. He contends that science education has neglected to synthesize into pre-college science curricula the important writing and insights of historians and philosophers of science. It is his position that leaders in science education should assess the value of models of the structure of scientific theories in developing science programs and curricula.

Orpwood (292) developed a framework for the analysis of the discourse of curriculum policy deliberation. The framework was tested through the analysis of transcribed samples of deliberation obtained from a science curriculum committee at which the investigator was a participant-observor. This analysis enabled both the identification of logical elements of deliberative discourse and a discussion of their relationship.

Just as was the case for textbooks and curriculum materials, we find reported discrepancies between the science curriculum as it is intended and the curriculum in actual practice. While the advocacy of a logical structure or framework for curriculum development is not new, the attention drawn by studies in this section to a framework for curriculum policy deliberations and to a consideraton of recent changes in the structures of scientific theories deserves our consideration.

Development Studies

The studies reported in this section deal with the cognitive development of learners. The majority of these studies are based upon the developmental theories of Piaget. The categories under which the studies will be summarized are cognitive growth and development, reasoning, achievement, and concepts and processes.

Cognitive Growth and Development

The studies in this category range from an examination of interrelationships of cognitive structures to the relationship of treatments to cognitive level. Alport (15) investigated the interrelationships between two concrete and three formal operational Piagetian structures. Tasks were devised to test for each of the structures and presented to a sample of 100 high school and college students. It was found, among other things, that there was a significant relationship between performance on three of the tasks and IQ, with performance improving with increasing IQ. No significant relationship was found between task performance and academic achievement. A significant relationship was found between task performance and academic level, with task performance improving with increasing academic level. A finding with implications for science educators was that no task was passed by more than 43 percent of the high school and college students, and that the most difficult task was passed by only 8 percent of the sample.

A study designed to ascertain the influence of an intervention in the development of operational seriation and transitivity in kindergarten and first grade students who had initially failed to demonstrate the ability to do seriation and transitivity problems was reported by Clark (76). The intervention program involved confronting 60 children with problems requiring concrete operational thought. She found that the subjects showed significant advancement toward concrete operation on the seriation problems but failed to show significant improvement on the transitivity problems. In addition, subjects who showed understanding of transitive inference also demonstrated success on seriation, but students who showed clear understanding of seriation did not demonstrate success on making transitive inference.

Based upon Piaget's developmental model, which includes a proposed order of attainment of the concrete operational level logical groupings (dealing with classification and seriation) and infralogical groupings (for space and time), Kelsey and Perry (213) examined the relationship between the spatial and formal structures. Three concrete operational tasks were chosen as representing the last logical, projective, and Euclidean groupings to develop. A task for the multiplicative measurement group was used to check the model's prediction that these structures grow out of those of Euclidean space. Two formal tasks were also given in the individual interviews with approximately 100 college general science students. Piaget's model predicts that the overall order of acquisition for the tasks should be: (1) Seriation Matrix; (2) Tilt of a Cone; (3) Model Landscape; (4) Location of a Point in Two and Three Dimensions; and (5) and/or (6) Bending Rods/ Projection of Shadows. The data showed no significant difference on the two formal tasks, so two separate scalogram analyses for the first four tasks plus one formal task were done. Both scalograms showed that the tasks scaled as the model predicts, with the concrete operational spatial groupings as necessary precursors of formal thought.

In a related study, Wavering, Birdd, and Perry (395) examined the performance of sixth, ninth, and twelfth grade students on five logical, spatial, and formal tasks. Approximately 100 students from the three grade levels were individually interviewed on five of Piaget's tasks. Data for each group were analyzed to look at general performance, grade level differences, and gender-related differences. It was found that only 54 percent of the subjects passed the concrete operational seriation task, less than 20 percent scored at the highest level of the projective space and measurement group tasks, and only 9 percent or less scored at the formal level on the separation and control of variables or proportional reasoning tasks. Grade level differences were found on the concrete operational and measurement group tasks, but not on the formal operational tasks. No clear pattern was found in gender-related differences.

Childress (74) reported a study to determine if the doing of a science project would advance the Piagetian developmental level in maturationally ready adolescents. Factors which might influence Piagetian developmental level were identified as: (1) saliency of tasks, (2) certainty of solution, (3) encoding, and (4) chunking. The first two factors were interpreted in the conventional sense and seen as being offered in a science project. Encoding was measured as time used by subjects on project activities which had been identified as basic process skills in science education. Time was measured on identified integrated process skills and recorded as chunking. The subjects were 73 students from 12 sections of high school chemistry. He found no significant difference in the three groups with regard to Piagetian developmental level at the end of nine weeks. The activities associated with chunking were most often used by project students. The students who showed the greatest absolute gains in Piagetian developmental level, as measured by the Test of Logical Thinking, also used activities associated with chunking.

Armstrong (25) used a combination of case study and experimental study approaches in examining earth science instruction as a factor enhancing the development of formal reasoning patterns with transitional subjects. The case study was to determine whether transitional subjects develop the ability to apply five operational schemes in a sequential order. The experimental study compared a learning cycle treatment, which used materials and activities that encouraged students to generate and test hypotheses, with a neo-Herbartian treatment, which restricted the opportunities of subjects to generate and test hypotheses. Of 43 ninth grade students identified as transitional, from three advanced earth science courses, 12 were randomly selected for a modified case study. Three clinical interviews were administered to these students at five-week intervals to assess their ability to apply five formal operational schemes. No common pattern of growth was found for these students. When the group data were analyzed, the order of difficulty among the schemes was: controlling variables, combinatorial reasoning, probabilistic reasoning, proportional reasoning, and correlational reasoning. There was no significant difference in content achievement or intellectual development between the two treatment groups immediately after the treatments or fifteen weeks after the treatments.

A similar study was conducted by McMeen (271) who examined the role of a chemistry inquiry-oriented laboratory approach in facilitating cognitive growth and development. The subjects were 73 control and 49 experimental students taking a one-quarter introductory college chemistry course. The experimental group was exposed to an inquiry-oriented laboratory approach, while the control course was a traditional lecture-oriented one with "cookbook" laboratory procedures. Pre- and posttests of the Test of Logical Thinking (TOLT) were given to determine level of intellectual development. The author reports the following as major findings: (1) Both students who had exposure to a traditional chemistry program and students who had an inquiry-oriented laboratory based chemistry program showed equivalent increases in intellectual development as measured by the TOLT test. (2) Significant positive correlations were found between pretest TOLT and final course grade and between posttest TOLT and final course grade. There was also found a significantly higher correlation of the posttest TOLT experimental group scores with final grade averages.

In another study along somewhat the same lines, Pilacik (305) examined the effect of historically-based laboratory activities in biology and the development of formal operational thought, knowledge of biology content, and student interest. Two intact sections of biology students were selected by lot for the study. Both the treatment group (N=26) and the control group (N=27) received instruction based on the same text and performed the same number of laboratories. Only the treatment group, however, received the laboratory-based case histories. To determine treatment effects, both groups were administered identical versions of three different instruments: the test of formal operations by Longeot, a 40-item biology content instrument, and a questionnaire assessing student interest. Significant positive correlations were found for the treatment group; correlations for the control group were neutral or negative. Significant interactions were evidenced in the treatment group on the analysis of variance for cognitive measures. Significant interactions were found within the control group on the interest measure. It was concluded that the historical treatment did help improve student scores on the cognitive measures and pupil interest in biology.

Sneider (352) conducted a study within the framework of the Theory of Contructive Operators (a neo-Piagetian theory proposed by Pascual-Leone) to determine whether subjects could learn how to control variables. The 275 subjects were drawn from schools and from non-school youth groups such as scouts and summer camps. They were presented with highly motivating activities: designing, building, and launching model rockets. It was found that: (1) children and adolescents, age 9-15, who participated in the instructional program significantly expanded the universe of tasks to which they could apply the controlling variables scheme; (2) a significant treatment effect was found among separate groups of 9-10, 11-12, and 13-14 year olds; (3) treatment effects were not found to be significant among subjects who had low information processing capacity; and (4) measures of information processing and field dependence/independence correlated more highly with posttest than with the pretest measures of the ability to control variables, suggesting that these cognitive capacities are important in learning to improve performance on controlling variables tasks.

In a study of the relationship between science process skills and formal thinking abilities, Padilla, Okey, and Dillashaw (299) administered paper-and-pencil measures of formal operational and integrated science process skill achievement to approximately 80 students in each of grades 7-12 (N=492). Correlations showed a strong relationship between achievement on the two measures (r=0.73) and on all subtests of both measures. Factor analysis data corroborated the correlational evidence. The fact that a single factor was identified to which all subtests of logical thinking and process skill tests contributed was considered by the researchers to be strong evidence for a common underlying construct. One suggested potential inference to be drawn from these results is that process skill teaching might influence formal thinking ability.

Two studies involved medical students as subjects. Hale (166) asked 59 second-year medical students to solve 12 Piagetian formal operational tasks. The purpose was to describe the formal logical characteristics of this sample of students in terms of their abilities to solve problems in four formal logical schema: combinatorial logic, probabilistic reasoning, propositional logic, and proportional reasoning. The tasks were presented as videotape demonstrations or in written form, depending on whether or not equipment manipulation was required, and were scored using conventional, prespecified scoring criteria. He found that approximately 96 percent of the sample (n=57) were functioning at the transitional (Piaget's 3A level) state of formal operations on all tasks. Because this sample demonstrated formal level thinking to a higher degree than other samples reported in the literature to date, it was suggested that these students were adequately prepared and developed to meet the challenges of their training.

In the second study, Pellens-Meinhard and Shier (301) reported on exploration of the development of logical thinking and social awareness in medical students, using methods derived from and compatible with the developmental learning theory of Piaget. Three of Piaget's logical thinking tasks and three paper-and-pencil social development instruments were given to a selected sample of first- and fourth-year medical students. The results reflected the growth during medical school in the areas of both logical thinking and social awareness.

Because the reported studies vary widely in methodology, subjects, and treatments, drawing general conclusions is risky at best. With this proviso in mind, it appears that the reported evidence tends to support Piaget's developmental theory. Results of treatment effects were mixed. There was, for example, some evidence that the ability to control variables could be expanded by treatment and that process skill teaching might influence formal thinking ability. Such findings were by no means unanimous. Clearly there is work still to be done in this area.

Reasoning

Eight studies were reported which dealt with reasoning. In most cases, reasoning was treated as being equivalent to the Piagetian level of formal operations. Lawson (234) administered two selection hypothesis testing tasks and nine evaluation hypothesis testing tasks, which varied systematically with respect to causality, response alternatives, and context continuity, to two samples of adults to determine the effects of those variables and to determine the degree to which the subjects reasoned with material conditional, material biconditional, partial, or partial plus biconditional connectives. The first sample consisted of 35 students enrolled in a single section of an introductory biology course at a major southwestern university; the second sample was comprised of 32 students enrolled in another section of the same course. The author interpreted the results as supporting the hypothesis that hypothesis testing reasoning in causal contexts begins with the material biconditional connective and involves schemata of controlling variables, probability, and correlations.

Lawson (235), in another study, tested the hypothesis that the basic "logic" used by individuals in scientific hypothesis testing is the biconditional (if and only if) and that the biconditional is a precondition for the development of formal operations. A sample of 387 students in grades eight, ten, twelve, and college were administered eight reasoning items. Five of the items involved the formal operation schemata of probability, proportions, and correlations; two items involved propositions and correlation; two items involved propositional logic; one item involved the biconditional. Percentages of correct responses on most items increased with age. A principal-component analysis revealed three factors, two of which were identified as involving operational thought, one of which involved propositional logic. As predicted, the biconditional reasoning item loaded on one of the operational thought factors. A Guttman scale analysis of the items failed to reveal a unidimensional scale, yet the biconditional reasoning item ordered first, supporting the hypothesis that it is a precondition for formal operational reasoning.

The effect of familiarity with content in logical ability in reasoning was studied by Petrushka (303). Forty-eight students (freshmen and sophomores, all science majors), enrolled in a biology course in a junior college were the subjects. Two tests, both syllogistic in form, were administered to each student. One test contained material concerned only with shape (circle or square) and size (small or large). The other test was concerned with familiar material currently under discussion in the biology course. The two tasks within each test were a material implication and an inclusive disjunctive. A statistical analysis of the means of the two tests showed that the subjects were much more successful with the familiar material task (at the 0.01 level).

The correlation was high between similar tasks (0.55 for the disjunction and 0.73 for the implication task).

In another study of influences on formal reasoning, Linn, Clement, and Pulos (249) compared laboratory and naturalistic content influences on formal reasoning tasks. A sample of 90 seventh, ninth, and eleventh grade students received both laboratory and naturalistic content tasks which required ability to control variables. The laboratory tasks had apparatus while the naturalistic tasks had pictures or props (e.g.; tubes of toothpaste with different characteristics) to illustrate the variables. It was found that content appeared to influence the subjects' expected variables and to influence reasoning. The content's effect suggested that certain reasoning problems are failed by subjects who know the controlling variables strategy, because the subjects only consider their expected variables in applying the strategy but do not consider other variables.

Maloney (261) tested 108 college students to determine the relationship between their ability to solve simple ratio tasks, i.e., their proportional reasoning patterns, and their rule governed behavior with the balance beam. A statistically significant difference was found between the proportionality scores of subjects using the most sophisticated rule and the next lower rule. It was concluded that, for the subjects in this study, there appeared to be a relationship between their proportional reasoning abilities with the six tasks used and the rule they employed in making predictions about the behavior of balance situations. The subjects were definitely using set rules in their attempts to analyze the behavior of the balance beam, implying that the students came equipped with set strategies and were not "blank slates" or "random responders."

Staver and Pascarella (357) reported an investigation of the effects of various methods and formats of administering a Piagetian task on subjects' performance. The task (the Mr. Short - Mr. Tall problem) was presented by four methods: (1) individual clinical interview; (2) group presentation of task followed by paper-and-pencil problem with illustration; (3) group administration of paper-and-pencil instrument with illustration; and (4) group administration of paper-and-pencil instrument without illustration. Each method included four formats: (1) completion answer with essay justification; (2) completion answer with multiple choice justification; (3) multiple choice answer with essay justification; and (4) multiple choice answer with multiple choice justification. The subjects were 376 students enrolled in a freshman-level biology course. The research design was a 4 x 4 factorial design with method and format of assessment as the main effects. Regression analysis with the individual as the unit of analysis showed that neither the method nor the format of assessment accounted for a significant amount of variance in student performance. The overall interaction was non-significant as was regression analysis with sections as the unit of analysis. The principal conclusion was that neither method nor format of task administration influenced the performance of subjects, and that this lack of influence was similar for various combinations of method and format.

Purser and Renner (313) conducted a study to answer two questions: (1) What is the influence of teaching methods upon content achievement of concrete and formal concepts by students who differ in level of operational thought? (2) What influence does concrete and formal teaching have upon the intellectual development of students? Sixty-eight ninth and tenth grade students enrolled in Biology I were randomly assigned to classes taught concretely (the learning cycle). A control group (n=67) of students from the same school was similarly assigned to classes receiving formal instruction of the same content (exposition). Five students from the entire sample began the investigation with a Piagetian classification of formal operational. Approximately half of each group were concrete operational and half transitional at the beginning of the investigation. There were no significant differences between the groups' intellectual development pretest means; however, the concrete instruction group posttested at a significantly higher level than the formal instruction group. When pretest to posttest gains in intellectual development were tested, the gain by the concrete instruction group was significantly greater ($p < 0.0001$) than the gains made by the group receiving formal instruction. It was also found that concrete instruction led to achievement of understandings of concrete biology concepts which was significantly higher ($p < 0.0001$) than comparable mean achievements for the group receiving formal instruction. For formal concepts, it was found that teaching method was irrelevant when attempting to teach formal concepts to this sample of primarily concrete and transitional students; not much achievement occurred. It was concluded that students taught using the learning cycle made much greater gains in intellectual development (reasoning) and in content achievement, for concrete concepts, than did students taught with the formal procedures (exposition).

Fuqua (146) investigated moral reasoning and formal-operational thought in science majors and religion majors enrolled in three church-related colleges. The sample consisted of 48 biology majors, 21 chemistry majors, and 42 religion majors. No significant relationship was found between academic major and formal-operational thought as measured by the Logical Reasoning Test. No significant relationship was found between academic major and principaled moral reasoning as measured by the Defining Issues Test.

These studies suggest that the ability to control variables, to deal with probabilities and correlations, and to handle the biconditional are necessary aspects of formal reasoning. Further, it appears that content influences reasoning, in that expected variables are considered in controlling variables while other variables are not, and that familiar content leads to higher success in logical ability. However, one study reported no significant relationship between academic major and formal operational thought. The reported evidence suggests that students bring with them set strategies and are not "blank slates," a finding with implications for teaching. With respect to teaching, the reported research suggests that the learning cycle is more effective than is exposition in producing gains in reasoning. For concrete and transitional learners, however, teaching method was irrelevant when formal concepts were involved; not much achievement occurred.

Achievement

The relationship between development and achievement was reported in six studies. Lawson (233) examined the relative ability of developmental level and specific prior knowledge to predict achievement of concepts of evolution and natural selection as assessed by three commonly used types of examination items: multiple choice items, a computational item, and an essay item. The effects of students' disembedding ability, mental capacity, and belief in evolution were also assessed. The subjects were 96 undergraduate students enrolled in three sections of a biological science course for elementary teachers. It was found that disembedding ability, prior knowledge, and belief in evolution were significantly related to overall achievement; developmental level and mental capacity were not. Developmental level was found to be the best predictor of performance on the computational item, while belief in evolution and prior knowledge were found to be the best predictors of performance on the multiple choice items. Mental capacity was found to be a predictor of performance on the essay item. The author argues that the cognitive variables influence different aspects of science achievement.

The effects of cognitive development, age, and inquiry strategy on the achievement of 151 elementary school students in grades one, three, and five were studied by Yore (416). Approximately one-half of the sample received instruction in each of two science units. One unit (Seeds) utilized a structured inductive inquiry teaching/learning strategy. The other unit (Magnets) used a semi-deductive inquiry teaching/learning strategy. Results from the analysis of achievement data from two content specific tests indicated that age became a non-significant factor after grade three, and that cognitive development was a critical factor for both inquiry strategies. Non-conservers and non-multiplicative classifiers generally scored significantly lower than did students who successfully performed the conservation and multiplicative tasks. The study suggested to the author that by age eight or nine year students possess the logical structures required by structured inductive and semi-deductive teaching/learning strategies.

Yeany and Porter (415) assessed the effects of three instructional strategies (treatments) on the immediate and retained retention of students studying homeostasis, DNA/protein synthesis, and mitosis/ meiosis. The three treatments involved the dimensionality of the instructional aids and materials used to enhance the lectures on the three topics of study. One treatment used only two-dimensional material such as diagrams, picture, and 2-D models; one treatment used only three-dimensional materials; and one treatment used a combination of both two- and three-dimensional materials. The subjects were also evaluated for their levels of cognitive development and spatial visualization ability and were categorized as to gender. Data analysis procedures, with SCAT verbal and math scores utilized as covariates, were used to identify treatment effects as evidenced by achievement scores and to identify the main effects of cognitive development, spatial visualization ability, gender, and their interactions. These techniques were also used to identify aptitude and gender interactions. It was concluded that: (1) the combination of two- and three-dimensional instruction was the most effective strategy; (2) formal operational students tended to score significantly higher than less-than-formal operational students; (3) spatial visualization ability had little relationship with achievement; (4) females tended to score higher than males; (5) the effects of treatment on achievement across (a) cognitive development, (b) spatial visualization ability, and (c) gender appeared to have been consistent; (6) in general, the achievement of students of varying levels of cognitive development tended to be consistent across gender; (7) the achievement of students of varying levels of spatial visualization ability appeared to have been consistent across gender.

The effects of presenting different sequences of visual materials with laboratory activities on the achievement of high school biology students of varying levels of cognitive development was studied by Buckner (58). Fifty-eight tenth-grade biology students were divided into two treatment groups. One treatment involved the presentation of visuals (35 mm slides, color photomicrographs) to students before they began laboratory activities. The second treatment consisted of presenting the same visuals to the students after they had completed the laboratory activities. Instructional topics included mitosis, animal tissues, algae, and vascular tissue. All laboratory activities involved the use of microscopes. A counter-balanced research design was used to evaluate the effects of treatment, cognitive development, and aptitude on achievement. The data were analyzed in two ways: (1) analysis of covariance with aptitude as a covariate, and (2) the data were combined and analyzed using a t-test for pair-wise differences. It was found that student achievement was higher when students viewed the visuals before engaging in the laboratory activities than when they viewed the visuals after completing the activities. These findings were consistent for all students at all levels of cognitive development.

Crenshaw (87) reported a study to determine the effects of a reinforced teaching method in biology on the achievement of non-science majors in a community college and to examine the interaction effect between the two teaching methods and the students' level of cognitive development. The reinforced teaching method utilized various teaching techniques and technologies to increase the effectiveness of presentation in a non-laboratory biology class. The control treatment was a lecture-only teaching method with the only mode of visual aid being the chalkboard. The sample consisted of 142 students, 73 in the experimental group and 69 in the control group. It was found that (1) there was no significant difference between the two groups prior to experimentation; (2) after the experiment, there was no significant difference in achievement between the two groups; (3) there was no significant interaction between the level of student cognitive development and teaching method; and (4) formal-operational students significantly outperformed concrete-operational students on the biology achievement test.

In a study of chemistry students in Zambia, Mulopo (280) studied the effects of traditional and discovery instructional approaches on learning outcomes for learners of different intellectual development. The subjects were 120 Form IV (11th grade) male students from two boys' schools. Sixty of these were concrete reasoners randomly selected from one school, 60 were formal reasoners randomly selected from the other school. Each of these groups was split into two subgroups of 30 students each. The traditional and discovery approaches were randomly assigned to each set of two subgroups. All subjects were pretested using the ACS Achievement Test, the Test on Understanding Science, and the Test of Scientific Attitude. Instruction was carried out over a period of approximately ten weeks after which the subjects were posttested using the same tests. It was found that: (1) for formal reasoners, the discovery group scored significantly higher understanding science scores than did the traditional group. For concrete reasoners, the mode of instruction made no difference. (2) Overall, formal reasoners earned significantly higher achievement scores than did concrete reasoners. (3) Overall, subjects taught by the discovery approach earned significantly higher scientific attitude scores than did those taught by the traditional approach. (4) In the area of achievement, the traditional group out-performed the discovery group. It was concluded that the traditional approach might be appropriate for teaching scientific facts and principles, while the discovery approach tended to be effective in promoting scientific attitudes and understandings (among formal reasoners). Intellectual development seemed to be related to achievement and understanding science but not to scientific attitudes.

Developmental level and achievement were found to be related in several studies. Not surprisingly, formal operational students tended to score higher than did students who were not formal operational. The relationship of cognitive variables to achievement is not so clear; the evidence suggests that these variables may influence different aspects of science achievement. The reported studies also support the use of visuals and other aids in teaching science. While an optimum sequence of presentation is not defined, use of multiple media and technologies seems clearly better than a single approach. Considering the findings of other studies dealing with individual differences and aptitudes, this is not surprising.

Concepts and Processes

Eight studies focused on concept learning. Emerick (121) analyzed the science education problem of teaching density from two different Piagetian research perspectives: operationlism and constructivism. The hypothesis of this study was that, through clinical interviews with junior high school students and classification criteria that were not task-specific, more students could be shown to be formal operational than had been reported on tests designed to classify students into stages. Clinical interviews were conducted with 15 junior high school students and the behavior on the interviews mapped onto the critical attributes of stages. Thirty-three percent of the students demonstrated formal operational reasoning, a finding that suggested to the author that tests can underestimate the cognitive development of students. It was also found that all students exhibited preoperational behavior at least once and that some of the subjects did have a concept of density, although it was not the formal operational concept of density. It appeared that their concept of density was the culmination of a long process of construction of intuitions, perceptions, and operations, possibly beginning during infancy. The author suggested that the concepts of density held by these subjects can be thought of collectively as a concrete operational concept of density.

Brouwer-Janse (55) examined comprehension of concepts of equilibrium by tenth graders (age 15), college students (age 20), and science professors in a developmental problem-solving study (n=48). Tasks were adapted from standard problems encountered in elementary chemistry. A general problem-solving model quantifying strategic and heuristic processes developed by Pitt and Brouwer-Janse was used to analyze thinking-aloud protocols. It was found that professors used a higher proportion of the 24 discriminable component subroutines, defined problems more completely, and used Evaluation, Selection, and Means-end strategies more exhaustively than did college students and tenth graders. College students were intermediate between professors and tenth graders with respect to defining problems and use of Selection strategy, but were close to tenth graders in overall use of subroutines and in their use of Evaluation and Means-end strategies.

In a study reported by Beison (36), an experimental group of college honors students was given instruction via researcher-developed Piagetian concrete operational strategies for the purpose of assessing the effectiveness of the strategies on acquisition of basic concepts in human genetics. Evaluation was by a constructed comprehensive and unit pre-/post-test administered to both the experimental and control group populations. The data indicated that both concrete operational learning strategies and lecture were effective instructional methods in facilitating long-term and short-term human genetics concept acquisition.

Forty-three students ranging from 8 to 17 were interviewed by Osborne and Cosgrove (294) to determine their conception of the changes of state of water: evaporating, condensing, boiling, and the melting of ice. Familiar kitchen equipment was used to demonstrate the phenomena and the students were asked to describe what they saw happening and then asked to explain what had happened. As a follow-up study, the prevalence of certain views identified thorugh the interviews was established by a paper-and-pencil survey of 725 students ages 12-14. Among other things, it was found that (1) pupils' understanding of scientific terms are frequently superficial despite the fact that they can often associate the correct technical term with an event or phenomenon; (2) pupils of all ages hold views about commonly observed phenomena and older children's views may be similar to younger children's despite the older pupils' considerable exposure to science teaching; (3) children will use scientific knowledge to support nonscientific ideas, and nonscientific ideas may become increasingly popular over certain age ranges; and (4) scientific models which pupils have been taught can appear to pupils to be rather abstract and hardly, if at all, relatable to everyday experience.

Brumby (57) used a carefully prepared concept map of immunity which was then described by 32 first-year medical students. In summarizing earlier work on mapping, Brumby found that concept maps may be complex, difficult to interpret, impossible to compare, and unproductive. These maps do not portray any of the dynamism inherent in the nature of learning. The greatest value of qualitative concept mapping may be in the role of a teaching tool, for it explicitly shows students the importance of making links between new and existing knowledge.

Cullen (89) investigated the effects of passive attempts to show conceptual linkages between a subsuming concept and other concepts in the discipline. Four sections of introductory chemistry students participated in the semester-long study. Two groups received written materials designed to introduce the concept of entropy and to show how entropy explained phenomena that were observed in the laboratory experiments that were performed; the materials also made numerous attempts to link entropy to other concepts in chemistry. The other two sections received the control treatment which contained the same factual knowledge about entropy but which made no overt attempts to show conceptual linkages. It was found that overt attempts to show conceptual linkages to a subsuming concept can cause a restructuring of an individual's conceptual structure so that the subsuming concept assumes a more dominant position in the hierarchy. It also was found that having a rich network of conceptual linkages between problem relevant concepts increased the success of solving novel problems.

Nussbaum and Sharoni-Dagon (286) gathered evidence to test the Ausubel-Novak hypothesis that primary grade childrean are able to learn meaningfully certain aspects of major science concepts in the "reception learning" model. The sample was composed of all second-grade children in an elementary public school in Jerusalem, Israel. There were three classes with n=41, n=37, and n=36, respectively. The instruction was six audio-tutorial (AT) lessons taken by the children individually. It was found that the children were able to learn abstract concepts about the earth's status as a cosmic body, thus supporting the Ausubel-Novak hypothesis.

Novak, Gowin, and Johansen (285) explored the use of concept mapping and knowledge Vee mapping with junior high school (7th and 8th grade) science students. Specific questions addressed were: (1) Can seventh and eighth grade students learn to use concept mapping and Vee mapping strategies in conjunction with regular science programs? (2) Will students' acquisition of science knowledge and problem-solving performance change as a result of instruction in the strategies? Instructional sequences were provided to introduce both Vee mapping and concept mapping. Use of concept mapping and Vee mapping then continued throughout the school year with the frequency of mapping varying from teacher to teacher. Maps constructed by the students were collected and scored by applying an "ideal" map as a template to judge student maps. To determine the effect of the learning strategies on transfer problem-solving performance, a series of evaluation measures requiring "higher" levels of performance, (as described by Bloom's taxonomy) were devised. It was found that, in general, students of any ability level could be successful in concept mapping and that other factors (e.g., motivation) were more important. It was also found that both seventh and eighth graders could acquire an understanding of the Vee heuristic and apply the learning tool in regular junior high school science. The data suggested that concept and Vee mapping were helpful. However, the data also suggested that effective use of the Vee heuristic takes time for students to acquire and that two or more years may be needed for 90 percent or more of the students to achieve high competence performance.

Cox (84) investigated the development of selected science process skills in required and elective science classes in the three high schools of a suburban Oregon school district. The subjects were 900 students in grades 9 through 12. Data were gathered by use of a Science Process Competency Test (SPCT) developed for the study. California Achievement Test scores were used as a measure of academic achievement. Tenth-grade students had significantly higher ($p < .001$) adjusted SPCT posttest scores than did ninth-grade students in required science classes. Science process skill knowledge was retained through the high school years. Students who had elected one or more years of science had significantly higher ($p < .02$) adjusted SPCT posttest scores than those students who had not elected science.

In examining the studies reported in this section, four ideas emerge. First, pupils' understanding of science concepts are often superficial and perhaps incorrect, regardless of their use of appropriate terminology. Second, understanding of science concepts appears related to level of development, experience, and prior knowledge. Third, the use of an organizational structure, such as concept mapping, may well improve concept attainment. Finally, many of the models and concepts in science are often presented in too abstract a manner for learners to apply to everyday experience. Based upon our collective experience in science education research and teaching, these findings seem eminently reasonable. It also seems obvious that these are interrelated findings and that they have implications for science teaching.

Instrument Development

This section contains 21 studies. Although the instruments under consideration range over a rather wide area of concerns, they have been grouped, for the convenience of the reader, into four loosely-related categories.

Learning and Achievement

Kueny (223) assessed the use of word analysis tests as a predictor of achievement in the learning of an energy related topic by senior high school chemistry students. The study was to determine whether or not the word analysis test showed an advantage over conventional testing in predicting change in achievement. Conventional tests included IQ, Preliminary Scholastic Aptitude Test (PSAT), Stanford Test of Academic Skills Form A (STA or TASK), grades (biology final grade and chemistry semester grade), and rank in class. The 80 students were divided into an experimental group (N=48) and a control comparison group (N=32), both of which received instruction in the interrelationship between heats of solution and the reaction tendencies related to the solution process. The experimental group was instructed using laboratory techniques; the control comparison group was instructed in the lecture mode. All students took an achievement pretest, followed by three word-analysis tests. The word analysis tests were designed to measure the student's specific ability to interrelate seven key concepts related to the instruction topic. After instruction, all students took a posttest. Analysis of the data showed that the Pearson r values were somewhat higher for the word analysis tests than for the conventional tests with the change in achievement. The word analysis test had a consistent advantage in the ranges of the lowest conventional scores.

Griffiths, Kass, and Cornish (163) reported on a study in which three psychometric methods for validating learning hierarchies were applied to one data set derived from responses of grade 10 chemistry students (N=269) to items representing skills in a hypothesized hierarchy for the mole concept. The hierarchy derived from the analysis was supported by a test for transfer of learning from subordinate to superordinate skills.

Falk (125) tested the validity of using time and behavior as predictors of learning by collecting detailed data of visitor behavior and expenditure of time while interacting with a participatory museum exhibit. The exhibit used for this study was a multiple-choice, push-button machine focusing on the role of hormones and the nervous system in influencing eight different bodily functions. The final subject pool included 63 subjects, all aged 12-13 (32 males and 31 females) drawn from three classes of an inner London compulsory school. Learning was measured by a 14-item, multiple-choice, true/false design test. Reliability of the test, using coefficient alpha, was 0.873. Time and behavior data were collected by means of video tape. These tapes were subsequently replayed to determine the length of time spent by each subject in front of the exhibit and the subject's behaviors. The data strongly supported the feasibility of using observable behavior and time at the exhibit as predictors of learning. Step-wise regression clearly showed the importance of the interactions of time and behavior as distinct from each separately. It also showed that there was both a quality of interaction factor and a quantity of interaction factor involved in the learning process. Neither time nor behavior by themselves were as good at predicting learning as was the interaction of the two.

As is often the case, the studies reported in this section each dealt with instruments specific to a particular situation. Hence, any attempt to summarize the results would be of little value. Readers interested in a particular instrument are encouraged to refer to the source report or document for more detailed information.

Reasoning and Logical Thinking

A paper-and-pencil test, a 2-d demonstration test, and a 3-d test of formal reasoning were compared by Carlson and Streitberger (68). The subjects were seventh and eighth grade students enrolled in science classes in a number of schools. All of the schools were judged to be from relatively similar economic and social areas. Students judged by their teachers to be extremely atypical in ability were excluded. Using a method of randomly splitting each class, large comparison groups were constructed for testing purposes. It was concluded that the use of 3-d materials in the 3-d demonstration test resulted in student scores that were significantly higher than scores on an identical test using 2-d demonstration materials. However, the difference between the mean scores of the 2-d and the self-administered test was not statistically significant. It was concluded that either of the alternative tests (the 2-d demonstration test and the paper-and-pencil test) was significantly more difficult than Lawson's 3-d demonstration test.

Stefanich et al. (359) investigated the convergent validity of individual clinical task interviews paired with three widely used group tests of cognitive development. The subjects were 182 university students; 88 percent were females, 12 percent males; their ages ranged from 18 to 28. The three group tests' raw scores paired with summed raw scores on four concrete-formal task interviews yielded the following Pearson product-moment correlations: Reasoning Test (Ankney and Joyce), 0.43; Logical Reasoning Test (Burney), 0.61; and Classroom Test of Formal Operations (Lawson), 0.37. Contingency tables were developed for the raw data ranked into cognitive level groups. Contingency coefficients determined were: Logical Reasoning Test, 0.52; Logical Reasoning Test (adjusted), 0.61; and Classroom Test of Formal Operations, 0.50. It was concluded that the correlations obtained were not sufficiently strong enough to warrant selection or categorization of individual students based on their test performance.

In an attempt to avoid the problems posed by clinical interviews and by other classroom tests of cognitive development, Roadrangka, Yeany, and Padilla (318) developed the Group Assessment of Logical Thinking (GALT). Items were constructed which presented a problem; the student was to select the best answer and write a justification for that answer. The Fog Index was used to adjust sentences to produce a written test at or above the sixth grade level. Each of the 21 items included a pictorial representation of a real object. In final form the GALT contained multiple choice justifications and was administered to 450 students in grades six through college. Conventional interviews were conducted with some students as a means of investigating the validity of the GALT. Coefficient alpha for the GALT was 0.89; internal consistency of subtests ranged from 0.13 to 0.85; item difficulties averaged 0.55; item discrimination indices averaged 0.44; the mean intercorrelation coefficients for subtests averaged 0.49. It was concluded that the GALT (1) validly measures six logical operations and (2) can be reliably administered in one class period.

In a related area, Morgenstern (277) analyzed standarized tests constructed for use with secondary school science to determine whether or not the test measured student achievement of the ten rational powers proposed by the National Educational Association in 1961. A group of experienced high school science teachers, after instruction in the evaluation procedure, analyzed 648 test items from 12 randomly selected school standardized science tests. It was found that 90 percent of the test items analyzed measured student achievement of the rational power of recalling. Less than 10 percent of the items collectively measured achievement of the rational powers of classifying, generalizing, inferring, deducing, evaluation, and synthesizing. No items were found to have measured student achievement of the rational powers of imagining, comparing, and analyzing.

The construction of an instrument to measure aspects of development such as reasoning that is valid, reliable, simple to administer and score, and time and cost effective is a persistent problem. The studies reported in this section indicate various degrees of success and the researchers should be commended for their efforts. We can only conclude, however, that a single best instrument that meets all of the described criteria does not yet exist.

Science Process Skills

Burns, Wise, and Okey (60) reported on the development of test items for assessing identification of variables, statement of hypotheses, operational definitions, design of investigation, and the display and interpretation of data. A pool of items in multiple choice format was developed for these outcomes, examined by experts for content validity, and field tested with students in grades 7 through 12. The resulting test was found to have high reliability, and difficulty and discrimination indices within the range of suggested test development standards.

The construction and validation of the Test of Graphing in Science (TOGS) was reported by McKenzie and Padilla (270). Skills associated with the construction and interpretation of line graphs were delineated, and nine objectives encompassing these skills were developed. Twenty-six items were constructed to measure these objectives. Content validity of the items and objectives was reviewed by a panel of experts who agreed with the test developers on the assignment of test items to objectives 94 percent of the time and on the scoring of the items 98 percent of the time. The TOGS was tested with 119 seventh, ninth, and eleventh grade students, revised, and administered to 387 students in grades seven through twelve. The reliability (KR-20) was 0.84 for all subjects and ranged from 0.71 for eighth grade students to 0.88 for ninth grade students. Point biserial correlations showed 24 of the 26 items above 0.30 with an average value of 0.43. It was concluded that the TOGS was a valid and reliable instrument for measuring graphing abilities.

Shaw, McKenzie, and Padilla (340) conducted a study using the TOGS to examine student competencies in the construction and interpretation of line graphs. The TOGS was administered to approximately 385 subjects in grades seven through twelve. Total test mean scores ranged from 11.16 to 15.42. Interpretation subtest mean scores ranged from 4.89 to 7.25; construction subtest mean scores ranged from 6.27 to 8.17. The objectives with the highest percent correct dealt with plotting points and determining the X and Y coordinates of a point. The most difficult objective dealt with scaling axes and drawing a best fit line. Ninth graders' scores exceeded all others. These results, according to the authors, suggest that graphing skills should be introduced in earlier grades and be properly emphasized in the science and mathematics curricula.

Ross and Maynes (323) developed multiple-choice tests for seven experimental problem-solving skills using learning hierarchies based on expert-novice differences. The seven skills were: developing a focus (i.e., formulating a hypothesis), developing a framework (i.e., designing an experiment), judging the adequacy of the data collected, recording information, observing relationships in data, drawing conclusions, and generalizing. The items were refined during three phases of field testing involving a total of approximately 1,600 students. Total test reliabilities (Hoyt) were in the 0.58 to 0.69 range with subtest reliabilities in the 0.25 to 0.45 range. Test-retest reliability using Cronbach's alpha was 0.722 and 0.789 for the two forms of tests; equivalent forms reliability (Cronbach's alpha) was 0.759 and 0.705 for the two orders of administration. The authors indicate that the low reliabilities are symptomatic of the heterogeneity of the domain of experimental problem solving; the skills are discrete components of the same domain. Face validity was established in the development and field testing stages. Several dimensions of construct validity were explored and evidence of criterion validity was obtained. The authors consider the reliabilities of the test to be sufficient for making judgments of group performance, but insufficient in a single administration for individual assessment. It was concluded that the tests could be satisfactorily used to measure problem solving skills. The tests provide a better means of measuring the performance of groups of students than do competing instruments, and they do so at little cost.

While there appears to be somewhat greater agreement on the components of science process skills than for other areas of assessment, there is by no means unanimity and this is reflected in the research. The practice of using an instrument in multiple studies to establish validity, reliability, and usefulness over a range of situations is to be desired and the two reports dealing with the Test of Graphing in Science (TOGS) should be noted in this regard.

Attitudes, Perceptions, and Interests

Four studies are reported which deal with instrument development related to the teaching of science. Tamir (370) reported on the Self Lesson Report Form (SLRF) as an alternative either to direct classroom observation or to commonly used questionnaires in which students and/or teachers report on practices used in their classes. Two hundred and fifty lesson reports were obtained from 250 physics, chemistry, and biology teachers in junior and senior high schools in various parts of Israel. In addition, 90 lesson reports were collected by 20 observers who used the same SLRF. A sample of 40 lessons that were reported by both teachers and observers was used to establish reliability. Overall there was, on the average, 80 percent agreement between observers and teachers. Validity was established by five science educators who examined the categories of the SLRF and found them to be adequate descriptors of classroom transactions.

Stevens (360) reported a study to identify those science teaching practices which were determined by science educators to be most and least essential and then to determine how elementary teachers intended to spend their time using these practices. Instruments were developed to measure the teachers' early and later intentions to use science teaching practices. Following a three-week interval, the teachers completed revised instruments to measure their actual use of these practices. It was found that if early elementary teachers taught science as a separate subject and had adequate storage space for materials (which might be interpreted as indicating that they had the ability to prepare and organize materials), this action could result in the teachers spending more time on practices designed to impart science process skills.

A study to develop a reliable and valid Likert-type attitude scale toward the teaching of simple chemistry concepts in the elementary school was reported by Shrigley and Hassan (344). Using Edwards' 13 validation criteria, a pool of 60 statements was written, randomized, and administered to 64 preservice elementary teachers. The data were subjected to a Likert analysis and a principle-components factor analysis. Statements with an item-total correlation coefficient of 0.30 or less and 25 percent or more undecided responses were either rewritten or discarded. Twenty statements, ten positive and ten negative, withstood those tests. A three-factor analysis was chosen to check the investigators' classification of statements into three categories: egocentric, sociocentric, and actioncentered. Using a three-factor solution, a varimax rotation resulted in 18 of the 20 items loading on one of the three factors. Factor 1 accounted for 25.92 percent, factor 2 for 11.45 percent, and factor 3 for 7.28 percent of 44.02 percent of the total variance. Fifteen of the 18 items clustered into three areas as predicted. When administered again to 98 subjects, the average item-total correlation coefficient (adjusted) was 0.59 and the reliability coefficient alpha was 0.91.

Interest in the patterns by which innovations are adopted was the basis for a development effort reported by Enochs and Harty (123) to design and conduct a preliminary validation of an Implementation Proneness Typology (IPT) for science techers. The proneness dimensions considered were assertiveness, surgency, conscientiousness, venturesomeness, imaginativeness, shrewdness, experimentiveness, self-sufficiency, humanistic classroom ideology, and internal locus of control. Content validity was determined by a panel of "experts-validators" in science educa-tion. Kendall's Coefficient of Concordance, as a measure of agreement among the seven validators, was found to be 0.89. Intra-rater reliability was determined, using Kendalls' Coefficient of Concordance, to be 0.94.

Jones and Butts (?03) described the development and valida-tion of an instrument for measuring students' scientific attitudes along four dimensions: concern for new evidence reacting to currently held ideas, belief in causation, honesty in reporting, and skepticism (involving suspension of judgment, concern for evidence, and use of many sources in information). From a field test with a sample of over 900 Year 10 students from nine Sydney (Australia) high schools, the authors contend that there is evidence to justify treating the scores on the four scales separately, rather than combining them to provide a single scientific attitude score. It was recommended that the instru-ment be used in curriculum evaluation as a means of identifying those attitudinal objectives of the science syllabus which may not be being achieved to the satisfaction of the teachers concerned.

A study to validate the intensive time-series design in gathering attitude data was reported by Mayer and Farnsworth (265). A pool of semantic differential items was formed with five concepts each with six or seven adjective pairs. Double-item instruments were prepared from this pool and administered in a multiple group, single intervention, time-series design for 56 consecutive school days. Two groups of students, one with formal cognitive tendencies and one with concrete cognitive tendencies, were administered the instruments. It was found that the inter-vention, a unit on plate tectonics, caused a positive shift in level of the series data. Also, there was a clear difference in attitudes on four of the five concepts between the formal tendency students and the concrete tendency students. This and other evidence led the authors to conclude that the data gathering techniques used in this particular intensive time-series study appeared to have yielded valid data on student attitudes.

Munby (281) reported on a conceptual analysis to determine the validity of the Scientific Attitude Inventory (SAI). He examined 30 studies in which the SAI had been used and, using conceptual perspectives developed in his study, demonstrated that many of the items thought to tap attitudes can be interpreted differently. The discrepant results obtained by using the SAI in quantitative research can be explained in this way. It was concluded that we can be less than certain of what is measured by the SAI and that it needs reworking before it can be used with confidence. He recommends a reanalysis of the concept "attitude to science," with special attention to the ambiguity of "science" itself in order to develop attitude instruments worthy of confidence.

Donovan, Fronk, and Horton (102) reported on the development and validation of a science and engineering career interest survey (CIS). This 56-question survey was developed to measure the overall science and engineering career interests of junior high school students (Grades 7 through 9). The CIS test-retest reliability over a one-week period was 0.96 (n=.57). Concurrent validity coefficients were calculated in two ways: 1) CIS scores were correlated with the Kuder GIS science subscale (r=0.75, n=45), and 2) CIS scores were correlated with a CIS verification scale (r=0.59, n=127).

Two studies dealt with the Draw-a-Scientist-Test (DAST). Chambers (70) reported on research covering a period of 11 years. The DAST was administered to 4,807 children in 186 classes from kindergarten to fifth grade. The schools were located in Quebec, Ontario, Texas, Oklahoma, Connecticut, New York, Vermont, and Victoria (Australia). An attempt was made to classify the schools according to socioeconomic categories: (a) clearly upper to upper-middle income, (b) mixed or middle income, and (c) clearly lower income. Seven indicators of the standard image of a scientist were chosen: (1) lab coat, (2) eyeglasses, (3) facial growth of hair, (4) symbols of research (scientific instruments and laboratory equipment of any kind), (5) symbols of knowledge (principally books and filing cabinets), (6) technology (the "products" of science), and (7) relevant captions (formulae, taxonomic classification, the "eureka!" syndrome, etc.). It was found that elements of stereotyping of scientists appeared with greater frequency as students advanced through grades three to five. A clear relationship between the number of indicators and the socioeconomic classification was found; the standard image was slower to appear in lower-income schools. Sex differences were also found. Only girls drew women scientists. Also, girls were less likely to associate science with war and more likely to fear accidents in connection with research. Although Chambers noted doubts about the validity of the Draw-a-Man test for intelligence (which is built into the DAST), he reported that high IQ children tended to produce the standard image at an earlier age in those groups tested for intelligence.

The second study, by Schibeci and Sorenson (331), examined the potential of the DAST as a quick, reliable method of assessing elementary school childrens' images of scientists in Western Australia. Two schools were chosen for the study. One was a rural school with black children; the second, with a predominately white population, was located in a metropolitan area. It was found, as in the Chambers study, that the average number of indicators increased with grade level. It was also found that the DAST could be scored reliably if the total number of indicators in a drawing was used as the criterion. The reliability coefficient for the two coders was 0.36 ($p < 0.01$). The reliability coefficient of the coding for the two sub-samples (rural black children from a low-socioeconomic area and urban white children from an upper-socioeconomic area) were, respectively, 0.78 and 0.98 (both $p < 0.01$). It was concluded that the DAST appeared to be a potentially useful method for gathering data about elementary school children's overall images of scientists. Whether these images are accurate or distorted, the authors emphasize, can only be judged against what we believe the "real" scientist to be.

Past reviewers have noted that instrument development related to the affective domain produces results that are even more equivocal than for the cognitive domain. This continues to be the case. However, three trends in this area appear worthy of note. The time-series design reported by Mayer and Farnsworth seems well enough established in the cognitive domain to justify an extension of their work with this technique related to student attitudes. The long-term research on the Draw-a-Scientist-Test (DAST) reported by Chambers and by Schibeci and Sorenson suggest stability and potentially high usefulness for this instrument. Most important, the work by Munby characterizes the kind of extensive and intensive study that is needed to refine science education research instruments. Only by such effort can we hope to clarify and extend our understanding of attitudes to science.

Science Teacher Education

The literature within this section was roughly divided into those documents related to preservice teachers and to those involving in-service teachers. Some clusters were identified within each of these two groups. Seventeen documents related to preservice teacher education; eighteen, to in-service teachers. The grade level at which the preservice teachers were planning to teach was not always specified but a number of these studies appeared to use elementary education majors as the subjects of research.

Preservice Science Teacher Education Studies

Attitude Studies

One of the commonly held beliefs is that elementary teachers do not hold positive attitudes toward science or the teaching of science. It is not surprising, therefore, that attitude formation or attitude change was a focus for a number of studies (Koballa and Shrigley, 218; Ginns and Foster, 158; Appleton, 24; Hassan and Shrigley, 175; Hassan, 174; Housel, 191; and Koballa, 217).

Two investigators (both of whom were associated with Robert L. Shrigley), Koballa and Hassan, looked at the effects of persuasive communication on attitudes of preservice elementary teachers. Hassan, reporting in his doctoral dissertation (174) and in a NARST paper co-authored with Shrigley (175), studied the effect of written persuasive communication on the attitude of preservice elementary teachers about teaching simple chemistry concepts. Ninety-eight student teachers, divided into three groups based on level of self-esteem as indicated by responses to the Revised Janis-Field Feeling of Inadequacy Scale, were randomly assigned to experimental and control groups. The experimental group received a written communication on the importance of teaching simple chemistry concepts to elementary school children while the control group read about sleep and dreams. Attitudes were investigated using the Hassan Chemistry Attitude Scale. Students were pre-tested on self-esteem and attitudes. Three weeks later the experimental group received the persuasive communication. Both experimental and control groups were tested immediately for attitude change. Three weeks later attitudes were again measured as a post-post-test. While Hassan found that the treatment group had a modification in attitude, which was unrelated to level of self-esteem, immediately following treatment, this change did not persist three weeks later.

Koballa and Shrigley, in an article published in the Journal of Research in Science Teaching (JRST) (218), compared the effects of integrated and nonintegrated communications on energy attitudes. Preservice elementary teachers (n=180) were divided into three groups--abstract, concrete differentiator, and concrete thinker--on the basis of their scores on a Divine Fate Control subscale from the work of O. J. Harvey and his colleagues. Three treatments, all consisting of 13 minute videotapes were used. An attitude measure was administered immediately following treatment and three weeks later. Koballa and Shrigley found that treatments T_2 and T_3 (T_1=control group) were equally effective for changing attitudes and that this change was sustained three weeks later. The integrated communication treatment was best for the abstract students; the nonintegrated, for the concrete thinker; and either treatment was effective for the concrete differentiators.

Koballa (217) also investigated the effects of one-sided and two-sided communications. He again used preservice elementary teachers (n=45). The topic was the importance of energy conservation topics in the elementary curriculum. Koballa reported that while both types of communications had the same supportive arguments, there were significant differences related to the non-supportive arguments.

Housel (191) looked at the effects of an experimental outdoor education component of an undergraduate science methods course on the attitudes to science of preservice elementary teachers, as well as on their perceptions of the amount of control and warmth or affection that should be given to children by teachers and schools. The 89 students enrolled in one semester of a science methods class were assigned to one of three treatment groups or a control group. The control group had no specific outdoor education experience. Treatments consisted of a three-day outdoor education camp experience without students, a one-day (Saturday) on-campus experience, and a three-day experience at the outdoor camp with fifth grade students. Shrigley's Pre-Service Teacher Attitude Inventory was used to measure attitudes and a VAL-ED instrument was used to measure perceptions relative to control or warmth. No significant differences were identified for any of the hypotheses in Housel's study.

Appleton (24), operating on the premise that the attitudes preservice students hold are set before they encounter methods courses, investigated the opinions of beginning students (n=90) in a Diploma of Teaching course. He was interested in knowing their opinions about teaching strategies to be used in primary science classes and to see if there were any relationships between these opinions and selected background characteristics of the preservice students (age, gender, school science background). A 15-item Likert-type survey instrument was used (a copy is included in Appleton's article, p. 113) during orientation week, with a 92 percent return rate. The three items receiving the most positive responses all related to the use of hands-on activities in teaching science. Appleton then completed six post-questionnaire interviews to discover when commitment to hands-on science had developed. Data from interviews indicated that students' own schooling experiences (both positive and negative) had influenced their opinions, as had observations of children enjoying hands-on science situations (p. 117). Appleton reported a lack of significant relationship between the amount of high school science the pre-service students had studied and their choice of teaching strategies, although female students who studied more science in high school tended to greater use of experimental worksheets (p. 116). Appleton acknowledged that this was an exploratory study and in no way predicted what these individuals will do when they get teaching jobs.

Process Skills and Logical Thinking

Two investigations involved science process skill development and logical thinking skills: Lee and Gosbi (239) and Jones (204). Lee and Gosbi looked for correlations between the Test of Science Processes and the Test of Logical Thinking. Preservice elementary teachers, grouped as early childhood, intermediate education, and college science majors were tested. The investigators found significant differences in the Test of Science Processes between the early childhood education students and college science majors, but there were no significant differences between the intermediate education group and either of the other groups. The scores on the Test of Logical Thinking (TOLT), SAT scores, and grade point average appeared to be the best predictors of science process achievement. Lee and Gosbi suggested that science teacher educators need to develop science process skills of preservice teachers if they wish these people to engage in inquiry teaching and that the science process and logical thinking tests can be used for diagnostic purposes in the preservice program.

Jones (204) examined the effects of a science methods course emphasizing mastery of selected science process skills on the level of development of logical thinking of preservice students. Eighty-one juniors enrolled in the methods course were the experimental group. Seniors who had taken a different version of this methods course were the control group. Lawson's group test of logical reasoning was used as a pre-post-test. Okey's group test of science processes was also given. Pre-post comparisons were made using the correlated statistic. Significant differences in growth of logical thinking were found for all levels of cognitive development in the students in the experimental group. Use of the Pearson correlation resulted in the identification of a statistically significant correlation between final logical thinking classification of students and their science process test scores. The use of analysis of variance produced significant differences in favor of the experimental group for post-test scores when experimental and control groups were compared.

Science Anxiety

Two studies related, in different degrees, to anxiety and its effects on the teaching of science by elementary preservice teachers. Sherwood and Westerback (341) reported on the factor analysis of a new form of the State-Trait Anxiety Inventory, form Y, with preservice elementary teachers (state = transitory anxiety; trait = permannnt anxiety). Believing that anxiety plays a role in the avoidance of science study, and later in the teaching of science, Sherwood and Westerback administered form Y to 103 elementary education majors enrolled in a science content course required for graduation. They concluded that the modified form of STAI-Y appeared to be a reliable indicator of state and trait anxiety and could be used by investigators in future research.

Duschl (112) used an ethnographic approach to document the training and educational activities of preservice elementary education majors to determine what, if any, aspects of their science education program contributed to developing apprehension toward science, science education, and the teaching of science. Duschl used Spradley's participant-observation method in two sections of an elementary science methods course, making one observation a week for 14 weeks. He also interviewed students and conducted surveys. Duschl reported that the students took their science methods course in a sterile environment, meeting in a room furnished in a manner that the students would probably never see again. The science methods course occurred in a quarter along with all other methods courses for elementary education majors. Students were treated as an intact group and the pace was hectic. Science knowledge appeared to be threatening to the students who appeared to be confused about what it meant to be doing science. In emphasizing science content, methods students overlooked science processes and objectives. The approach in the science methods course was on science as a process while the students had been exposed to science as a product in the two science courses they were required to complete for their certification. Duschl suggested four alternatives for improving the situation he described (p. 753).

Methods Course Studies

Malone (260) presented a paper at the 1983 NARST meeting that was focused on determining the effect of a traditional science methods course vs. a concerns-based science methods course on attitudes of preservice elementary student teachers. Malone used the Teacher Concerns Questionnaire, the Stages of Concerns Questionnaire, and Science Teacher Attitude Scales as pre-test, post-test, and delayed post-test measures. He found that both treatments resulted in significant improvement in attitudes, with student teachers' concerns shifting from lower to higher level concerns about teaching science. When Malone studied data from correlational analyses, he found that younger student teachers and student teachers with lower grade point averages, while holding less positive attitudes to science, had fewer concerns about themselves as teachers and more concerns about the impact of their teaching on pupils.

Slinger and Anderson (347) looked at teaching styles among ten preservice teachers. Students were interviewed and were given planning tasks. Their lesson plans were examined. The researchers found five different teaching styles: performer, text driven, anxiety driven, end results oriented, and conceptual change oriented. When lesson plans were examined after the methods course was completed, the performer style had disappeared, and all ten preservice students had exhibited some positive change in their teaching style.

Three papers (Hope and Townsend, 189; Northfield and Gunstone, 283; Gilbert, 156) were related by the topic of misconceptions or alternative conceptions. Gilbert defined an alternative conception as an interpretation of ideas which differs significantly from the accepted scientific view at any time. He reported that research data exist that provide evidence that some preservice physics teachers had conceptions similar to those of 12-year-old students. Such preservice teachers need time to articulate their alternative conceptions, to confront these and modify them, through the same treatment they would be expected to use with their students.

Hope and Townsend (189) examined the extent to which accurate scientific conceptions in certain physical science and biological science concepts are held by first-year teacher education students. They were also interested in looking for possible relationships to the gender of the preservice teacher. Their population consisted of 36 males and 146 females enrolled in their first year of teacher training. These students were tested with items from surveys from the Learning in Science Project (LISP) designed for the first six years of education in New Zealand. The students were tested voluntarily, 20 at a time, from classes other than science. Biological science items required students to classify organisms as plant, animal, or living. Physical items had diagrams related to friction, force, gravity, friction and reaction rates, friction and heat. Students had to select the correct interpretation from among alternatives.

The researchers assumed that male students had studied more physical science than had female students, with the reverse situation holding for biology. They found biological concepts were relatively well understood although some scientific misconceptions still occurred, particularly related to animal and living categories (p. 179). Males were more accurate than females for physical science concepts but the level of performance was similar to that of younger students. Hope and Townsend suggested that their research provides evidence of the need to include science in teacher education programs, particularly phyical science information for female students. They also suggest that teachers need to develop skill in detecting inaccurate conceptions in their students (p. 182).

Northfield and Gunstone (283), in an article in the same publication, provided a report on activities used in a teacher eduation program that are designed to assist student teachers to understand their own learning or to increase their understanding of children's learning. Students are exposed to the study of personal models of reality and to the idea of student misconceptions.

Miscellaneous Studies

Two papers did not seem to fit into any of the described categories: Ginns and Foster (158) and Crawley et al. (86).

Ginns and Foster (158) reported on the re-analysis of an earlier study of the effects of science presented via lecture-lab as compared to an activity oriented approach. The re-analysis took into account gender and the extent of previous science training in the data analysis. The preservice students were considered to possess a science background if they took one or more courses in grades 11 or 12 or no science background if their last science course was at grade 8. Data were collected on understanding of science using the Test on Understanding Science (TOUS) and on attitudes using the Moore-Sutman Science Teacher Attitude instrument. A three-way analysis of variance (treatment, gender, science background) was performed. Males and females did respond differently to treatments: males had higher positive attitudes with the lecture-laboratory approach, while females were more positive if they had been involved in the activity-oriented approach. The investigators hypothesized that the difference in attitude indicates that females were more comfortable with a higher level of personal involvement. They also suggested that the lack of significant effects for the TOUS could be interpreted to indicate that the differences in attitude can be planned for without altering students' understanding of science.

Crawley et al. (86) presented a paper set at the 1983 NARST meeting. The presenters discussed the measurement, via attitude and achievement, of the effectiveness of matching student teachers and their students on cognitive style, locus of control, and need level (relative to concerns). Sixteen student teachers and thirty-two pupils from a total of one hundred fifty-four students enrolled in ninth grade physical science were involved in this study. Crawley et al. reported that directness of teaching strategy used by the student teacher correlated with pupil achievement. However, neither the concerns level nor the varied nature of the teaching strategies used were related to the attitudes of the ninth grade pupils to the student teachers.

What can we say about research on preservice science teacher education as reported in the 1983 literature? Science educators are still concerned about, and investigating, attitudes with mixed results. Some methods courses do make a difference--on certain variables; others do not. If we want our students to teach science as a process, not as a product, we have to counter their experiences with science content courses in which the product aspect is stressed. The investigation of misconceptions that pre-service teachers, and their pupils, hold appears to be an area that deserves more work.

Studies Involving In-Service Science Teachers

Within the group of studies whose subjects were in-service science teachers, a variety of research was reported. One cluster related to evaluations of the effectiveness of in-service programs, many of which were designed to improve teachers' knowledge of and attitudes about energy education. Another cluster was related to teachers questioning skills and the use of wait time. A third cluster, less obviously related, was composed of studies focused on teachers' behaviors. Several studies were clustered because they involved the use of surveys although the information surveyed varied with each study.

In-Service Program Studies

Studies in this group included those by Cooper (83), Klemm (215), Barrow and Holden (32), Ellis and Zielenski (119), Riley and Feller (317), Van Koevering and Sell (383), and Bethel and Hord (38).

Cooper (83) investigated the impact of an in-service program on elementary teachers. The experimental group was composed of 43 teachers from two school districts; the control group consisted of 44 teachers from one district who received no in-service. In-service activities involved instruction in four content areas. Cooper reported significant differences between experimental and control groups in attitude toward teaching science and in teaching style.

Klemm (215) looked for relationships between characteristics of teachers involved in a high school marine science workshop and teacher scores on the workshop content mastery test. Sample size was not given in the literature reviewed. Workshops apparently took place in Hawaii and in Massachusetts. Workshop participants were pretested before each unit was introduced. The post-test occurred at the end of the workshop. Klemm reported that teacher characteristics had a closer relationship to biological science scores than to physical science scores and a closer relationship to pre-workshop scores than to post-workshop scores. Significant relationships existed between selected teacher characteristics and teachers' scores on the content mastery test. Klemm concluded that workshop leaders could use preregistration data to predict scores and to plan modifications of activities to meet individual needs.

Bethel and Hord (38) presented a paper at the 1983 NARST meeting in which they discussed the results of a year-long program designed to improve in-service elementary teachers' knowledge of environmental science and their attitudes toward environmental science, using the Concerns Based Adoption Model to design and implement this program.

The other studies in this cluster all involved in-service workshops related to energy education. Barrow and Holden (32) looked at energy knowledge and attitudes and locus of control of participants in a faculty development workshop sponsored by the Department of Energy and compared these data with data from a 1980 group. Twenty-nine teachers, seventeen of whom taught science, were in the 1981 group. An Energy Inventory and

Environmental Q-sort were used to measure knowledge and attitudes. James's Internal-External Locus of Control Scale was also used. An increase in the knowledge subscale and the use of energy items was reported. The science teachers in the 1981 group had greater energy knowledge than did the non-science teachers, a finding different from that of the 1980 group.

Ellis and Zielenski (119) evaluated a summer energy education workshop for teachers in Texas. Twenty-five teachers participated in 62 hours of instruction, 32 hours of field trips, and 14 hours of lab work. Items from the National Assessment of Educational Progress's (NAEP) energy test for young adults were used to evaluate the workshop. The researchers reported an increase in both positive attitudes and in energy knowledge.

Riley and Feller (317) evaluated two DOE-sponsored teacher workshops. They reported that the workshops increased teachers' knowledge about energy. When their data were compared to those from a sample of the general public, the teachers' scores were significantly higher on the overall cognitive energy test developed from released NAEP items.

Van Koevering and Sell (383) pragmatically decided that if the payoff from workshops was to be a positive one, it was important to identify topics that should and should not be emphasized in workshops for elementary and junior high school teachers. Six workshops involving 135 teachers were assessed. Each workshop consisted of 15 contact hours and was composed of lectures, discussion, and hands-on activities. Participants were asked to complete a questionnaire, at the beginning and at the end of the workshop, and were asked to respond to items about their level of knowledge on various topics and the potential use they would make of the topic in their classrooms. The investigators found that the topics teachers were knowledgeable about prior to the workshops were all topics popular with the general public and had often received media attention. In the post-assessment teachers indicated that, although they had gained substantial knowledge about some topics, they would probably not include these in their teaching. Van Koevering and Sell suggested that, if time of the workshop was limited, workshop leaders would do well to avoid the more political and technical aspects of energy (p. 158).

Teachers' Questioning Skills, Use of Wait Time

Five studies were focused on these topics: Samiroden (328), Abegg and Corindia (2), Tobin (376), Otto and Schuck (296), and Swift and Gooding (365).

Tobin (376) reported, at the 1983 NARST meeting, on an investigation of changes in discourse attributable to use of an extended teacher wait time in a sequence of seven lessons related to probabilistic reasoning. Ten intact classes in grades six and seven in suburban Perth (Australia) schools were used for this study. Tobin reported that teacher wait time increased significantly over the seven lesson sequence, from an average of 1.9 seconds to an average of 4.4 seconds. He also reported that, with extended wait time, teacher talk after a pupil responded changed: teachers tended to probe to obtain further pupil input rather than mimicking pupil responses.

Although Samiroden (328) worked with preservice teachers rather than in-service, his study is included here because it is related to questioning skills and wait time. He wanted to determine the relationship between higher cognitive level questions and wait time range and student achievement. Samiroden assumed that higher level cognitive questions merited more wait time, for pupil thought and extended response, so he attempted to train student teachers to use either 1-4 seconds of wait time or 4-7 seconds. Seventeen student teachers were asked to teach a 60 minute lesson to two eleventh grade biology classes. In one class, they were to use 1-4 seconds wait time (treatment 1); in the other, 4-7 seconds (treatment 2). Only eight student teachers were able to achieve the desired wait time lengths. Their pupils were given achievement tests (pre-and post-lesson) and a questionnaire. Classes receiving treatment 2 (4-7 seconds wait time) scored significantly higher than those receiving treatment 1. The high school pupils did perceive their student teachers differently depending on the wait time length used.

Swift and Gooding (365) investigated the effects of increasing teachers' wait time on general questioning skills in science teaching. They hoped to bring the teachers to the use of a wait time of three seconds. Forty teachers were involved, ten each in one of four treatment groups: a control group, a group receiving printed guides on discussion techniques, a group using an electronic feedback device, and a group using both the printed guides and the device. Swift and Gooding did find a change in wait time with higher cognitive level questions, as well as greater contributions by students to the classroom discussion. The feedback device did help to increase wait time although teachers never reached the 3 second criterion. When the device was removed, wait time decreased. The use of the guides appeared to make little difference. The researchers had hypothesized that the group using both guides and the feedback device should have the longest wait times but this was not the case. It appeared that they were unable to manage multiple tasks (p. 729).

Abegg and Corindia (2) concentrated on investigating the relationship between students' questioning level, their cognitive level, and their teacher's questioning behavior. Three sixth grade teachers using SCIS or ESS materials for their science lessons were involved in the study. The researchers found that the students modeled their teachers in the level of questions asked. In addition, concrete-level students asked more formal-level questions after their teachers had been trained to increase the proportion of higher-level questions they asked.

Otto and Schuck (296) studied the feasibility of training teachers in the use of a questioning technique and the resultant effect on student learning. Six biology teachers volunteered to participate in the study, as did eighth grade students. The first 90 student volunteers were assigned to six groups of 15 students each for the study. Three teachers formed the experimental group; three, the control group. The researchers chose a questioning model developed by K. George and associates because it "appeared to have face validity for teacher acceptance" and because of its minimum requirements in terms of resources. The treatment group received 15 hours of training in the use of this model. Their questioning behavior was later categorized by six observers who had received 13 hours of training in how to categorize questions. Otto and Schuck reported that the teachers could use the model in classroom settings and that their students achieved higher scores and retained knowledge longer than did those in the classes of the control group teachers.

Teacher Behavior Studies

This cluster is less tightly-constructed than was the previous one in terms of the focus of the studies reported. Mullinix (270) looked for associations between teacher behaviors in BSCS classes and the cognitive learning of their students. Eight teachers using the BSCS materials and 353 of their tenth grade students were involved. A student checklist was used to obtain students' perceptions of teacner behaviors. A biology test was given as a pre-post achievement measure. Among the findings Mullinex reported were (1) classes taught by teachers who ranked higher on a direct-to-indirect scale of verbal behaviors showed a higher mean content gain than did the classes of teachers who ranked lower on this scale, and (2) classes taught by teachers who ranked high on a less-to-more inquiry scale showed a higher mean content gain than did the classes of teachers who ranked lower on this scale.

Pratt (308) studied 42 secondary science and mathematics teachers to compare their belief systems with observational data. Teacher beliefs were related to teacher responsibility for student failure or for success. Four categories of verbal behavior were studied: indirect behavior, direct behavior, praise, and criticism. Comparisons were made between science and mathematics teachers, junior high and senior high teachers, and teachers of basic or of advanced classes, as well as between verbal behavior and belief system. Pratt reported that only advanced-class to basic-class comparisons produced any significant differences in teacher beliefs and behaviors.

Teachers of basic students assumed more reponsibility for student success, less responsibility for student failure, and were more direct in verbal behavior than were teachers of advanced students. Female teachers were significantly higher than were male teachers in incidences of indirect behavior and combined indirect-direct behavior.

Brockley (53) attempted to identify factors related to science teaching among in-service elementary teachers and looked for relationships of the amount of science taught, anxiety about teaching science, preception of importance of science, and other demographic information. Seventy in-service elementary teachers in Australia responded to Speilberger's State Trait Anxiety Inventory. Brockley reported that many teachers sampled had little science background and little in-service training in science. While 90 percent rated science as important or very important, only one-third of the group reported teaching science more than one hour per week.

Levin and Jones (244) wanted to compare data on preservice (n=48) and in-service (n=77) elementary teachers' attitudes about science and science instruction. They looked at four attitudes: science as a male domain, science usefulness, confidence in teaching, and liking of science. They reported significant differences for the main effects of professional status, science instructional ranking, and gender; and also for the interaction effects of professional status x college science, science ranking x gender, and science ranking x college science.

Agar (7) was interested in comparing teacher evaluations from students, from certified science supervisors, and from teachers, to look for differences when the same evaluation instrument was used. He worked with 11 teachers, 2 supervisors, and 773 students in two suburban schools. The instrument used was the Teacher and Student Perceptions of Teaching Practices form from the assessment materials produced by the National Science Teachers Association. Agar reported that significant differences "probably do exist" but did not specify what these were in the literature reviewed. He found what he termed "remarkable agreement," with a level of disagreement better than 50 percent on only 3 of 38 items. There was greater agreement between evaluations of students and teachers and between students and supervisors than there was between teachers and supervisors. Agar concluded that students should be allowed to participate in teacher evaluation.

In another study also focused on student perceptions of teachers, Lawrenz and Welch (231) were interested in seeing if students perceive their science classroom environment in significantly different ways depending on the gender of their teacher. They used a stratified random sample of teachers in 14 states, involving 331 classes (110 junior high science, 80 biology, 99 chemistry, 42 physics). Eighty percent of the teachers were male. The majority of the female teachers taught junior high school science or biology. The Learning Environment Inventory was used to obtain data on student perceptions. Lawrenz and Welch suggested that the science classroom learning environment may contribute to socio-cultural pressures due to differences in classes taught by male and female science teachers.

Students perceived classes taught by female teachers as more formal, more goal directed, and more diverse. Clases taught by male science teachers were perceived as more difficult. The researchers cautioned that this was an exploratory study and raised the question as to whether statistically significant differences were also educationally significant (p. 660).

Cwick (90) wanted tc identify selected criteria in teacher effectiveness in secondary school science classrooms to see how students feel about these criteria as compared to science teachers' and administrators' thoughts on the same items. Thirty-two administrators, 34 secondary school science teachers, and 747 students from 15 high schools of three different sizes responded. The criteria related to teacher activities in (1) lecturing, (2) laboratory teaching, (3) leading discussions, (4) maintaining good discipline, (5) fairness in dealing with students, (6) understanding of student problems, and (7) use of multi-media presentations. Cwick administered a questionnaire on site in the 15 schools, ensuring a 100 percent response. He reported significant differences among groups related to (1), (2), (3), (4), and (7) but no significant differences for (5) and (6). There were no significant differences among groups based on school size.

Frielich (144) wanted to get an idea of what variables were important in instruction at the college level. A list of 28 items thought to help students learn was given to 107 students enrolled in general chemistry for engineering students at Purdue and 106 students enrolled in general chemistry for liberal arts students at California State at Hayward. Twenty-three faculty members and graduate teaching associates were also asked to respond to the list of items. Respondents were asked to pick five items most important in helping them learn and five least important for this purpose. Frielich got 192 usable responses for analysis. Some items had tied ranks. Only one item was commonly ranked in the top five for helping students to learn by both students and instructors: "they are provided with study problems." (The list of the 28 items and their ranking by both groups are printed in the article.) Frielich found that "... each and every item was ranked as one of the five most important by at least five students and as one of the five least important by at least three students..." (p. 220). Also, the higher rated items tended to be those leading to the accumulation of facts and the lowest rated ones were those which approximated problem solving situations found in the real world. Frielich wondered if students responded to strategies that helped them memorize rather than those which helped them to think (p. 220).

If classroom management can be considered as a teacher behavior, two more studies belong in this cluster. Sanford (329) reported on a field experiment done to verify and extend findings of previous research on management in junior high school and middle school classes in English and reading. Sanford's report involved 26 classes taught by 13 middle or junior high school science teachers. Data were gathered through 25 observations of each teacher. Effective management practices for general classroom procedures, managing student behavior, laboratory procedures, managing student assignments, presenting content, and structuring note taking are briefly described and illustrated in this report, based on data about good classroom managers.

Beasley (33), operating on the premise that the classroom is a manipulable behavioral system, looked at the role of the science teacher in managing student-centered laboratory activities. He wanted to identify and describe teacher actions that maximize attention of students to allocated tasks. Twenty-four science classrooms in six schools were involved in this study. Lessons were videotaped, with one recorder focused on the teacher at all times while the other was focused on the students. Based on analyses of the tapes, Beasley concluded that teachers who operated more at the whole class level had classes with a higher degree of task involvement. When teachers interacted with a small group on some investigation, the remainder of the students tended to wander off-task. Beasley's findings caused him to wonder how to reconcile his data with the idea of value of independent group investigations.

Survey Studies

A variety of questions are contained in this cluster. Rutland (326) sent questionnaires to 64 secondary school science teachers and 64 college science teachers in Georgia to ascertain the extent to which measurement of organizational identification and departmental cohesiveness differed between the two groups. She found no significant difference between the two groups with respect to identity (using Patchen's Identification with Work Organization Indicators) or cohesiveness within their department (using Schutz's Cohesiveness Scale). However, the correlation between measures was stronger for the college group.

Englin (117) surveyed Georgia science teachers for opinions regarding teaching of creationism. Englin sent a questionnaire to a stratified random sample of 62 high school science teachers. She reported that 97 percent of the teachers responding indicated that they were familiar with creationism and 30 percent thought it was acceptable to teach creationism. Twenty-eight percent indicated that they actually were teaching it. Teachers with a liberal religious viewpoint and familiar with creationist literature and philosophy were more likely to disapprove of teaching creationism, as were teachers with advanced degrees. Englin also reported that, overall, her respondents indicated little enthusiasm for teaching creationism.

Joss (206) conducted a survey of science teaching practices in selected fundamentalist Christian schools in the United States. Completed in early 1981, this survey was designed to establish a data base to inform decision makers about changes in program, facilities, instructional media production, and teacher education. Joss reported the existence of 5761 Christian elementary schools in the 50 states, employing 184 administrators and 334 teachers and working with 29,550 pupils in grades K-6. Questionnaire data provided evidence of many similarities with public schools: science teaching had a low priority, barriers to effective teaching were reported, and teachers were dependent on a single textbook. Joss reported that public school teachers were better prepared and that Christian school class sizes were smaller than those in public schools.

Williams (403) conducted a survey of science teacher supply and demand in North Carolina. Williams reported that, in 1982, there were 1500 science teachers in North Carolina who were teaching subjects other than science and that 800 certified science teachers were working in non-teaching assignments. He remarked that "such facts seldom come to light" when articles decrying the shortage of science teachers are written. William's article in Science Education merits reading by science teacher educators as well as by researchers.

When science education research involving in-service teachers is considered, the picture is not radically different from those drawn in previous reviews. Many reports on the effectiveness of a particular in-service program are just that; they do not appear to deal with questions that have a broad generalizability, although that of Van Koevering and Sell (383) was an exception. The line of questioning and wait-time research continues. Work in this area does seem to hold promise for impact on practice, particularly in situations in which this research is continued over a period of time as is the case with Swift and Gooding (365). Perhaps it is time to call a moratorium on developing new models to categorize questions and instead to concentrate on using those already in existence, varying instructional modes. Perhaps the lack of significance in some studies comes as a result of attempting to provide teachers with too many tools as Swift and Gooding speculate was the case for one of their treatment groups. We need to replicate and extend rather than adding yet another category system and model to the literature.

The teacher behavior studies were so varied that it is difficult to generalize from their findings. Agar (7) concluded that students can be used in teacher evaluations, but Frielich (144) showed that choices for what instructor behavior is useful in helping them learn varies from student to student. Lawrenz and Welch (231) speculated that the variable of teacher gender influences student perceptions; this certainly deserves further study.

Foreign Contributions to Science Education Research

Research studies published in foreign journals typically evaluated problems in non-North American contexts and used methodologies commonly employed by domestic researchers. The topics investigated and the apparent qualities of these research studies varied widely.

We have divided this year's "foreign" research studies into five categories: (1) learning studies, including non-Piagetian and Piagetian work; (2) descriptive classroom studies; (3) curriculum developmental and evaluative research; (4) descriptive comparative studies, examining science and non-science orientations; and (5) teacher-training studies.

Learning Studies

Non-Piagetian studies examined the teaching of process, compared instructional strategies with each other, and explored reasons students develop misconceptions about scientific concepts.

Ahmad and Rubba (8) investigated the extent of process skill achievement among a sample of recent Malaysian high school graduates and the relationship of their scores to science scores. The sample was one of convenience and consisted of 73 high-ability Malysian students who had recently graduated from high school and were beginning undergraduate work. Gender, Malysian Certificate of Education (MCE) Examination scores, professional goals, and process skill achievement data were collected on each student. Based on their analysis of data, the investigators inferred (1) the process skill achievement appeared not to be related to student gender; (2) that biology, chemistry, and physics tests in the MCE Examination appeared apparently to place little, if any, emphasis on assessment of process skills; and (3) that students who planned to enter science related careers had higher process-skill achievement apparently than did those not planning to enter such careers.

Abanami's study (1) was to determine the percentage of eleventh- and twelfth-grade earth science students who demonstrate a reading ability at the independent, instructional, or frustrational levels; to establish the Cloze score intervals at each level; and to determine the efficacy of using the Cloze procedure to measure reading comprehension in the Arabic language. The study sample consisted of 157 eleventh-grade and 152 twelfth-grade students drawn from six high schools in the district of Riyadh, Saudi Arabia. The results suggested that a majority of students encountered reading difficulty and needed additional reading instruction in order to learn the material presented in their earth science textbooks. In addition, the Cloze test appeared to be an appropriate testing procedure for measuring students' reading comprehension of earth science textbooks in the Arabic language.

Four experiments focused on teaching methods and instructional aids. Specifically, Harty and Al-Faleh (172) compared the large lecture-demonstration and the small-group laboratory approaches on 74 eleventh-grade Saudi Arabian students' chemistry achievement and attitudes toward science. Findings indicated that students taught by the small-group laboratory approach achieved better on both immediate and delayed posttests than did students taught by the lecture-demonstration method. The results also indicated that students taught by the laboratory approach possessed more desirable attitudes toward science.

Selim and Shrigley (337) compared the effectiveness of two instructional modes, discovery and expository, for teaching science knowledge and science attitude to 276 male and female fifth-grade Egyptian students. The results indicated that students taught using discovery instructional strategies scored higher on achievement measures and on a science attitude measure than did students taught using an expository method. Science achievement and science attitude scores for females were similar to the scores for males.

Lazarowitz and Meir (237) used pictures representing six levels of biological organization in an imposed strategy as visual stimulators for high school students' questions. Most students' questions were found to be related to organism, population, and community; on biological content, they related mostly to structure and function. Results regarding cognitive levels showed that most of the questions were asked in the low levels. The results were considered encouraging regarding the use of pictures as stimulators for students' learning motivation, as well as deepening the understanding of curricula planners in relation to students' interests and needs in science subjects.

Zakari (417) reported a study designed to ascertain the effects of specific behavioral objectives versus study questions on learning by undergraduate biology students. Eighty-two freshman biology students in Saudi Arabia were randomly assigned to one of four groups: (1) specific behavioral objective and study questions together, (2) study questions alone, (3) specific behavioral objectives alone, and (4) control group using none of the strategies. It was found that students with study questions performed significantly better than did students without study questions on a posttest given during the last day of instruction and on a retention test given a week later. It was concluded that study questions should be employed as a pre-instructional strategy.

Four other studies in this category examined specific science concepts and potential misconceptions. First, Hewson and Hewson (182) investigated 90 Form 2 (grade 9 equivalent in

USA) students' alternative conceptions and instructional strategies to effect change from alternative to scientific conceptions. Results indicated that significantly larger improvement in acquisition of science concepts (mass, volume, density) resulted from using strategies/materials dealing with student alternative conceptions designed for the targeted student group.

Second, Fensham (127) examined the factors of mathematical content, chemical language, and the meaning and role of chemical equations as they related to learning chemical stoichiometry. He found that misconceptions about what a chemical equation described often resulted in students being unable to solve stoichiometry problems even though they have the required math skills.

Two studies related to students' conceptions/notions about the energy concept were reported by Duit (108). The first study dealt with learning the energy concept during a grades 7 and 8 instructional unit on energy, work, force, and power. The second examined outcomes of physics instruction in grades 6 and 10 with respect to the energy concept. Among other things, Duit found that physics instruction did not alter drastically students' notions about energy. In addition, most students preferred conceptions and notions stemming from everyday experiences. This suggests that the concept of energy should not be restricted to the ability to do work and that the traditional way to the energy concept via work causes severe learning difficulties.

Hewson and Hamlyn (181) examined the role played by particular intellectual and physical environments on concept formation, focusing on conceptions concerning heat, in a group of non-western subjects living in the interior of southern Africa (North Sotho and Tswana peoples). Subjects (n=20) included school-age children and schooled/non-schooled adults, with whom Instances-about-Interviews and Piagetian clinical interviews were conducted. The results suggest that the Sotho people may be at a relative disadvantage in learning about heat energy when compared to their western counterparts because their existing knowledge is, in some sense, close to a kinetic view.

Four Piagetian studies described or compared attributes of students with their performances. The first three studies reported comparative descriptive works. First, Allison, Hann, Chin, and Fowler (13) determined whether selected science experiences affected the fourth-grade Korean child's concept of Piagetian physical causality and whether cross cultural differences existed between children of Korea, the United States, and Trinidad and Tobago. The study involved 208 randomly selected fourth-grade Korean children of which 108 were assigned to an experimental group and 108 to a control group. The experimental group was taught the concept of floating and the concept of living for 150 minutes respectively; the control group was taught language arts as a placebo for 300 minutes. From the results of this study, it was concluded that the causal relations of animism and dynamism could be taught to the fourth-grade Korean children. The fourth-grade Korean child's ability to understand the causal relations of animism and dynamism was in general similar to that of children of the United States and Trinidad and Tobago.

Adey (6) reviewed the major purposes, conclusions, and criticisms of cross cultural Piagetian studies conducted during the last two decades in light of the availability of new instruments for assessing levels of cognitive development and for analyzing science curricula.

Comber (81) described a study of concept development related to particulate theory of matter in 130 children in two contrasting Warwickshire middle schools in terms of background policies/practices in science teaching as revealed by responses from teacher questionnaires (n=60) and analysis of science curricula. It was found that concepts related to the particulate theory of matter could be given more attention at the middle school level. It was suggested that concepts concerning the nature of matter need to be developed earlier in the middle years, requiring direct sensory experience of the properties and behavior of a wide range of materials.

Two African studies in this category involved experiments. First, Ehindero (118) used a quasi-experimental design to investigate the long-term effects of preferred and actual instructional styles of two preservice science teachers on the cognitive growth and biology achievement of 80 high school students in Nigeria. Results of this study implied that teachers should be introduced to as many different instructional strategies as possible.

Second, Mulopo (280) sought to determine the differential effectiveness of traditional and discovery approaches for teaching scientific facts, understandings about science, and scientific attitudes to students in the concrete and formal stages. The subjects were 120 Form IV (11th grade) male students from two boys' schools in Zambia. Sixty of these were concrete reasoners randomly selected from one boys' school; the remaining 60 were formal reasoners randomly selected from the other school. Each of these two groups were randomly split into two subgroups of 30 subjects each. The traditional and discovery approaches were randomly assigned to the two subgroups of concrete reasoners and to the two subgroups of formal reasoners. It was found that for the formal reasoners, the discovery group earned significantly higher scores on understanding science than did the traditional group. For the concrete reasoners, mode of instruction did not make a difference. Overall, subjects taught by the discovery approach earned significantly higher scientific attitude scores than did those taught by the traditional group outperformed the discovery group.

Descriptive Classroom Studies

Descriptive classroom studies generally compared attributes of learners and of classroom environments. Fraser and Fisher (141) used a sample of 2,175 students in 116 science classes which formed the basis of a description of perceived actual and preferred classroom openness along five continuous dimensions (personalization, participation, independence, investigation, and differentiation) and cognitive and affective attributes. The findings supported the value of employing a person-environment interactional framework in open education research and suggested that actual-preferred interaction could be at least as important as openness in predicting student outcomes. In addition, Fraser and Fisher (142) developed and validated short forms of two types of classroom environmental instruments. Tests measuring perceptions of actual classroom environments included the Individualized Classroom Environment Questionnaire (ICEQ), My Class Inventory (MCI), and Classroom Environment Scale (CES). Analogous tests measuring preferred classroom environment were also developed.

Furthermore, Fisher and Fraser (136), using the ICEQ and the CES, found that junior high school students (n=2,175) preferred a more favorable environment than the environment they perceived, and that their teachers perceived the classroom environment more favorably than did their students. In addition, Fisher and Fraser (135) investigated associations between student perceptions of classroom psychosocial environment, as measured by the Classroom Environment Scale, and their achievement of nine affective and cognitive aims, as measured by the Test of Science-Related Attitudes (ROSRA) and the Test of Enquiry Skills (TOES). The results confirmed the existence of sizeable and statistically significant associations between student learning outcomes and their classroom-environment perceptions as measured by the Classroom Environmental Scale.

Other descriptive classroom studies evaluated general learning attributes, attitudes, and environments including laboratory work, chemistry and physics. Taglieber, Lunetta, and D'Ambrosio (367) discovered that cognitive science achievement can be influenced by a complex set of independent factors. This study examined the general picture of science achievement at the eighth-grade level and how some of those independent factors actually worked in a setting like the schools of Santa Catarina.

Lin (247) examined the Taiwanese junior high school climate and its relationship to student attitudes toward science. The Learning Environment Inventory and the Test of Science-Related Attitudes were used with a sample composed of 40 eighth-grade classes, consisting of a total of 1,269 students. The result showed that students' gender and ability were not crucial factors related to classroom climate and students' attitudes. Taiwanese classrooms were characterized by high competitiveness, cohesiveness, great diversity, less apathy, and favoritism.

Al-Hajji (9) assessed attitudes of students and science teachers toward science laboratory work in the middle school of Kuwait. A random sample of 1,480 students in the four middle school levels in 14 schools responded to a Likert-type questionnaire; 51 science teachers who taught the students in the sample responded to the teachers' questionnaire. The data from the two questionnaires suggested that there should be a re-evaluation of the cognitive level and the time requirements of the experiments students were required to do in the four middle school levels.

Dos Santos Silva and Colletto (103) tried to find out if the results obtained by students on the physics test of the University Entrance Examination could be used as indicators of achievement in a general physics course at the Federal University of Santa Maria, Rio Frand do Sul, Brazil. The 289 students who participated in the study passed the University Entrance Examination in 1979 and 1980 and enrolled in the major areas of physics and engineering. The general physics course was required of all of them. The results showed a positive correlation between the performance on the University Entrance Examination and achievement in the general physics course.

Almas (14) conducted a study to determine if there was a difference between students' and teachers' evaluations of instruction and if there was a correlation between students' opinions and evaluation of their knowledge in physics. The sample consisted of approximately 5,000 second-grade and third-grade students (equivalent to eleventh- and twelfth-grade students in the U.S. and Canada) combined, who were enrolled in Saudi Arabian secondary schools. He found that third-grade students (equivalent to twelfth grade in U.S. and Canada) considered the teacher's role, the textbook, discussions, and overall instructional procedures more important than did second-grade students. Moreover, physics teachers, second-grade students (equivalent to eleventh grade), and third-grade students gave the textbook approximately the same rating. No relationship was found to exist between the performance of second-grade and third-grade Saudi Arabian students on physics examinations and their opinions about instructional procedures in physics examinations and their opinions about instructional procedures in physics.

Shuaibu and Ogunsola (345) found that analyses of cognitive preferences of chemistry students (n=156) in the School of Basic Studies (SBS) at Ahmadu Bello University indicated that the four preferences (recall, principles, application, and questioning) appear to be unrelated to sex and location of previous school for these Nigerian students. However, they did find significant differences in the distribution of subjects among the four modes. The distribution was in the ratio of 5:3:1:1 and in order Recall--Principles--Application--Questioning.

Hofstein (184) conducted a study to determine what relationship existed between students' achievement in introductory physical science and the following factors: (1) the ability to think scientifically (enquiry skills), (2) curiosity, (3) gender, (4) locus of control, and (5) grade in school. The subjects were 237 seventh- and eighth-grade students in junior high schools in Israel. He found, using multiple regression analysis, that 28 percent of the total variance of a student's score in science was explained by the score on the various skills of the test of enquiry skills. Only a small proportion of the variance was explained by the curiosity variable, student's gender, and locus of control.

Tamir (369) found that the Biology Cognitive Preference Inventory taken by grade 12 Jewish (n=406) and Arab (n=297) biology majors revelaed similarities between the groups with respect to cognitive preferences, achievement, and background variables. Both groups became oriented toward principles/questioning rather than memorization.

Curriculum Development and Evaluation

Three studies focused on the development or evaluation of curricula in foreign countries--Great Britain, New Guinea, and Israel. Black and Driver (42) found that large scale monitoring of pupils' performance produced results which teachers, parents, and politicians wished to use. This paper discussed the problems of interpretation of results, with reference to the national monitoring of school science in the United Kingdom. Adults, individuals and groups, were asked to answer selected test items, to predict pupil scores, and to specify minimum scores for satisfactory performance. The samples were drawn from both inside and outside teaching. The main result was the wide variations within groups, and disparities between many different aspects of their responses. It was concluded that if actual test items are the starting point, then no consistent pattern of expectation emerges.

Maddock (258) presented a brief history of the development of science curricula for primary and high school science in Papua New Guinea. A discussion of the research associated with this period (1960-1980) is accompanied by consideration for future directions in science education.

Sabar (327) investigated the implementation of a seventh-grade biology curriculum ("Animal and its Environment") in Israel. The sample included 42 junior high school teachers in 28 schools spread throughout the central area of Israel. Although some objectives were implemented (including those related to subject matter and integrating laboratory work into regular class sessions), others (mainly those related to the affective domain and higher order inquiry) were partially or totally lacking.

Comparisons of Science and Non-Science Majors

A considerable amount of work was reported in the descriptive comparisons of science majors and scientists with each other and with other non-science majors.

A study to test the popular belief that Asian and Pacific Americans (APA) are strongly science-oriented and to investigate the factors that influenced their career choices was reported by Bagasao (28). The study sample included 226 college-bound high school seniors of several APA ethnic populations; a sample of 384 white college-bound seniors served as the comparison group. Bagasao found that, contrary to popular belief, Asian and Pacific Americans were not judged to be "all alike." They varied with respect to science-career planning and type of science career planned. The profile of the APA science-career planner was strikingly similar to the white science-career planner.

In addition, Lijnse (246) compared the attitudes toward science of students in Holland who had studied a lot of science with the attitudes of the average citizen. The views of the "average Dutch citizen" were drawn from the results of an opinion poll conducted by the nine member states of the European Economic Community. A representative sample of about 1,000 people responded to the poll. A total of 450 pupils (about half at the end of the ninth grade and half at the end of the eleventh grade) participated in the study, from four pre-university education schools, the most academic type of school in the Dutch system. It appeared that the pupils' general image of science as reflected by the opinion poll was hardly influenced at all by their above-average schoolastic knowledge of the laws and facts of science. The "average citizen" and the "privileged pupil" had roughly the same positive attitude toward science. However, it was suggested that pupils had a more critical attitude toward fundamental research, which was also reflected in a more critical attitude toward scientists. Possibly, the pupils expect too much of science. It appears that greater attention in science instruction should be paid to the values of science.

Udoibe (378) conducted a study to determine any relationship which may exist between Nigerian students' values and educational goals in science and non-science majors. A survey was administered to a random sample of 166 undergraduate Nigerian students; a parallel survey was completed by a random sample of 56 American students. There was no significant evidence to conclude that Nigerian science and non-science majors differed on values, educational goals, or life satisfactions. Also, it was found that American students, like their Nigerian counterparts, valued economic security, career, and personal identity as their primary sources of life satisfactions. However, career and family were more popular among American students.

Umelo (380) assessed the perceptions and knowledge of environmental issues possessed by science and non-science educators in Nigeria and determined whether any relationships and differences existed in their perceptions and knowledge of environmental issues. An inventory of environmental issues was administered to 21 college science educators, 30 science-oriented teacher trainees, and 45 non-science-oriented teacher trainees. Umelo drew the following conclusions from his study: (1) that perceptions of environmental issues among educators who were academically oriented toward science did not depend on their knowledge of environmental issues; (2) that among educators who were not academically oriented toward science, perceptions of environmental issues were related to their knowledge of environmental issues; and (3) that educators responding to the survey generally possessed favorable perceptions and moderate knowledge of environmental issues.

Collings and Smithers (80) reported a study to describe boy and girl sixth-formers studying physical and biological science "A" level courses. Data were collected from a total of 1,897 students categorized as physical sciences, biological sciences, non-sciences, and mixed. It was found that sixth-form pupils studying the physical and biological sciences had rather different psychological profiles. The differences between physical and biological scientists tended to be of the same kind as those between scientists as a whole compared to non-scientists. Physical science choosers were found to have, on average, a higher measured intelligence than did their biologist peers, to rate themselves as being good at mathematics, to be convergent in their thinking, and to be less person-oriented than did the biologists. The female physical science and biological science students were like their male counterparts but with some differences. The girls appeared to have some doubts about their femininity and attractiveness. This may be due to their stepping out of "expected" sex roles. It was noted that the personalities described may not be psychologically necessary for the study of science, but rather the by-products of prevailing social conditions.

Teacher Training Studies

Finally, five teacher-training studies are described in this section. Zurub and Rubba (420) described the development and validation of an inventory designed to identify the needs of science teachers in developing nations, particularly the Arab countries, using the instrument Science Teacher Inventory of Need (STIN). Based on a survey of the literature, a set of science-teacher task descriptors were developed and the content validity judged by a panel of experts. A total of 76 tasks were identified for the inventory, which was administered to 444 upper-secondary-level (U.S. grades 10-12) science teachers in four of the five districts in Jordan. Reliability estimates for the STIN were determined, using the alpha coefficient and the adjusted split-half methods, and found to be 0.95 for both methods. Construct validity of the STIN as a measure of science-teacher needs was substantiated by factor analysis, which showed nine factors to be significant and to account for 84.9 percent of the total variance in the instrument; 71 of the items were found to be interpretable across the nine factors.

McKenna (269) was concerned with preservice primary school teachers (n=100), a group of tertiary students who traditionally came from the secondary school stream who, on the whole, had avoided subjects like physics, chemistry, and mathematics that demanded a high-level of cognitive development for understanding/assimilating abstract concepts. He focused on the cognitive developmental levels of these individuals and sampled their science teaching styles. The results indicated that final-year students in the transitional stages of cognitive development exhibited teaching behaviors in elementary science lessons that were of a higher quality than did those students who were in concrete or formal operational stages. It was suggested that concrete-operational students entering teacher-preparation programs be identified and given opportunities to develop to higher cognitive levels. Formal-operational students were considered capable of conducting lessons of high cognitive level but appeared to lack understanding of the intellectual problems facing children, probably because they could not relate to problems of abstract reasoning not encountered by themselves. It was suggested that since both concrete and formal students tended to conduct less practical, hands-on science lessons than did the transitional students, strategies fostering such teaching methods be considered.

Ouyand (297) compared the feelings and attitudes of two groups of elementary science teachers toward the New Elementary Science Curriculum in Taiwan. The groups included experimental school teachers who had received training in the teaching of the New Elementary Science Curriculum and regular school science teachers who had not received special training. He found that the two groups agreed on their overall philosophy of current science teaching, did not agree on their attitudes toward science, did not agree on their preference of science teaching methods, and had equal knowledge of basic science concepts.

A project to develop background maps of teachers' cognate perceptions of Australian Science Education Project (ASEP) units were described by Fawns (126). Teachers, all volunteers, were asked to draw a concept map describing an ASEP unit as a whole. It appeared that the unit maps drawn by the teachers could be taken as a projection of a stable "cognitive structure" in the sense that the structures reflect relations that the teachers feel will not change. It was suggested that cognitive mapping may offer a useful technique in assessing the impact that curriculum ideas have on teachers' understanding and organization of science teaching.

Ilyas (195) conducted a study to determine the effects of science process skills instruction on in-service secondary teachers' (1) achievement of science process skills, (2) attitudes toward the use of science process activities, (3) selection of process objectives for a science unit, and (4) writing of process objectives and process activities for students using mastery-teaching strategy. The subjects were 24 secondary school science teachers of Islamabad (Pakistan). The experimental group (n=12) received science process skills instruction through self-instructed modules via a four-step mastery teaching strategy until they reached an 80:80 mastery-level criterion. The control group (n=12) received placebo instruction for the same duration. It was found that the teaching of science process skills to secondary school science teachers enabled them to acquire science process skills competence and to select science process skills objectives and process skills activities significantly better than could the untrained teachers.

The variety of findings drawn by the investigators' studies cited here are generally consistent with the findings of other people in other lands. Thus, it is difficult, if not impossible, to comment summarily on how the studies directly contributed to our understanding about science teaching. Perhaps, these reports permitted us to view more clearly and precisely the observed variables and better clarified and defined the meaning of good teaching in the science classroom.

A major problem in educational research conducted and reported outside of the United States and Canada is that the world-wide research community has trouble synthesizing the findings of such research into a usable body of knowledge. We hope that the accent placed in this summary on foreign contributions published during 1983 will help ameliorate this unfortunate and wasteful situation.

Special Topics

In other annual reviews of research, the "special topics" section was categorized as "miscellaneous studies." We felt there was some order among the miscellany and, therefore, changed the title of the section accordingly. Approximately 45 studies were placed in this section, not all of which will be discussed. However, all are listed in the bibliography.

Meta-analysis Studies

One of the largest groups of studies within the special topics section consists of those reports of meta-analysis (Willson, 404; Willson, 405; the entire issue of Volume 20, issue 5, of the Journal of Research in Science Teaching; Kahl and

Anderson, 208; Maehr, 259; Kulik, 224; and Yeany and Miller, 414). Kulik (224) has provided a succinct description of the meta-analysis process:

> ... Reviewers who use it first locate studies of an issue by clearly specified procedures. They then characterise the outcomes of the studies in quantitative terms. As a third step, they code as many features of the studies as possible. Finally, meta-analysts use statistical procedures to summarize findings and relate study features to study outcomes (p. 957).

The meta-analysis Kulik conducted examined studies of the effects of educational technology in college teaching. Five types of educational technology frequently used in college science teaching were considered: Keller's Personalized System of Instruction (PSI), 74 studies; computer-based teaching, 59 studies; programmed instruction, 57 studies; audio-tutorial instruction, 48 studies; and visual based instruction, 74 studies. Kulik reported that educational technology had a basically positive influence on student examination performance. Studies using PSI had stronger results than those in other categories, so Kulik examined this group for research reports in which some feature was changed. He found that it was possible to change many features of PSI without changing its effects, but that there were four features that could not be changed without reducing the effectiveness of PSI (244, p. 758). Kulik cautioned that the effects of teaching vary with the educational level, so results from college studies should not be generalized to other grade levels. He reported that the effects of programmed instruction were more positive now than those of earlier studies, concluding that we do learn from experience.

Volume 20, issue 5, of the Journal of Research in Science Teaching was composed entirely of reports of a multi-institutional meta-analysis research project (Anderson et al., 21; Shymansky et al., 346; Willet, et al., 401; Wise and Okey, 408; Lott, 251; Sweitzer and Anderson, 364; Druva and Anderson, 107; Malone and Fleming, 137; and Anderson, 19). This project was an attempt to integrate findings of extant research studies of major science education research questions. It involved six institutions, a six-member advisory board, and a ten-member research team distributed among the six institutions. Thirteen research questions were identified but one, "What are the goals and priorities of science education?," was eliminated because of insufficient empirical studies. The other 12 questions were reformulated into six broad questions:

1. What are the effects of different curricular programs in science?

II. What are the effects of different instructional systems used in science teaching (e.g., programmed instruction, mastery learning, and departmentalized instruction)?

III. What are the effects of different teaching techniques (e.g., questioning behaviors, wait-time, advanced [sic] organizers, and testing practices)?

IV. What are the effects of different preservice and inservice teacher education programs and techniques?

V. What are the relationships between science teacher characteristics and teacher behaviors on student outcomes?

VI. What are the relationships between student characteristics and student outcomes in science? (21: p. 381)

All studies included in the meta-analysis were screened using four restrictions: (1) the study was conducted in the context of grades K-12; (2) the study was conducted in the United States; (3) studies related to questions I-IV involved a control group; and (4) the study was published in 1950 or later (p. 382). Nearly 2,000 studies were read and 769 were coded. The most common reason for not including a study was not one of the four restrictions identified above but was inadequate reporting--not enough information was provided to make calculation of an effect size possible (21: p. 383). Uniformity across institutions in analaysis and coding was accomplished by a week-long work session for all researchers. At this time initial coding forms were developed. One research article associated with each of the six previously-identified questions (two articles for question III) has been printed in issue 5 of Volume 20 of JRST.

Kahl and Anderson (208) produced a document containing data from the multi-institutional analysis meta-analysis project reported in Volume 20, issue 5, of JRST for inclusion into the ERIC data base so that researchers at other institutions could work with these data. The data tape is described in this document. Also included are separate bibliographies for each of the research studies.

Shymansky et al. (346) studied the effects of new science curricula on student performance, using 105 experimental studies. These studies involved more than 45,000 pupils and 27 different new science curricula and contained one or more measures of student performance. The researchers reported that, across all new science curricula analyzed, students exposed to new science curricula performed better than students in traditional courses in general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies, communication). They also developed a more positive attitude toward science. They considered that there is a substantial body of research literature which collectively points to the new science curricula as a successful attempt to improve science education (346:402).

Willett et al. (401) examined the effects of different instructional systems used in science teaching. This group of researchers coded 130 studies relative to 12 different instructional systems: audio-tutorial, computer-linked, contracts for learning, departmentalized elementary school, individualized instruction, mastery learning, media-based instruction, personalized system of instruction (Keller's PSI), programmed learning, self-directed study, use of original source papers in the teaching of science, and team teaching (401:406). Willett et al. found, on the average, that an innovative system was only about one-tenth of a standard deviation better than traditional science teaching. In this meta-analysis the most successful innovative systems appeared to be mastery learning and PSI for cognitive achievement.

Wise and Okey (408) looked at studies of effects of teaching strategies on science achievement. Twelve categories of teaching techniques or strategies were identified: audio-visual, focusing, grading, inquiry/ discovery, manipulative, modified, presentation mode, questioning, teacher direction, testing, wait-time, and miscellaneous (408:421-423). They coded 76 variables from 160 studies, and found that in an effective science classroom students are kept aware of instructional objectives and receive feedback on their progress toward these objectives.

Lott (251) compared inductive and deductive teaching approaches and also looked at research involving the use of advance organizers. Thirty-nine studies were analyzed for the first part of Lott's research and 16 for advance organizer use. Lott characterized inductive teaching as that in which examples or observations were provided for students prior to formalizing generalizations, whereas deductive teaching consisted of formulating generalizations prior to any illustrative examples. Lott reported there were essentially no differences between the two approaches. However, the inductive approach apparently has positive effects with intermediate-level students. It is also more useful when high levels of thought, learning experiences, and outcome demands are placed on students. He suggested that more research is needed concerning level of inquiry as well as the effect of inquiry experiences on comprehension and process skills outcomes. Lott stated that there was a limited data base relative to advance organizer research literature. Based on the limited number of studies Lott analyzed, it would appear that advance organizers are more advantageous in instruction in urban settings than in rural or suburban schools. There was little effect dependent on grade level, style of organizer, or characteristics of materials. Lott suggested that new advance organizer research patterns are needed.

Sweitzer and Anderson (364) analyzed studies of teacher education with measured outcomes of one or more variables associated with inquiry teaching. Sixty-eight studies were read and coded for 114 variables with 117 effect sizes. The outcome most frequently measured was knowledge of science processes. They found a wide variety of potentially successful approaches to teacher education although all were not of equal potential. These researchers suggest that science educators explore carefully alternative means of achieving particular objectives of a given teacher education program.

Druva and Anderson (107) examined science teacher characteristics (gender, coursework, IQ, etc.) as independent factors and their relationships to teaching behavior in the classroom and student outcome characteristics. They used 26 factors related to teacher behavior and 23 to student outcomes in the 65 studies they coded. In general, quite low relationships were found between teacher characteristics and classroom teaching behavior and student outcome characteristics. However, they advised prospective employers to hire teachers with a thorough preparation in both professional education and in science. Science courses, education courses, and overall academic performance were positively associated with successful teaching.

Fleming and Malone (137) looked at six student characteristics (general ability, language ability, mathematics ability, socio-economic status, gender, and race) and their association with student science performance or science attitudes. They reported reading 122 dissertations but did not give a final total of studies read and coded. They found that general ability, language ability, and mathematics ability had the strongest positive relationship to performance on cognitive science achievement and science attitude measures and that this finding was consistent across grade levels and science subjects. Science attitude data exhibited a much smaller relationship with all personological variables than did achievement data. Gender exhibited the weakest relationship with males generally scoring slightly higher than females. This, however, was not consistent across grade levels. In the middle school males' performance on cognitive and science achievement measures exceeded that of females, but the attitudes of females were more positive than were those of males. They suggest that more research needs to be done to look at performance differences among races and between sexes.

An article by Anderson (19) concluded issue 5 of volume 20 of JRST in which he attempted to relate findings from these various meta-analyses. He stated that data from four meta-analyses (364, 346, 408, 251) favor an inquiry approach although the evidence for this approach varies in its strength from one meta-analysis to another. Problem solving and critical thinking can be successfully taught using the new science curricula, teaching strategies, and systems. In terms of the production of effective science teachers, training in education appears to be as important as course work in science. One disturbing finding reported in the Shymansky et al. study (346) was that teachers using new science curricula with no instructional preparation did better than those with such preparation. This needs further investigation. When gender differences were considered, there was essentially no relationship between teacher gender and teaching performance. When gender differences were considered for students, there were apparently greater differences in favor of males on cognitive and achievement measures in middle school compared to earlier and later educational levels. Performance of students in single gender classes was lower than in classes of mixed gender.

This last finding is in contradiction to a report by Willson (404) of a meta-analysis he conducted to look for correlations between science achievement and attitude of K through undergraduate college students. Willson examined 43 studies, using 14 variables. He reported that, overall, the relationship was moderate (0.16) with differences between elementary, junior high, senior high, and college groups. (Junior high included grades 7-9; senior high, 10-12.) For elementary students, sex differences were significant. All male classes scored higher than all female classes, but both were higher than scores for mixed gender classes. Data from attitude scales contained no significant differences for interest in science at this level. At the junior high level, sex differences were not significant but favored males over females, with mixed groups the lowest. Willson reported that results were confounded with the type of attitude measure examined. At the senior high level, sex differecces were significant with male and female classes scoring higher than mixed. At the college level, sex differences were not significant. No all-male groups were found in the literature, but scores of classes of females were higher than those of mixed gender. Willson considered the male-female differences to be due to cultural expectations. He pointed out that while they were small, differences in achievement in science seemed more highly related to interest in science than to psychologically scaled attitudes. He said, if data are to be believed, successful achievement in science will cause positive attitudes.

In a paper presented at the 1983 NARST meeting Willson (405) discussed a procedure using Bayesian analysis to integrate new research findings with previous meta-analysis studies.

In yet another meta-analysis Yeany and Miller (414) reviewed and analyzed results of experimental studies based on diagnostic prescriptive instruction as it affects science achievement. They analyzed 28 studies and classified them into one of three types: I) no diagnosis and no remediation, II) diagnostic feedback only; and III) diagnostic feedback and remediation. They found that impact the on science achievement of types II and III was essentially equal. Although attitude data were available only from type III studies, there did not appear to be much attitude difference resulting from the treatment. It appeared that achievement could be significantly and positively influenced through diagnostic feedback with the remediation process not adding any statistically significant influence.

Maehr and Steinkamp (259) conducted a meta-analysis study to determine the magnitude and direction of sex differences in school age boys' and girls' motivational orientations and science achievement. They found sex differences in motivation and achievement smaller than generally assumed. With few exceptions, these differences favored males. Differences were larger for achievement than for motivation, were apparently greater in the United States than elsewhere, and greater for children in the upper socio-economic levels than in the lower. While girls say that science is not just for boys, boys are more inclined to engage in science-related activities than are girls. Maehr and Steinkamp concluded that school intervention was needed, especially during the pre-adolescent years.

Anderson's article (19) contains a synthesis of findings from the multi-institutional meta-analysis research project. Some of the generalizations he reported are supported by other meta-analysis studies: the effectiveness of PSI as a method of instruction as reported in Kulik's research and the effects (or lack of same) on achievement of sex differences. Willson (405) has developed a technique to integrate new research with previous meta-analysis studies so that it is possible to extend these techniques in the hope that, if a longer span of time and more data are included, researchers may discover new information. Despite Anderson's remarks (19) that meta-analysis involves long hours of tedious work and that a tolerance for ambiguity is essential to a meta-analysis scholar, the technique continues to be used, as probably will be evident in the 1984 review of research. Science education researchers could brighten the lives of both meta-analysis scholars and reviewers of research if they would improve the organization of their reports and would label tables clearly.

Studies Focused on Race and/or Gender

The meta-analysis studies by Maehr and Steinkamp (259), by Fleming and Malone (137), and by Willson (404) were discussed in the previous section and will not be re-analyzed here although they do deal with matters related to race and/or gender and science. Nine studies (DeBoer, 94; Davidson, 92; Baker, 29 and

30; Marrett, 263; LeBold, 238; Jacobowitz, 196; Kahle and Lakes, 209; and Huftele et al., 190) not discussed elsewhere in this review will be described.

Investigations took place at various grade levels; Jacobowitz (196) investigated factors relevant to science career preferences of black eighth grade students. She worked with 113 males and 148 females in an inner city junior high school. Of all the independent variables, sex was the strongest predictor of science career preferences. Early adolescents' career preferences appeared to be related more to interests consonant with sex-role considerations than to realistic assessment of mathematics or science achievement. There were no significant differences between male and female students on mean scores in mathematics and science. Significant differences were found between mean scores of science self-concept and science career preferences, with males scoring higher on both variables. Jacobowitz concluded that the relationship between science self concept and sex role self concept may be stronger than the relationship between science self concept and mathematics and science achievement.

Baker (30) also worked with junior high school students in a study of the relationship of attitude, cognitive ability, and personality to science achievement. She found that attitude and mathematics ability seemed to affect science grades more than did personality factors. Baker found few sex differences, although she reported that the junior high school females were more extroverted, less likely to have a positive attitude toward science, and more likely to have higher science grades than their male peers.

Marrett (263) looked at enrollment trends in high school science and mathematics among black women and compared their patterns with those of other groups in an attempt to determine conditions that seemed to enhance enrollment among black women. She administered questionnaires to teachers in 20 schools, as well as making some school visits. Marrett found that black males were ranked lowest on the course ladder, with black females just above them. Enrollment trends were more similar between black males and females than between black females and white females. Teacher satisfaction appeared to correlate strongly with enrollment. School climate was related to enrollment in science but not in mathematics.

Baker extended her investigations of sex differences in science to the college level in a study published in 1983 (29). She worked with 180 junior and senior college students to determine which factors, related to success in science, were present among biology, physical science, and non-science majors. She obtained her subjects by recruitment via newspaper ads and the payment of $5 for participation. Baker looked at mathematical and spatial ability, at personality type, at masculinity and femininity, and at attitudes toward science using the Cube Comparisons test for a spatial rotation task, the Myers Briggs Type Indicator for personality type, and a Personal Attribute Questionnaire for masculinity-feminity. Data on mathematics ability were obtained from SAT scores, and subjects completed a questionnaire designed to provide attitude data. Baker reported that she was interested in learning why so few women science majors went on for doctoral work and why those who did chose to work in the biological sciences rather than the physical sciences. She assumed that the college students on whom she gathered data had the potential to pursue graduate studies. Baker found that males differed from females primarily in terms of decision making relative to their personality types. Males had higher mathematics scores than females, with science majors having higher scores than non-science majors in mathematics. Science majors had better spatial ability than had non-science majors and also held more favorable attitudes toward science and a scientific career. Within the science majors there were few sex differences. Baker concluded that the size of the differences between male and female science majors was not enough to account for the differences in numbers of women and men found at the doctoral level.

DeBoer (94) also studied college students, working with 133 Colgate freshmen students to examine the characteristics of males and females who experienced high-low success in their first college science course. He reported significant score differences on three variables (persistence, lack of recklessness or rash tendencies, future orientation) for high and low success females, but not for males in either high or low success groups. DeBoer hypothesized that these results indicate that career goal orientation may be important to women's success in science and that women continue to struggle against a social norm that says science is a masculine field.

Davidson (92) examined women's participation in the community college science curriculum and looked for factors related to women's decisions to study science as well as any evidence of the impact of the community college on women's choices in this matter. She surveyed 3,098 women and 3,246 men enrolled in the Los Angeles community college district in the fall of 1980. Davidson found that high school participation in science had an impact on future science studies. Sex differences existed. Those women who had participated in science courses in high school were less likely to continue their science studies and were less confident in their abilities, but they earned higher science grades than did men. Some women who were low science participants in high school did become high science college women. This group showed more confidence, requested more counseling, and used more support services than did women who moved away from science in college.

LeBold et al. (238) compared early career decisions, initial and 1981 employment, professional activities and post-graduate education of new, non-traditional engineering graduates (women, Hispanics, Blacks) with their peers, using a mail survey. They found relatively few differences between men and women, minority and non-minority groups related to initial and current employment, professional activities or achievement, and factors influencing career decisions. However, men had significantly higher supervisory responsibilities and salaries 10 years after graduation than did women.

Two other reports in this cluster involved research spanning several age groups. Kahle and Lakes (209) used data obtained from the 1976-1977 National Assessment of Educational Progress (NAEP) and analyzed that portion of the NAEP data dealing with attitude toward science. Data were obtained from 9 year olds, 13 year olds, and 17 year olds in the NAEP survey. Kahle and Lakes examined the gender categories only for the attitude data (not geographic location or SES). They speculated that a lack of science experiences by female students may lead to lack of understanding of science and thus contribute to negative attitudes toward science (209:137). Kahle and Lakes provide suggestions for ameliorating this situation in the schools.

When it became apparent that no NAEP survey of science was going to take place in the early 1980s, the Science Assessment Research Project (SARP) of the University of Minnesota decided to gather data using the NAEP model. Results of this survey are reported in Images of Science (Hueftele, Rakow, and Welch, 1933). SARP researchers found that 9 year old male students scored slightly higher on achievement items and that differences between white and black students in this age group dropped from about 15.0 (in 1977) to 12.5. For the 13 year old group, attitudes toward science classes, teachers, careers, and the value of science were down 2.6 percentage points, with the attitude drop greater among white students than black. Males continued to outperform females and racial differences persisted. For the 17 year old group, interest in science, especially in the value of science, declined although increases were noted in science careers and science activities. Males outscored females by 3.3 (1977 lead had been 4.2). Racial differences on achievement items were down by 1.5, with white students outscoring blacks by 15 percentage points (193:iv).

A Reaction

Rowe and DeTure who produced the review of research for 1973 said (p. 42) that, in the research reviewed, females performed as though they came from a handicapped group. The situation in 1983 does not seem much improved. Several researchers talked about the influence of socialization or the social climate as the probable cause of the situation they reported. It would appear that research needs to be done to develop and test some intervention programs and then to study the effects of those intervention programs over an extended period of time. Although the usual producers of research are doctoral students, several institutions might develop a long-term interest in this area so that the research would continue although some of the members of the research team would change as students completed their dissertations and graduated.

Other Studies

Two studies hardly constitute a cluster but they have some common characteristics. Gallagher, Zehr, and Yager (151) collected information on faculty members at the 35 largest graduate centers for science education in order to provide a status study. One hundred sixty-eight faculty members were involved. Although this article contains a variety of data, the picture the authors provide is that of graduate faculty relatively homogeneous as to age, sex, rank, academic preparation, previous experience, research productivity, and professional involvement. The individuals in this picture are, in the majority, white and male. The authors postulate that if graduate faculty remain in their institutions until retirement at age 70, there will be little opportunity for graduates of these institutions to obtain employment at these centers. The question of how to maintain the development of new ideas by aging professionals is discussed and eight recommendations are included.

Dowling and Yager (104) collected information for another status study to serve as a companion to the one by Gallagher et al. In this study data were collected on the support for science education from the 50 state departments of education. They looked at changes in the total professional staff, at job analyses, at budget and special projects, and at other job-specific items over a 20-year period. They sent questionnaires to all 50 states and received replies from 40. Data from these 40 questionnaires were treated as a pilot study and reported in the article cited here. Dowling and Yager reported that state science consultants were in their mid-40s, had completed more than 10 years of classroom teaching, and had worked in state positions from 1-8 years. Half of them hold doctorates. They work in local schools, write proposals, serve as members of evaluation teams, and assist with other administrative work. Their duties have become more general, with less time spent exclusively on science education duties. During the 20-year period surveyed there has been a decline in numbers of state science consultants, budget for science education, and general support for science education projects in state departments of education.

Although not a status study, another report on science education appears to relate to these concerns. In February, 1983, the National Institute of Education convened a conference whose title was "Teacher Shortage in Science and Mathematics:

Myths, Realities, and Research." A report of this conference was prepared by Good and Hinkel (160) and was published in May, 1983. Suggestions for future research are to be found in the "directions for action" section of this report. Conference participants declared that curriculum reform was needed but were not in agreement as to what direction this reform should take. Research aimed at increasing the quantity and quality of science at the elementary school appears as a need. While a national curriculum was not advocated, the importance of the delineation of key curriculum and instructional terms was emphasized. Investigations need to be made concerning when these terms should be introduced and what should follow their introduction. Because teachers rely so heavily on textbooks, textbooks need careful examination. Research needs to be done on productive strategies teachers can use, problems or misunderstandings students are likely to develop when attempting to learn concepts, how these misconceptions can be detected, and what specific strategies teachers can use to help students who hold particular misunderstandings. Basic research is needed on classroom processes related to curriculum goals in science and mathematics. More research is needed on how skills effective teachers use can be taught to other teachers. If research is to be effective, its context must be focused. However, within a given research study, there is a need to know the concepts and subject matter issues being studied and how teachers and students think and behave when they study particular concepts. Curriculum researchers have tended to investigate content, sequence, and pace issues and to ignore what teachers and students do when they actually study curriculum. More complete theories of instruction in mathematics and science need to be developed.

Another two-study group was identified. Anderson (43) and Anderson and Kilbourn (23) were concerned with the creationism-evolution concept. One report by Anderson (43) was his doctoral dissertation and the other (23), a journal article on this topic. Anderson's dissertation (43) is a philosophical analysis of the creation-evolution conflict in which two significant curricular questions are addressed: What subject material emerging from the conflict should be taught? and What pedagogical approach should be taken in teaching the material to secondary school biology students? The journal article (23) is also a philosophical analysis of the creation-evolution conflict. The authors emphasize that how this topic is taught is as important as what is taught.

Gordon (151) attempted to identify and describe the theoretical propositions that characterize phenotype development so these could be examined for their implications for program development in secondary school biology. She looked at the BSCS biology materials and reported that evolution was only one of 12 themes. Gordon, citing the existence of competing positions on the nature of the process of evolution, said that lack of agreement precluded the use of the unconstructed theory of evolution as a basis for program development.

Waterman (390) attempted to identify beliefs people hold about the nature of scientific knowledge. She conducted individual interviews with 30 college biology students who had completed a survey of the nature of scientific knowledge. Waterman reported that she found three themes in students' comments about the nature of and growth of knowledge: (1) knowledge based on observed facts, it is discovered and it accumulates rather than changes over time; (2) knowledge is discovered as in (1) but it changes with new evidence and better techniques; and (3) knowledge is constructed based on theories which guide and limit observations and objectivity and evolves via changing theories (390:44).

Kwon and Mayer (225) presented a paper at the 1983 NARST meeting on a method for interpreting data from time-series analyses studies. They said that several studies have revealed a post-intervention increase in the level of achievement data (momentum effect). They consider the method discussed in the NARST presentation to be useful in representing and identifying the presence and duration of the momentum effect in time-series data.

The diversity of topics in this section precludes any generalizations. The two status studies probably deserve some comment in that the information they provide indicated that if there is some crisis in science education, it extends beyond the concern of teacher shortages.

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