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ABSTRACT

This review presents a broad picture of science education research during 1977 and discusses how this research relates to the past and how it can be of use to teachers. The review is organized in four sections. The Overview is a presentation and discussion of research dealing with the philosophy of science education, its goals, objectives and priorities, and research related to the status of the science education research enterprise. The second part, Ex Post Facto and Survey Research, includes studies which attempt to explain a phenomenon that had already occurred and surveys about the characteristics of students, teachers, or others. The third part, Experimental Research, focuses on those studies reported in 1977 which evaluated the effect of some variable, such as a specific curriculum or method of teaching, on students or teachers. And the fourth part links the major findings in 1977 with trends and issues of the past five years of research in science education. (Author/BB)

A SUMMARY OF RESEARCH IN SCIENCE EDUCATION—1977

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INTRODUCTION

There is an interesting brief history about the past 50 years of effort by science educators to review and summarize research related to science teaching (Mallinson, 1975). It is not surprising to find that each review has a character of its own which reflects the authors' perception of the task.

Beyond these differences in character, their common function has served to produce a systematic and thoughtful record of the development of a small specialized field of research which pertains to science teaching. Members of the science education community can look with satisfaction on these efforts by the profession to insure that others can follow the historical course of development that this branch of research has taken.

The character of the present annual review is reflected through the objectives described below, and through the organization and features which have been adopted to achieve those objectives.

Objectives

Our primary objective in this annual review has been to portray a sense of the broad picture of what occurred in science education research during 1977 and to identify some of the unique features of the year's research. Put another way, we have tried to describe the landscape and point out a few key landmarks in this survey of approximately 350 research studies.

Our second objective was to link the major research findings of 1977 with the past. Our effort was modest in this regard; we simply studied the ERIC annual reviews from 1972-1976 and attempted to relate our conclusions to trends and issues discussed by the authors of those reviews. We now recognize the need for a more systematic and careful synthesis of research over this time period.

Our third objective was to communicate as directly as possible with teachers, hoping to increase the likelihood that research findings might be applied in classrooms. This objective was accorded the highest priority for research in science education by members of the National Association for Research in Science Teaching, according to Butts, et al. (see page 7 of this review). In the interest of broadening our view of research, we shall discuss Kerlinger's (1977) opposing view in the CONCLUSIONS section that there are deleterious consequences to the view that research should have "payoff" and be "relevant" to classrooms (see p. 79).

Organization and Features

To achieve these objectives, the review is organized into four major parts, which are in turn divided into a number of sections.

The OVERVIEW is a presentation and discussion of research which dealt with (1) the philosophy of science education, (2) its goals, objectives and priorities, and (3) research which is somehow related to the status of the science education research enterprise. This latter section includes a description of other reviews of research in science education. PART ONE is a sort of introduction to the research landscape.

The second part, EX POST FACTO and SURVEY RESEARCH, is based on Kerlinger's description of these two kinds of non-experimental research. Included are all of those studies which attempted to explain a phenomenon that had already occurred (ex post facto) or surveys about the characteristics of students, teachers or others (science supervisors or scientists) and science programs.

Quite often these two kinds of research are placed in literary competition with experimental research, and—not surprisingly—accorded "honorable mention" status. Yet, ex post facto research is sometimes our only choice in research because we simply do not have control of the variables of interest; and surveys are just as often the logical prerequisite to experimental research, unless of course we presume to change situations about which we have very little basic information.

Thus, we have placed these non-experimental studies in a division of their own in order to focus readers' attention on their results.

The third part, EXPERIMENTAL RESEARCH, focuses on those studies reported in 1977 which evaluated the effect of some variable, such as a particular curriculum or method of teaching, on students or teachers.

The second and third parts have been organized to reach two audiences: teachers and researchers. Within these parts, studies are presented in categories that pertain first to the grade level of the student population investigated, and second that pertain to traditional areas of interest such as achievement or attitudes. Illustrative examples follow.

Teachers will find in the first section of part two and again in the first section of part three all of the research related to the grade level of greatest interest to them: elementary, middle school/junior high, secondary or college (which includes Community College and University populations). In the second section of the respective parts two and three, teachers will find research about themselves, the teaching population.

Researchers who wish to read reviews of studies related to cognitive development, achievement, attitudes and perceptions or instruction will find a matrix in the introduction to part two and another matrix introducing part three. These two matrices provide page numbers for references to the areas of particular interest.

The second and third parts have a common feature which, we hope, will enhance communication with teachers. In each section, several logically related questions are asked, and each question is followed by a description of one or more studies. The studies we cite are not intended to be definitive answers to the questions but rather are simply the findings that investigators reported during 1977 in relation to the questions.

There are two reasons for using the question-posing feature. One reason has to do with our objective to communicate more directly with teachers, in an effort to improve the applicability of research findings. To strengthen the link between research and classroom practices, we rhetorically asked ourselves, "What does this research have to do with teaching science?" From that general question we derived a number of specific questions that served to organize the studies we report. Basic research or studies without immediately apparent classroom applicability were often described sans an introductory question.

The other reason for the question-posing feature has to do with the trend toward multivariate research. It is increasingly difficult to talk about research in single or univariate categories like achievement or attitudes because so many investigators prefer to measure multiple outcomes upon diverse populations. The result is that research findings are more often reported as having different effects on the various subgroups, understandably. Reviewing multivariate studies, however, presents a special problem which is discussed in the fourth part, CONCLUSIONS. In presenting this research, we used the question-posing feature to tie studies together.

Readers will find most of this discussion of the organization and features of the second and third parts repeated in the respective introductions to those parts; the repetition is for the benefit of readers who begin reading this review at one of those points.

The fourth part, CONCLUSIONS, is focused on the broad picture, and links the major findings of 1977 with trends and issues of the past five years of research in science education, as suggested by the ERIC annual reviews from 1972-1976. In the fourth part, we have cut across grade levels and cut across research designs (ex post facto, survey, experimental) in order to focus attention along traditional lines of inquiry: (1) cognitive development, (2) achievement, (3) attitudes and perceptions, and (4) instruction.

The fourth part is a substantial part of the review in terms of space, summarization and synthesis. In our view, brief, regularly placed summaries at the ends of sections would have added little to the discussion, in many cases; and so we often preferred to wait and discuss the findings of each section in a larger context.

To conclude part four we have addressed some of the implications of the year's research to teachers and other implications to researchers.

Finally, we encourage readers to look at Appendix A, Other Papers, for a brief reference to several excellent research papers that seemed to resist fitting into our major organization.

OVERVIEW

Introduction

In this part we discuss research which deals with three aspects of science education: its philosophy, its goals, objectives and priorities, and finally the status of the research enterprise itself in the field of science education, as indicated by the number of studies reviewed herein and by a brief description of foreign reviews of research that have come to our attention.

Philosophy

In a discussion or review of research in science education, the search for "wisdom, knowledge and principles underlying the nature of the universe" (Webster) is probably most appropriately considered at one of two times: either at the beginning or at the end.

After reading the ideas expressed in the three theses on philosophy this year (Bird, 1977; Mitchell, 1977; T. R. Peterson, 1977), it seemed like a natural place to begin our discussion, for the authors ask questions which are timeless and yet have that sense of urgency about them that demands our attention. The authors of these dissertations ask questions about the nature of inquiry in science, the nature of knowledge, and the source of human values.

One of the principal purposes of education, J. A. Bird of the University of California, Santa Barbara, proposes, is to provide students with faculties required for life in a world increasingly influenced by scientific technology and to help them gain capabilities to broaden the base of responsibility in its use.

In his dissertation entitled Inquiry, Integration and Immediacy in Science Education, A Philosophical Perspective, Bird (1977) describes particular concerns in our culture which indicate the growing need for a deeper and more comprehensive understanding of science and technology. He examines recent developments in science education which may enhance this understanding among a greater portion of individuals in society and offers an expanded view of science and education, to demonstrate that their correlation can provide a unique opportunity to increase students' awareness of their own resources and their responsibilities in a scientific and technological society.

To move from inquiry to a contrasting point of view, we see in T. R. Peterson's (1977) dissertation (University of Illinois at Urbana) a comparison of Schwab's notion that all knowledge is tentative and Bruner's notion of knowledge as based on ideas which are constructs used in science to serve as models that give meaning to the regularities we experience. Both Schwab's and Bruner's views of knowledge are juxtaposed against a Thomistic philosophy whose underlying theme is the issue of certitude in this thesis, The Albertus Magnus Lyceum: A Thomistic Approach to Science Education.

M. B. Mitchell (1977), from the University of Toronto, undertook the topic, The Nature of Scientific, Historical and Evaluative Judgments with Some Implications for Education. He discusses the similarities of methods used by scientists and historians and rejects the notion that art or history provides a unique type of knowledge that cannot be tested in the same manner as scientific knowledge. The nature of history is characterized by the way in which hypotheses are corroborated, he claims, and suggests that this methodology corresponds to the scientific model.

One implication of this thesis, Mitchell points out, is that value judgments have important functions in the work of scientists and historians. Mitchell argues that this should be much more clearly revealed in the teaching of these subjects.

There is a flavor of optimism in Bird's philosophy that readers will sense as he examines the goals of science and education and reaches the conclusion that students can discover how to accept and appreciate science in society. The questions Peterson and Mitchell take on are in fact the same ones we ask at the conclusion of our review, questions about how certain we are of the new knowledge that has been suggested by research, and questions about integrating this knowledge into prevailing human values.

The logical place to begin as we keep these questions in mind is considerations about goals, objectives and priorities for research in science education. But before we leave philosophy, we wish to note with appreciation the comments of Moravcsik (1977) in "Two Views of Science—As a Student and 'vingt ans apres'" which appeared in The Physics Teacher, January, 1977. After 20 years as a research scientist, Moravcsik reflects on one element of his philosophy that has not changed:

> ...It is the esthetic excitement and satisfaction that we . . . obtain from enlarging our understanding of how nature works.... (p. 36).

We find that Moravcsik's view of "enlarging our understanding of how nature works" coincides with our view of nature which includes the nature of teaching and learning in science education.

Goals, Objectives and Priorities

The goals, objectives, and priorities of academic disciplines may be reflected by the activities the members choose to pursue. Such activities, it can be argued, are the de facto goals, objectives, and priorities of individuals that comprise the group. Thus a survey of the members' chosen activities, such as those reflected in this annual review of science education research, can be inferred to represent both the cohesiveness and diversity of our discipline's goals. Another way to think about our goals, objectives, and priorities is to ask the members to describe their notion of this important focus.

What areas of research should have highest priority?

This question was asked of National Association for Research in Science Teaching (NARST) members in a survey which used the three-phase Delphi technique. Butts et al. (1977) reported on the results of the survey at the annual NARST meeting in Cincinnati, Ohio.

In the final report of the Delphi study, five statements characterized the final consensus of responses regarding areas and priorities for research in science education: (1) Application of learning and cognitive development theories to classroom instruction; (2) Analysis of classroom learning behaviors that facilitate science learning; (3) Identification of the elements that are essential in translating both research and development activities into classroom practice; (4) Analysis of strategies for acquisition, retention and transfer of problem solving in students; and (5) Identification and validation of strategies to assist preservice and inservice teachers in acquiring specific teaching skills.

The authors of the Delphi study reported on the relationships among demographic information provided by NARST members and their ratings of priorities for research in science education. Correlations were provided (1) between the ranking of importance of research by respondents and their ranking of the research statements, (2) between the research productivity of respondents and their ranking of research statements, (3) between the amount of formal training respondents had and their research productivity, and (4) between the amount of budgeted research time and their research productivity.

The authors report that the lack of major correlations between the demographic variables and the ratings of the research statements (i.e. priorities) "indicate the broad-based support for those activities with the highest research priority" (p. 10). Very high correlations, positive or negative, between demographic variables and priorities would have been evidence of polarity among NARST members, reflecting differences in priorities among those with differing amounts of training, years of experience or research productivity. Thus, even though only 13 percent of the NARST members responding to the Delphi study have published an average of one article per year over the past five years, and 50 percent of the respondents have none, or one article, published during the past five years, there appears to be a moderate degree of consensus among those surveyed.

The Status of Research in Science Education

In this section we discuss the status of the research enterprise, not the status of science education itself, a topic to be discussed later. Our discussion of status is a reflection of numbers of studies and reviews, rather than a qualitative assessment of their value.

Within the 1977 annual review of research in science education, 356 reports of research or research-related papers are represented. Of these, 26 individual reports of research in foreign countries are described and listed in Appendix B (Australia, Canada, Israel, Kenya, Nigeria, Puerto Rico, Scotland, Thailand, U.S.S.R., and a European consortium of sorts), and 330 reports of research conducted in the United States are represented.

No doubt many unexplored avenues and unmentioned references need to be brought to the attention of the ERIC staff so that future reviewers can characterize a broader view of science education research at the international level. Such information should be directed to the attention of the Director of the ERIC Clearinghouse for Science, Mathematics and Environmental Education at The Ohio State University, Columbus, Ohio, 43212.

To reflect a wider international view of the status of science education research, we wish to describe and refer readers to three reviews of research from foreign countries and two U.S. reviews.

Studies in Science Education (Layton, 1977) is an annual publication which has created its own niche by publishing reviews of research about specific areas of science education and by offering through analytical surveys, a synthesis of recent contributions which come from a wide variety of sources.

In the fourth volume, Power (1977) offers an overview and critical review of research which deals with science classroom interactions. Other reviews deal with the meaning of, and arguments for, science (S. Brown, 1977), trends in choices of science courses in secondary schools (Entwistle and Duckworth, 1977), and cultural borrowing and comparative research in science education (Holmes, 1977).

A publication called Research in Science Education (Power, 1976) describes the proceedings of the Australian Science Education Research Association's annual conference. This volume presents topics including undergraduate research experience, science concept development, science and perception, classroom environments, cognitive preference, and intellectual development.

Research in Science and Mathematics Education (Wanchos and Raina, 1976) examines research in India and the question of whether science and mathematics education in that country influence social change. This publication deals with research in science and mathematics education, curriculum, methods, instructional materials and evaluation.

A brief digest was prepared by P. M. Mathis (1976) and was presented as a paper at the annual meeting of the Tennessee Academy of Science in Chattanooga. The author reviewed studies which pertain to teaching and learning about the nature of science. May and Riley (1977) reviewed and evaluated research literature on the link between teacher behavior and learner outcomes.

We bring these references to the reader's attention, and resist the temptation to review reviews of research.

EX POST FACTO AND SURVEY RESEARCH

Introduction

When you want to explain a phenomenon that has already occurred, Kerlinger (1973) tells readers, you are confronted with the unpleasant fact that you don't have real control of the possible causes; that is why it's called ex post facto research.

As researchers, we are adequately aware of the possibilities for misinterpreting events and the ease of thinking that one thing causes another simply because they occur in sequence. Unfortunately, knowing about these dangers does not solve the problem. Until we gain control of all the variables in classrooms (and that's not likely to be for a very long time), we need ex post facto research.

Similarly, we need surveys to accurately assess the characteristics of students and classrooms before presumptuously designing experiments to improve them.

Ex post facto research and surveys are generally placed in literary competition with experimental research, and as such, given "honorable mention" status at the ends of sections describing experimental studies.

We have placed ex post facto research and surveys in a section of their own, not because we are concerned with questions of status but because we recognize they are often the first step and only logical prerequisite to experimental research; and for this reason it is important to focus attention on the results of the studies themselves.

As we looked at the various studies conducted in 1977, we tried to fit them together like pieces of a jigsaw puzzle. Although far from all the pieces fit and many crucial pieces were missing, some rather interesting bits of pictures began to emerge as we tied the 1977 studies to related research from the past five years. We discuss this broader picture in CONCLUSIONS.

Some readers will caution that we ought not try to generalize from studies which have differing purposes and populations, but it is easy to postpone generalization or synthesis with the rationalization that more comprehensive studies are needed. In the meanwhile other ex post facto researchers and surveyors continue to ask questions and conduct investigations. Therefore, we have taken these studies which cover a variety of issues and attempted to interpret them as clues to larger questions whenever possible.

This part is divided into three sections: (1) studies about students, (2) studies about teachers and others involved in science or science education in some way, and (3) studies about science programs.

In each section, several logically related questions are asked and each question is followed by a description of one or more studies. No pretense or assumption is made that any one or two studies really answer the question posed, but the studies are offered as possible clues to broad questions.

There are two reasons for using the question-posing technique. One reason has to do with the applicability of research findings. We have attempted to strengthen the link between research and classroom practice by rhetorically asking "What does this research have to do with teaching science?" The other reason has to do with the large number of multivariate studies and will be discussed shortly.

Because of our attempt to find practical applications wherever possible, we have presented the studies about students by grade level so that teachers might easily look for results of surveys pertaining to students of their level of interest.

As researchers, we are unaccustomed to organizing research by grade levels but it has turned out to be an acceptable solution to a difficult problem. The trend toward multivariate research makes it increasingly difficult to talk about research within traditional categories of achievement, attitudes and so forth, simply because one must deal with the interactions among many dependent variables. This condition, more than any other, led us to use grade level as the most stable category, and also led us to use the question-posing technique as a strategy for dealing with multivariate research. (A more thorough discussion of the influence of multivariate studies on science education research is found in the CONCLUSIONS section. Whenever possible, however, we have discussed research within a framework of cognitive development, achievement, attitudes and perceptions, and instruction.) Matrix 1: <u>EX POST FACTO AND SURVEY RESEARCH</u> is provided to help readers locate discussions which relate to those areas of interest.

MATRIX 1: EX POST FACTO AND SURVEY RESEARCH

	Cognitive Development	Achievement	Attitudes and Perceptions	Other Behavior
Elementary Students	pp. 12-13	- -	pp. 13-14	- -
Secondary Students	pp. 14-18	pp. 18-20	pp. 20-22	- -
College Students	pp. 22-23	p. 23	pp. 23-25	- -
Teachers	pp. 29-31	- -	pp. 25-29	pp. 27, 29-31
Science Supervisors	- -	- -	- -	p. 31
Scientists	- -	- -	- -	p. 31

Each cell contains page numbers where research on topics may be found.

Students

Elementary Students

We begin this section by looking at studies that reveal something about cognitive development and processes, and ask the following question:

How do children think?

Among the many studies which deal with Piagetian theory, there is one that stands out for its unique approach. Kraft (1976) looked at what goes on beneath the child's verbal response to Piagetian tasks.

Kraft studied the hemispheric brain functioning of 18 children (aged six to eight years) as they solved Piagetian and curriculum tasks. Electroencephalograms portrayed the proportions of right/left hemisphere functioning and the shifts between hemispheres for each child during conservation tasks (substance and area), spatial tasks, and curriculum tasks in reading, syllogistic logic and mental arithmetic.

Kraft concluded that

> tasks (Piagetian and reading) which had initial visuo-spatial components during the stimulus (or encoding) period, tended to elicit right hemispheric activity during that period. If that task had verbal or logical components during the subsequent response (or decoding) period, then left hemispheric activity tended to be elicited. However, high performers on these tasks tended to show a greater proportion of right hemispheric activity during the subsequent response period than low performers indicating that the verbal left hemisphere of the high performers utilized greater ability to tap the visuo-spatial right hemisphere's knowledge about the stimulus. Therefore, the investigator suggests that Piagetian tasks are behavioral measurements of interhemispheric communication and selective inhibition and further, that the ontogeny of Piagetian stages is a behavioral index of maturing neural fibres (between left and right cerebral hemisphere and from the reticular activating system to the two hemispheres) which facilitate these processes (p. 5587-A).

What are some of the implications of Kraft's study? First, if the technique she used is replicated by others, we may begin to look for training-effect differences in hemispheric functioning among school aged pupils and tasks. Because this is a relatively new approach to the study of cognitive development, it appears premature to us to recommend direct classroom application.

Dean (1977) conducted an investigation of how children (aged 7 and 12 years) perform learning and recall tasks by applying an Information Theoretic Analysis model. Behaviors were studied to determine how information is processed and how subjects formed cued and non-cued recalls in immediate and delayed remembrances. Dean's major findings were that children of different ages assimilated information and schematized it for different operational structures.

To help us understand how children of different ages and cultures understand concepts at different levels of complexity, Raven and Thongprasert (1977) compared Thai and American students' (169 fifth graders; 159 eighth graders) acquisition of 13 concepts in physics. Using the Test of Elementary Physical Science Cognitive Structure (TEPSCS) they report "differences among the three levels of cognitive complexity exist in the two age groups studied within the Thai and American cultures, ...and between the Thai and American cultures."

Steller (1977) conducted a survey to measure the ability of children (ages 12-13 years) to recognize and transfer the concept of controlling variables. Readers have a treat in store as they follow the author's account of administering tasks to Netherlands students. Steller found those who were able to control variables in tasks where they could see the objects, could not always do so in abstract situations.

Smith and Padilla (1977) examined the strategies used by first grade children in performing a seriation task, using materials varying in length or weight. The authors describe a "concept-task-strategy" employed by the children. Za'Rour's study (1977) retested and confirmed Piaget's position that two types of conservation, identity and equivalence, are concomitant developments.

Owley (1977) tape-recorded interviews with 132 children to study the development of the child's concept of ecology, and found that children's cognitive stages (intuitive, concrete, formal) were related to their development of the concept. The effect of gender and place of residence (urban, rural) on concept development were also discussed.

<u>How well do children's behaviors match their self-perceptions as problem-solvers?</u>

To answer this question, Shymansky, Penick, Matthews and Good (1977) assessed 201 elementary students' perception of their own problem-solving abilities and students' actual classroom behavior solving hands-on science problems. At the beginning and ending of the school year, students in grades one through five were administered the Shymansky Self-Perceptions in Science-II test (SPS-II) and observed by trained observers using the Science Curriculum Assessment System (SCAS). Results indicated that children who perceived themselves as self-reliant were more independent in solving problems than children who viewed themselves as dependent-prone. Dependence upon others by dependent-prone students was more evident in higher grades. The authors discuss the implications of their findings for teachers who use hands-on student-activity-oriented science programs.

How are children affected by having open- or close-minded teachers?

Kadlecek (1977) analyzed the behavior of 20 fourth, fifth and sixth grade teachers and their classes. Using the Rokeach Dogmatism Scale to assess open/closed-mindedness in teachers and Figert's Elementary School Dogmatism Scale (ESDS) for children at the beginning and end of year, he was able to assess changes in class mean scores, and detect the direction of individual score changes. Additionally, Kadlecek analyzed childrens' classroom behavior during science by applying the Verbal Interaction Category System (VICS) to regularized samples of tape recordings.

Kadlecek found that student mean ESDS scores for classes taught by open-minded teachers changed (indicating more open-minded individuals) to a greater degree than those for classes taught by closed-minded teachers. Analysis of tape records showed there were greater amounts of teacher listening and acceptance of students' ideas by open-minded teachers while there was more teacher rejection of student talk and more periods of time when no interaction occurred in classes taught by close-minded teachers.

Objectivity is a behavior that science teachers and curriculum developers have given considerable thought to enhancing. If we assume that open-minded teachers are better able to model objectivity than close-minded teachers, then it may be of value to assess open/close-mindedness among student teachers in order to increase their self-awareness and potential for modeling that behavior for students.

Secondary Students

We begin this section by looking at surveys which reveal something about the cognitive development and processes of high school students. Among the many studies that dealt with Piagetian studies, a survey by Karplus et al. (1977), is exceptional in scope. If we assume that an understanding of students' logical reasoning abilities will enable us to improve instruction, then it makes sense to look for differences among large groups of individuals receiving similar kinds of instruction.

Are there variations in the logical reasoning abilities of adolescents of the same age among European and American schools?

For the first time (1977), we have a substantial international survey of the logical reasoning ability of adolescents. Karplus et al. administered two Piagetian tasks (Ratio Paper Clip task and the Control of Variables task by Wollman) to approximately 3500 students in Copenhagen (N = 399), Sweden (N = 280), Italy (N = 467), United States (N = 1020), Austria (N = 595, Germany (N = 319), and Great Britain (N = 376). The two tasks were translated into five languages and presented in collaboration with science education research groups in each country.

The authors analyzed test performance in terms of students' country, gender, and socioeconomic status or achievement level—depending on the school organization in each country. They reported that

> Differences in achievement [we assume this to mean task performance] among countries were smaller than differences among groups within a country....Both socioeconomic status and selectivity of school affected school performance significantly....The effects of gender were not associated systematically with a particular form of school organization, nor with classes segregated by gender. Significant differences that did occur always favored the boys.... (p. 416).

The authors conclude "...it appears from the small but significant country-to-country differences that teaching can have some influence on the development of reasoning by the students in the age range being investigated here (ages 13-15 years)" (p. 416).

If such differences in approach to teaching are responsible for differences in reasoning patterns, there is reason for optimism among science educators: teaching is one variable over which schools have control.

One of the major contributions of the Karplus et al. study, aside from the data, is that it sets the stage for demographic mapping on a new scale. We shall discuss the implication further in the CONCLUSIONS section. The report by Karplus et al. of inconsistent differences between sexes leads to our next question, which is an old one:

<u>What accounts for the sporadic differences in logical reasoning performance between genders?</u>

Piburn (1977) examined the relationship between gender, field-dependence and formal thought. Subjects for the study (30 males, 36 females) were equally represented in numbers from junior high school, high school and college. Their performance on 12 Piagetian tasks (4 written, 8 clinical, i.e., manipulative) and the Embedded Figures Test for field-dependence was analyzed.

Although Piburn found that males and field-independents outperformanced females and field-dependents, the data show that differences in performance between the sexes cannot be explained simply in terms of field-dependence, nor in terms of written versus clinical tests as some have suggested.

"Even at the relatively weak one-tailed 95 percent confidence level, only four significant differences were revealed," among 15 comparisons. Males were more successful on two of four proportionality tasks, and thus the total for that schema, and subsequently for the total overall tasks; but no significant differences were found between the sexes in performance on the five combinatorial tasks or three correlational/probability tasks.

Sex differences, he concluded, "are restricted to very specific abilities, and cannot be explained away as the result of some other factor." His data show that proportionality is one such ability that deserves further attention. To relate cognitive development and processes specifically to science, we ask another question.

Is logical reasoning related to success or achievement in science?

Kolodiy (1977) administered two Piagetian tasks (Chemical liquids; Inclined plane) to second-year BSCS high school biology students (N = 20), college freshman from introductory physics (N = 25) and college seniors majoring in science (N = 25). He reports scores for high school and college freshmen that are nearly equal (35 percent and 32 percent Formal; 50 percent and 60 percent Transitional; 15 percent and 8 percent Concrete), and significantly different from the college senior sample (64 percent Formal; 28 percent Transitional; 8 percent Concrete). Correlations were significant between SAT math scores and scores from the two tasks, and between the Chemical liquids task and SAT math/SAT verbal scores.

Readers will wonder, along with Kolodiy, what happens to the students who do not continue in science. We encourage longitudinal studies. Do those who appear to change majors do so because they lack abstract reasoning prerequisites, fail tests which require formal thought, or because science courses fail to provide appropriate logical abstract reasoning experiences? And what accounts for the success of the 36 percent of the college seniors who are science majors and yet are Transitional (28 percent) or Concrete (8 percent)? Perhaps they are part of that population which cause professors to assign grades of B and C to majors.

To consider the relationship between cognitive development and grades, we consider a study by Subhadhira (1977) next. In Thailand, tenth and twelfth grade students who demonstrate formal operational thought receive higher grades in science than do students who are not yet formal, according to Subhadhira. We wonder whether the model developed by Raven and Thongprasert (see Surveys about Elementary Students) for levels of logical complexity might not be a useful follow-up survey for Subhadhira.

In this survey, which involved 48 seventh, tenth and twelfth grade science classes in six public schools of Bangkok, Subhadhira's dissertation abstract reports no significant relationship between cognitive development and achievement among seventh grade students. This interesting finding may be due to homogeneous groups of students who are at the concrete operations level, or due perhaps to teaching methods or materials that are keyed to students' levels of cognitive development.

Previously (Surveys about Elementary Students), we discussed Raven and Thongprasert's findings about the relationship between conceptual complexity of reading materials and students' understanding at various age levels. A study by Harkabus (1977) leads back to a familiar question.

<u>What is the relationship between measures of logical reasoning ability and reading ability?</u>

Harkabus found no significant difference in the logical reasoning abilities between adolescents who were reading at grade level and those who were reading two or more years below grade level.

There are two points of interest here: First, Harkabus was able to control for differences in socioeconomic status, which is a factor often related to reading levels. In this study, Harkabus limited his sample to affluent subjects, and his findings demonstrate that there is little variation in logical reasoning ability among high school students from affluent homes, a finding also consistent with research by Karplus and Peterson (1970).

A second point of interest is Harkabus' finding that neither group (at- or below-reading level) among affluent high school students, achieved at the upper formal level (i.e. 75 percent criterion on any formal tasks). Thus, the result shows that affluence alone does not contribute to exceptional differences in logical reasoning abilities.

Other demographic surveys on cognitive development dealt with proportional reasoning, preferences for solving problems, and reasoning of male students. Wheeler and Kass (1977) studied the proportional reasoning abilities of 168 tenth-grade chemistry students from large high schools in Canada. They report administering four tasks (Balance task, Ratio task, Metric Puzzle, and Islands puzzle) with the following results overall: 22 percent of the students were "late formal," 27 percent "early formal," 22 percent transitional and 29 percent concrete; significant correlations were found between proportional reasoning in chemistry and achievement in chemistry.

The authors report that instruction in proportional reasoning in chemistry did not appear to enhance students' general proportional reasoning. This point will be reintroduced in the section entitled EXPERIMENTAL STUDIES; but it is worth noting here that their result appears to conflict with a conclusion of Karplus, et al. "...it appears from the small but significant country-to-country differences that teaching can have some influence on the development of reasoning by the students in the age range being investigated here (ages 13-15 years)" (1977, p. 416). We interpret Wheeler and Kass' statement to reflect short training periods in proportional reasoning.

Dunlop and Fazio (1977) compared students' preferences in solving three problems within a Piagetian setting. Students' preferences for solving a hypothetical model may quickly change when the problem is real. According to Dunlop and Fazio, on tasks involving fossil identification and electrical circuits, students shifted from the concrete mode to the abstract; on a balance problem, students shifted preference from an abstract mode to the concrete.

Two surveys dealt with cognitive processes that differ from those described in Piagetian surveys. Both looked at ways students solved problems in science and are discussed below.

Gough (1977) studied the responses of adolescents as they solved multiple-choice and essay problems in biology. She found that students used the same processes—analysis and hypothesis formation—to solve both kinds of problems; but in the solution of essay problems, these processes increased along with inferences and observation of problem data and differences. By comparing the processes used by successful and unsuccessful problem-solvers, Gough found that wrong solutions in multiple-choice problems were characterized by increases in concern over knowledge possessed for multiple-choice problems. Wrong solutions for essay problems revealed students' increased hypothesis-generation and reduction in observation of differences.

A major contribution of Gough's study, beyond the data themselves which were generated by visually impaired adolescents, is the technique employed. Gough taperecorded students' verbalized thought processes and analyzed protocols using a classification code which was developed for the dissertation. This technique and code may be useful to others and could be standardized.

The final survey in this section was conducted by Squires (1977) and reports no correlation between gender and cognitive styles in solving "released" National Assessment test items. It is important to look at the items to see if they are physical or biological science, in interpreting Squires' study.

<u>Do students who major in science differ from those who choose other majors?</u>

This question and others similar to it, which relate to academic counseling for students, have been of great interest for some time. A number of studies dealt with this issue in 1977. One is reported here and others are reported elsewhere (Surveys about Teachers).

To look for differences between students who chose science as a major and those who did not, Ben-Zvi et al. (1977) tested 233 tenth grade chemistry students from five Israeli high schools. "According to the prevailing educational system in Israel, all tenth-grade students study chemistry together, and are then, for the eleventh and twelfth grades, divided into science and humanities majors" (p. 434). Performance and attitude scores were compared in (1) I.Q., (2) achievement in science, (3) problem-solving ability, (4) manipulative skills, (5) observational skills; and (6) science interest and attitudes. The results of the survey indicated that students who chose science as a major attained higher scores in the cognitive area; I.Q. and two achievement tests loaded highly on this factor. When it came to practical abilities—tests of problem-solving ability, observation skills, manipulative skills—and attitudes and interest in science, there were no significant differences between the two populations. Teachers' assessments of students' performance in chemistry were based on cognitive tests only.

Before readers simply say "So what?" two points deserve to be considered. First, there is the question of teaching "required" science classes to non-science majors: The results of this study suggest that interest, problem-solving, observation and manipulation go well together. If the latter three, called the "practical domain" by the authors, had been eliminated from the Israeli chemistry classes, leaving only the cognitive domain of the course, one suspects the non-majors would have experienced less success and could have left tenth grade with a negative attitude toward science. That may be an important fact to keep in mind when one begins to compute the cost of improving the attitudes toward science held by the general adult population. Secondly, readers should recall this study when they refer back to the survey conducted by Wheeler and Kass (p. 17).

What are some invisible barriers to success in science?

A list of factors comes to the minds of high school and college faculty: math, reading, logical reasoning, perhaps self-concept (also see Surveys about College Students). Should we expect some differences in barriers between high school and college students?

Reading ability is at least one barrier, according to Keenan's study (1977): tenth grade science students must be able to read at the twelfth grade level if they are to successfully answer 75 percent of the comprehension questions at an independent reading level.

This question of barriers takes on additional meaning when we consider the fact that modes of instruction are changing and present new requirements of students. For example, as one minority student recently said, "Just when I figured out how to study for science (the traditional lecture/lab model), they change the rules!" She found herself faced with new requirements in a self-directed learning lab in science.

Sheehan and Hambleton (1977a) provide a clue about some of the difficulties students have to overcome in individualized science courses. While their survey focused on predicting final grades in individualized classes, the data answer the larger question about succeeding in science. Four variables are identified as predictors of final grades: success in math and science achievement on standardized tests, inductive reasoning, study habits and attitudes.

In Great Britain faculty are faced with a problem of transition; students who have learned material incorrectly or misunderstood it in (high) school have special difficulty at the university level trying to unlearn topics. Furniss and Parsonage (1977) discuss possible origins and solutions of this difficulty. Other surveys related to achievement of high school students are reported by Locke (1977) and Preece (1976).

<u>Do changes in interest levels cause changes in achievement levels or vice versa?</u>

To address this interesting problem, Eisenhardt (1977) analyzed measures of interest and achievement scores for 71,701 pupils from four academic areas: science, mathematics, social science and English. Sixth through ninth or sixth through eleventh graders were tested over a two-year interval using the Scholastic Testing Service <u>Educational Development Series</u> (EDS).

> The findings suggest that the predominant causal sequence is from changes in achievement levels causing changes in interest levels across all sample groups in each of the four academic areas...more often than changes in interests cause changes in achievement (p. 4225-A).

As we see it, there are a number of important implications related to Eisenhardt's findings. We shall discuss them at length after introducing studies by Sayavedra, Heiting, Adkins and Orgren, and under CONCLUSIONS.

<u>How is the classroom learning environment related to students' attitudes?</u>

To answer this thoughtful question, Manley (1977) studied 80 chemistry classes in New England; all were using the same curriculum, <u>Interdisciplinary Approaches to Chemistry</u>. By administering the Student Opinion Survey in Chemistry (SOSC) to assess attitudes and the Learning Environment Inventory (LEI) to assess students' perceptions of a wide range of instructional and social cues in the classroom, Manley used a two-group discriminant analysis to test for overall significant differences in the learning environments. Univariate F statistics were used to examine specific LEI differences between the first and fourth quartile groups from SOSC.

Several important differences were found in the learning environments of students having positive or negative attitudes about chemistry. Students who had the most positive attitudes viewed their classes as (1) being significantly less difficult, (2) having a slower rate of progress, (3) having a better physical environment, (4) being more goal-directed, (5) and having less favoritism.

There are a number of important implications of Manley's study. Most of these will be discussed in the CONCLUSIONS section as we look at the broad picture. However, it is worth noting here that Manley's research technique is worth replication. He has isolated an attitude target (positive attitudes in chemistry) and described the characteristic surroundings. It is an elementary rule of research that one describes the target before trying to change it; but we found very few attitude studies of this kind.

How are successful and unsuccessful science students different?

In this section we enlarge on a question we posed earlier. Ogden and Brewster (1977) conducted an in-depth search for differences between successful and unsuccessful science students and portray a picture which might surprise science teachers.

The major elements of successful (upper 25 percent) science students in a Texas population included: (1) ability to gain meaning through senses, (2) enjoy the beauty of an idea or object, (3) commitment to a set of values or group of principles, (4) ability to judge correct physical and social distances to maintain relationships with another person, (5) personal knowledge of oneself and influence by family members, (6) categorical reasoning, (7) reasoning which utilizes magnitude, difference and relationships in reaching conclusions, and (8) behaving according to time expectations.

Minor elements which characterized differences in unsuccessful science students (lower quartile) were: (1) the ability to find meaning in terms of numerical symbols and words, (2) deductive reasoning, and (3) reasoning that uses logical proofs.

These elements, which the authors call cognitive style, suggest a set of characteristics that most teachers might expect from the top 25 percent of their students. An important question to ask is whether these elements fall along social, economic, or cultural-ethnic lines and are learned elsewhere. If so, they may represent a barrier to science as well.

What governs students' choices of classes?

Keys and Ormerod (1976) found that factors other than personal preference influence students' choices of secondary science courses. Both boys and girls who "disliked" a particular science course were found to take the course anyway, and girls who "liked" a science course (either physics or chemistry) were found often to drop the class.

Hofstein et al. (1977a) also surveyed students in secondary science courses of schools in Israel to investigate factors affecting students' choices of academic orientations. Selection of a physical science stream was found to be related to socioeconomic background.

Among 300 high school freshmen of an eastern seaboard city, Taylor (1977) found that black students identified as science magnet students were significantly more often influenced by teachers, family and avocational interests than non-specialized students.

Pell (1977) describes the results of an attitude survey of physics students in Great Britain, from an attempt to identify factors responsible for the low enrollments in science classes. This may also be of interest to those in career planning.

How effective are work-study programs?

Follow-up studies are often frustrating to conduct because of population dispersion rates. However, Eisenberg (1977) received responses from 84 percent of the students who had participated in a Chemistry Study Skills program. In this dissertation, Eisenberg describes the success of the program as measured by factors such as job placement after school, length of time in jobs, and acceptance of subsidized continuation of education.

Other attitude surveys addressed specific subjects (Hofstein et al., 1977a), programs (Mills and Eubanks, 1977), science activities (Bottomley and Ormerod, 1977), or cognitive preferences (Lunetta and Tamir, 1977).

Finally, Slater (1977) describes factors related to creativity, and Evans (1977) describes the development of an attitude questionnaire.

College Students

Looking back over the past five years, we see how few surveys have been conducted among post secondary students. Perhaps no other student population is so diverse in terms of age, academic preparation or social-economic resources and expectations. What kinds of information would be useful to have from surveys that pertain to college students and our responsibilities to them as advisors and teachers? Perhaps we should give it some thought. In this section we begin by looking at the development of logical abstract reasoning among college students. And we return to a question we asked at the secondary level.

Are logical reasoning abilities and reading abilities related at the college level?

Hargrove (1977) found that among college students from introductory biology courses, logical reasoning ability (Combinatorial Chem-Task;

Proportionality Balance Task, and Paper Clip Ratio Task) and reading comprehension (Cloze Test I, II, III; Davis Reading Test) in science and non-science areas were positively correlated.

Using passages selected at the eleventh grade level of difficulty, Hargrove concluded that the logical complexity of the written passages is not being measured by readability formulas. Here again, we refer readers back to studies by Raven and Thongprasert (Elementary) and Harkabus (Secondary). During 1977, the question continued to be asked:

What factors are correlated with success in college and university science and engineering courses?

The doctoral dissertations of Demas (1977), Kalmbach (1977), Schexnayder (1977), and Thomas (1977) report findings comparable to those surveyed in last year's annual review (Renner, et al., 1976, pp. 110-111); that is, standardized test scores such as ACT and SAT and pre-college preparation such as the number of high school science courses taken and grades earned in high school science courses are still the best predictors of success in college science courses. Individual researchers found additional factors relating to success in their university's courses, depending upon the populations sampled. Others have reversed the question:

What predicts failure in college physics?

Hudson and McIntire (1977) provide a test and clue. Scores on a mathematics pretest that they are willing to share are a better predictor of failure than a predictor of success. "...mathematical skills alone are not sufficient to guarantee success in physics, but ... unless the student has the mathematical skills, ... performance in physics will be poor" (p. 470).

What factors lead black students to choose the field of science as a career?

Opoku-Agyeman (1977) surveyed black students who attended either predominantly black or predominantly white four-year institutions and had registered as science majors. Through questionnaires and interviews Opoku-Agyeman found that the following factors were related to a science career choice: (1) socioeconomic status, (2) contact with scientists, especially science teachers, (3) secondary school preparation, (4) academic achievement in secondary school science courses, (5) to a lesser degree, school-related extra-curricular science activities, (6) non-school-related events and experiences related to science, (7) achievement in college science courses, (8) age of stimulation of interests in science, and (9) attitudes of teachers and students.

In seeking to identify salient factors affecting black students' choice of a science career, this study has provided data relevant to administrators, teachers, academic counselors, science foundations and organizations, parents and students, which can serve as a basis for each to more meaningfully participate in the development of more black scientists.

What factors mitigate against participation and achievement of Blacks in science?

Dillon and James (1977) designed a survey to compare attitudes and perceptions of black science majors and non-majors. They concluded that high school science courses "have a lasting impact on attitudes toward science," while a similar influence of college science courses is absent. The authors plead for deliberate and organized efforts to enrich high school science curriculum so that black students may become more aware of career opportunities in science as well as the achievements of black scientists. They urge that "...no students' experience in science courses should leave them feeling incapable of coping with problems in daily life that require some basic knowledge or skill related to science" (p. 600).

Why do college students switch majors from natural science (biology, chemistry, physics, etc.) to other majors?

R. G. Brown (1977) found that the reasons most frequently given by students (N = 219) from six predominantly black colleges and universities were: (1) teaching methodology, (2) lack of awareness about career opportunities, (3) course difficulty, (4) dullness of courses. The professors (N = 150) who taught the courses in these six institutions ranked differently the reasons why students in the study changed majors, and strongly disagreed with the students' ranking of the four most important influential factors.

Five other surveys among college students were conducted. Stocker (1976) reports a before-and-after study of students' attitudes in an introductory college physics class; and Preiss (1977), Krienke (1977), Harvey (1977), and Feiker (1977) describe the results of surveys related to programs for anatomy-physiology students, chemical technicians, nurses, and dentists, respectively, in their doctoral dissertations.

What is effective teaching?

J. A. Ruph (1977) reports general agreement between students and faculty as to what constitutes effective teaching in engineering courses where lecture/lab is the instructional model. As readers might expect, quality of lectures and technical competence of lab instructors were ranked most important by both students and faculty. There was complete agreement on the importance of student interest: ranked second in importance in lectures, third in importance in labs (following second place quality and availability of lab equipment). Students placed more importance on printed materials (texts, handouts, outlines) than did faculty, while faculty consistently viewed a "well-defined grading policy" as a more important factor in effective teaching than students viewed this factor.

Is moral reasoning related to choice of academic major?

We also learned from Lockley (1977) that there is no significant relationship between Rutgers students' level of moral reasoning (measured by James Rest's Defining Issues Test) and their area of academic specialization (majors in natural sciences and humanities). In this dissertation Lockley explored a number of other interesting relationships between levels of moral reasoning, choice of terminal and instrumental values (Rokeach Value Survey), and student characteristics.

Teachers and Others

What has been learned about teachers from surveys in 1977? Several interesting pieces of information which pertain to teachers' attitudes and perceptions, behavior and cognitive development. This section also includes the results of a limited number of surveys pertaining to science supervisors and scientists. We begin this section by looking at surveys that reveal something about the attitudes and perceptions of teachers.

Do science teachers treat high- and low-potential students equally?

After Rosenthal and Jacobson wrote Pygmalion in the Classroom (1968), there was little doubt in most of our minds that somewhere teachers were capable of treating students differently according to their expectations of each pupil's potential. Assuming that teachers today are aware of the Pygmalion Effect, it seems unnecessary to ask the question above. However, Sayavedra (1977) observed 20 high school physical science teachers (10 Mexican American, 10 Anglo American), and found that pupils for whom the teachers had high expectations received significantly more teacher-pupil contacts than did pupils for whom teachers had low expectations.

Early in the semester, the teachers were asked to rank pupils in their classes in order of expected achievement in physical science. Two trained observers used the Brophy and Good Observation System to observe in each classroom for six randomly spaced 60-minute periods.

The investigation revealed that Mexican American pupils generally received fewer teacher contacts from both Anglo American and Mexican American teachers than did their Anglo American peers. While Mexican American teachers held higher expectations for Anglo

American pupils, they still provided more teacher-pupil contacts for Mexican American pupils than Anglo teachers provided Mexican American pupils.

While it is common for teachers to differentiate among students for instructional purposes, many teachers assume that they treat pupils more or less equally, at least in terms of contacts initiated. Apparently, they do not always. An interesting addition to Sayavedra's survey would have been to administer a self-perception inventory to the teachers. We look at another study to consider teacher perceptions.

<u>Do teachers and students share common perceptions of their classroom interactions?</u>

By administering the Relationship Inventory (RI), Heiting (1977) found that there was a significant difference between secondary science teachers' perceptions of their interactions with their students (N = 56) and those of their students (N = 1300 in grades 7-12). In this dissertation Heiting describes the nature of these differences in perception, and demonstrates that the discrepancies between teachers' and pupils' perceptions appear to be independent of class size, class racial composition and educational level.

<u>Do teachers and students share common perceptions about their science program?</u>

Oriedo (1977) administered two versions of the Science Classroom Survey Questionnaire (SCSQ: one for teachers, the other for students) to 29 unified science teachers and their 628 students. Oriedo found no significant relationship between students' and teachers' perceptions of the implementation of the unified science guidelines. If teachers and pupils do not share common views of their programs, then one might ask:

<u>Do teachers and school counselors view science courses the same?</u>

According to Wolff (1977), high school science teachers (N = 51) and school counselors (N = 35) of Omaha, Nebraska, did not agree on several key aspects of science instruction. Science teachers tended to think of science courses as unique in the curriculum and more difficult than other courses while counselors did not. One wonders if the perceptions of non-science teachers would differ in this regard. Science teachers, less than counselors, tended to stereotype science students. On the other hand, science teachers and counselors were in agreement about goals and outcomes of science instruction, laboratory work, prerequisites. On the whole, Wolff concludes they shared more attitudes and perceptions about science than they found themselves in disagreement.

Do high school science teachers grade more severely than their non-science teaching colleagues? Are science class enrollments correlated to teachers' practices in grading?

To answer these questions, Adkins (1977) analyzed data from high school science students (N = 1890) enrolled in first year biology, chemistry and physics classes and from the 31 teachers of these courses in a Midwestern county school system. By comparing the final grades students received in science to the grades they received in their non-science courses, a measure of ease-of-grading was developed and subsequently compared with enrollment data for advanced science courses taught by the same teachers who taught the first year courses. Adkins found that science teachers were more severe graders than were their non-science teaching colleagues, and that enrollment in subsequent science courses was positively correlated to ease-of-grading in initial science classes. "The more severe grading teachers discouraged students from selecting further science courses" (p. 6389-A).

A number of interesting questions come to mind as a result of Adkins' survey. First, it would be helpful to know whether these same teachers would describe their rationale of philosophy for grading in connection with expectations of neighboring colleges, universities or national standards. Second, we might conjecture that severity in grading is positively correlated with the degree of structure controlled by the teacher rather than by the students. We make this conjecture based on the assumption that increased structure increases specificity of expected outcomes. Finally, to connect Adkins' survey findings with those of Wolff, we might speculate as to whether teachers who view science as unique, more difficult than the rest of the high school curriculum, and as attracting certain kinds of students, might not also fulfill their own prophecy by grading more severely and thereby limiting enrollments in future courses. These questions about teachers' perceptions and behavior lead us to think about underlying attitudes.

Does the use of curriculum change teachers' attitudes toward inquiry?

Lazarowitz (1976) wanted to know if there was a correlation between the number of years that new inquiry-oriented programs (such as BSCS, PSSC, HPP, Chem Study, CBA and ESCP) have been used, and the attitudes of teachers toward the inquiry approach. When 508 junior high and high school teachers of earth science, life science, biology, chemistry and physics responded to the Inquiry Science Teaching Strategies instrument (ISTS) and a Personal Data Form (PDF), the results of the survey showed that teachers who used the above-mentioned programs had more favorable attitudes toward inquiry than had those Lazarowitz termed as "Nonusers." However, the author cautions, neither the use of these programs nor the length of time they are used assure proper interpretation of the inquiry approach. "The results suggest that teachers need more training in specific competencies of elements of inquiry..." (p. 552) and that the ISTS instrument can be used as a diagnostic tool. Lazarowitz' study will be discussed later as it relates to an investigation by Orgren.

How are self-concept, attitude toward science and achievement related?

To answer this question, Campbell and Martinez-Perez (1977) administered three tests at the conclusion of a one-quarter elementary science education course designed to help teachers implement science process skills and develop positive attitudes toward science. Tests included Moore and Sutman's Scientific Attitude Inventory (SAI), Campbell's Basic Science Process Skills (BSPS) and Integrated Science Process Skills (ISPS), and Fitts' Tennessee Self-Concept Scale (TSCS). Significant positive correlations were found between teachers' achievement scores and their attitude and self-concept scores, but only self-concept was found to predict achievement. When we consider the positive correlation between self-concept, achievement and attitudes toward science, we may wonder:

What are the career implications for elementary teachers?

Earl and Winklejohn (1977) administered Moore's Science Teaching Attitude Scales (STAS) and found that the major difference in attitude between those elementary teachers (N = 52) who became team/cooperative teaching science specialists and those who taught (science) in self-contained classrooms (N = 49) was a difference in attitude toward teaching science but not a difference in attitude toward science *per se*.

Can use of a mandated curriculum change teachers' behavior?

Orgren (1977) reports that the 1970 Revised Version of the New York State Regents Earth Science Syllabus (RRESS), which is similar to the nationally developed Earth Science Curriculum Project (SCP), was mandated for use in New York in 1971 and has had an important and significant long-term effect on the teaching behavior of the teachers involved. In this expertly designed study, Orgren compares those teachers mandated to adopt the new syllabus in 1971 (Experimentals) with those teachers who volunteered to begin teaching the new syllabus in 1970 (Controls). A carefully constructed and validated test, Earth Science Classroom Activity Checklist (ESCAC), was administered "before and after" the mandated change. A t-test was then used to estimate the likelihood that the 1971-75 ESCAC score gains by the experimental group—relative to the control group—could have occurred by chance. Other relevant statistical tests were also applied and discussed.

The results of Orgren's survey demonstrate that teachers who adopted the new curriculum under mandate changed their teaching behaviors in the direction advocated by the new curriculum. "After four years' experience with the new materials, they continue to employ the new [student activity oriented, investigatory-approach] behaviors" (p. 424). These results should be of interest to curriculum developers as well as science teacher educators.

It is tempting to believe that a curriculum alone can change teachers' behaviors; at the same time, we might give careful thought to the simultaneous requirement of the New York Regents exam, based on the new syllabus, and its potential for changing teaching behaviors. The changes Orgren reports are impressive whether the mandated curriculum alone or along with the simultaneous requirement of the Regents exam, accounts for the change. As we reflect back on Lazarowitz' survey of changes in Texas teachers' attitudes due to use of similar inquiry-oriented curricula, the prospects are encouraging.

Nimmer (1977) found that elementary science teachers surveyed in South Dakota, Iowa, Nebraska and Minnesota expressed a significantly higher degree of satisfaction using NSF curricula than did their teaching peers who used non-NSF curricula.

A number of other surveys relate to teachers' objectives, competencies and abilities.

<u>Can teachers agree on teaching objectives?</u>

Whittaker (1976) listed ten science objectives from which primary teachers selected the six most important to teach, and differentiated between two clusters of teachers: those who preferred objectives involving active student exploration, and those who preferred objectives involving orderly critical handling of information. R. E. Rowe (1977) reported divergent opinions about the desirability and feasibility of science teaching objectives among Wisconsin middle grade teachers.

In an interesting survey by Wilson (1977), 191 Scottish secondary physics teachers report their (1) aims of practical work, (2) types of practical work undertaken, (3) methods of organizing work, (4) reasons for science demonstrations, (5) pre-experiment instructional techniques, and (6) methods of recording work.

<u>What competencies do science teachers need most?</u>

Stallings (1977) describes a study of practitioners' ideas on preservice competencies needed for high school biology teachers. And Onyike (1977) reports a survey of the competencies desirable for secondary school science teachers in Nigeria, with carefully drawn implications for teacher education.

Are elementary preservice teachers thinking more logically?

Joyce (1977) and Ehindero (1977) administered Piagetian tasks to prospective elementary teachers. Joyce reports surprisingly high percentages of elementary education students (University of Northern Colorado) in the upper range: 26 percent "very formal" or successful on all five tasks, 52 percent formal, or successful on four of five tasks, 15 percent transitional, three of five tasks and 8 percent concrete.

It is not difficult to guess from Joyce's use of the term "very formal" that it refers to what Piaget calls stage III-B; but it is less clear how Joyce has concluded that the Karplus Ratio Task (Mr. Tall and Mr. Short) has greater intrinsic complexity than has the Equal Arm Balance Task.

Ehindero collected data from 44 prospective elementary teachers and found 68 percent exhibited formal thought on five Piagetian paper-and-pencil tasks. He also reported significant relationships ($p < .01$) between scores on Piagetian tasks and STEP-SCI (Sequential Test of Educational Progress), SCI-PROD (Science Product), and SAT-Q (Scholastic Aptitude Test, Quantitative), but no significant relationship between Piagetian scores and ATS (Attitude Toward Science) or ATST (Attitude Toward Science Teaching). This latter result is interesting and will be discussed later.

Carter (1977) wanted to know more about the kinds of teachers who have the greatest number of misconceptions about science. Among 401 elementary teachers in West Virginia, women teachers held more misconceptions than did men teachers, rural teachers held more misconceptions accepted by teachers of grades one through six varied inversely with the grade level of their teaching assignment. Carter notes that the number of misconceptions held by these West Virginia teachers was found to be independent of their level of education, institutional affiliation (private or public), or number of years of teaching experience. The results of this doctoral dissertation might be compared with those of research on scientific literacy or with Piagetian research on teachers. R. E. Rowe (1977) also found that middle grade teachers ($N = 50$) of Wisconsin held views of scientific laws and theories that were frequently contradictory and philosophically inconsistent.

Other studies which dealt with teachers' abilities, frames of reference and perceptions were conducted by Preece (1976), Kaikumba (1977), Frazier (1977), Calcote (1977), and Tamir (1976).

Still other surveys dealt with curriculum or training. Carter (1977) reported a survey on the use of the Nuffield Combined Science program; Colglazier (1976) reported on the impact of participation in NSF-sponsored teacher education programs in Indiana; Mason (1977) reported a survey of Earth Science classes in secondary schools of Virginia; and Kagan and Tamir (1977) surveyed the participation of secondary school mathematics and science teachers in in-service training activities in Israel. Three surveys were conducted which pertained to science supervision (Ritz and Felsen, Ellis, Ortiz Plata).

What does a science supervisor do during a typical work week?

In a survey conducted in New York State, Ritz and Felsen (1976) asked this question and found that five activities were most likely to occur: consulting with teachers, teaching of pupils, curriculum activities, activities related to supplies/equipment, and evaluation of teachers. Ellis (1977) conducted a survey in Florida to determine the status of science supervision and found that the perceptions of Florida supervisors of science (N = 45) differed from current research recommendations related to preparation programs. In Puerto Rico, Ortiz Plata (1977) asked what role expectations for science coordinators were held by four groups composed of (1) district superintendents, (2) principals, (3) teachers, and (4) science coordinators themselves. From 717 respondents, Ortiz Plata found some agreement among groups but the amount and degree of consensus varied.

Is the profile of the scientist changing?

This important question has not been answered by this year's surveys, but if a study reported here by Beane (1977) were to be replicated every fourth year or so, we would be able to answer the question. In this dissertation, Beane reports the results of a survey of 103 scientists and engineers as he studied the relationship between life history and personality variables in scientific attainment.

McCaulley (1976) also described the characteristics of "science-minded types" (Myers-Briggs Type Indicator), the frequency of these types that can be expected to occur in high school students and teachers, and the implications for conveying information to the less science-minded public.

Surveys About Elementary and Secondary Science Education Programs

Three surveys of major significance were conducted in 1977 with NSF support. One of these studies will be reviewed here, since the report itself was published in 1977; the other two surveys were published early in 1978 and will be reviewed next year. The latter two are mentioned here as a service to readers: (1) Final Report of the 1977 National Survey of Science, Mathematics and Social Studies Education, R. E. Stake and J. A. Easley, Jr. Both documents are several hundred pages and deserve careful study.

The first of this triad to be published and described here was The Status of Pre-College Science, Mathematics and Social Studies

Education: 1955–1975, Volume I, Science Education by S. L. Helgeson, P. E. Blosser, and R. W. Howe.

The task that was undertaken was to characterize the impact of 20 years of extensive federal, state and local funding, as well as extensive involvement and activity by professional, governmental and community personnel—all directed toward improving science, mathematics and social studies education. The survey is archival in methodology, using the ERIC data base, Education Index, Reader's Guide to Periodical Literature, Dissertation Abstracts International and books, journals, files, reports and other pertinent written materials.

The findings are summarized in an Executive Report (six pages) and in a longer report (260 pages). The following summary appears in the Executive Report:

Findings:

Selected summary statements are presented for each major section of the report.

Practices and Procedures

- Enrollments have been increasing but are beginning to decline, with elementary enrollments declining earlier than secondary.
- The effect of enrollment change may be heightened by emigration of students.
- Just as increasing enrollments had an impact on schools, decreasing enrollments will impact on schools, particularly financially.
- Stated objectives for elementary school science have not changed significantly since 1955.
- Objectives for secondary school appear to be in transition; the importance of science in the general education program is receiving less emphasis.
- The percentage of students enrolled in science has increased until 1973-74 and since has remained relatively stable.
- Class sizes have been reduced between 1955 and 1975.
- Perceived barriers to effective science teaching have not changed appreciably over the past 20 years.

- The individual classroom teacher is still the primary mode of instruction in most classrooms. Less than 10 percent of the schools have used innovative practices such as modular scheduling, television, or computer assisted instruction in any consistent manner.

- Since 1955 there has been an increase in student-centered and hands-on instruction but a substantial percentage of students are not involved with such procedures.

- There are far more alternatives for instructional materials currently than in 1955. Relatively few of these are designed for use in an articulated program.

- The variables for effective teaching are generally agreed upon and the most important, with the current mode of instruction, is the teacher.

- About 50 percent of the students take no science after grade ten.

Science Teacher Education

- State certification criteria still do not reflect those proposed by professional associations in that the professional organizations call for an increase in science content.

- Over the years the guidelines proposed by professional organizations have broadened their focus from science content to include such things as interpersonal relations and ability to deal with societal problems. Guidelines related to content areas are the most likely to be implemented, however.

- Preservice programs in science education reflect increased field experiences and, in general, increased time in the education component.

- While NSF and OE did offer intensive institutes in the late 1960s and early 1970s, the majority of teachers currently teaching have not participated in these.

- The bulk of the science instruction for the secondary program is in the junior high school (nearly 50 percent of the students take no science after tenth grade); this level has the teachers with the least adequate content preparation, poorest facilities, and fewest certification programs available.

- Even though more science is being taught at the elementary level, elementary school teachers are most comfortable when science consultants are available.

- Although secondary school science teachers are currently younger and better educated than in the 1950s; there is still a critical need for inservice education, both as perceived by the teachers and as indicated by research.

- The average tenure for teaching was about eight years in the late 1960s and early 1970s; it is currently increasing. This has implications for inservice education since it appears that the more recent graduates are those more likely to go back to school.

- There is a critical need for preservice and inservice science education to be viewed and dealt with as a continuous program rather than as discrete entities handled by two different sets of people.

- Teachers are being impacted upon by the press for accountability, the back to basics movement and textbook controversies, but these are rarely the kinds of issues dealt with in their preparation.

Controlling and Financing Education

- The influence of state governments on science education has increased markedly since 1955.

- There is extreme variation in state control and influence, but regional patterns do exist.

- Some examples of areas in which considerable state control is exerted are school organization, school curriculum, teacher certification and financial support for schools. Science education has been impacted both negatively and positively by state influences.

- The percentage of financial support for the schools from federal and state sources has increased since 1955; the percentage of financial support from local sources has decreased since 1955.

- Federal support for science education has declined since the late 1960s.

- Since state support tends to follow federal trends, state support for science education has also declined and is likely to continue to do so.

Needs Assessment Efforts

- The greatest single need facing education is an improved program of financial support.

- There is increasing emphasis on basic skills; knowledge of science is rarely considered basic.

- An important and complex need is for equal educational opportunity.

- Pressure for accountability has increased markedly within the past ten years.

- Science education is rarely included in state needs statements. When it is included, it increasingly reflects concern for life skills and work skills.

- Nearly all states have some form of accountability or assessment procedure.

- The major objectives in science education have not changed markedly over the past 20 years. The emphasis is beginning to shift, however, at the secondary school level.

- Continuing research in science teaching-learning is vitally needed. However, the results of that research which has already been done needs to be better communicated and applied.

(Helgeson, Blosser and Howe, 1977)

A number of other surveys were conducted in 1977 and characterize science education in more specific ways: NSF programs, academic disciplines or geographic areas. They are presented below according to their target or sample groups.

Horn and Marsh (1976) surveyed six school districts scattered across 50 states to compile information regarding the implementation of NSF curricula. The results report data about school size, class size, instructional assistance, and dissemination/implementation efforts. The major recommendations coming from teachers were that (1) teachers should receive training in teaching strategies of the curriculum and (2) teachers' understanding of learning theories and intellectual development should be coupled with the implementation efforts.

Boroughs (1977) was also interested in the use of NSF curricula and surveyed 602 elementary school principals in the state of South Carolina. Results of the survey indicated that 9.3 percent of the classes in the schools of the respondents had used NSF programs in their schools. "NSF users" rated the importance of science in the total curriculum significantly more important than did "non-users." Yet Boroughs found no significant difference in the annual per pupil expenditure for science between the two groups. In a related study Nimmer (1977) reports on the effectiveness of mass media methods in disseminating information about NSF curricula to the general public and the school community.

Streitberger (1977) reports the results of surveying university professors' opinions on the question, "What should we be teaching in high school chemistry?" Krieger (1977) conducted a similar study of chemistry requirements for allied health programs.

Two surveys on the status of public school science education in foreign countries are reported by Igambi (1977) on Kenya and by Tongsookdee (1977) on Thailand.

Surveys About College Science Programs

Among the ten surveys which characterize science teaching at the college/university level, several reflect national trends while others relate to local institutions. In the interest of brevity we must refer readers to these surveys by title only.

Of national scope, surveys by Blatt (1977) report the status of college and university chemistry courses for non-science majors and by Hendrix (1977) report the status of bioethics courses in universities. McKnight (1977) describes the results of an investigation of major training factors in allied health programs in junior colleges, with particular reference to science-oriented experiences. Baker (1977) conducted a survey of the relationship between students, college physics course performance and high school preparation. Two other surveys of U.S. college programs are reported by DeShong (1977) on freshman engineering students and by D. I. Johnson (1977) on environmental education.

Readers interested in university programs in foreign countries will want to read Terapigittra's thesis (1977) on the analysis of science preparation in an institution in Bangkok, Thailand and F. J. Thomas' (1977) study on the cultural relevance of science instructional materials in the People's Republic of China. These might be compared with the reports on science education from <u>Soviet Education</u>, a publication of U.S.S.R. Several abstracts from 1977 issues of <u>Soviet Education</u> have been prepared by Janice Cruz, Department of Teacher Education, California State University, at Hayward and appear in Appendix C.

EXPERIMENTAL RESEARCH

Introduction

In the preceding part we presented ex post facto and survey research, in this part we discuss experimental studies. The most important characteristic of experimental research, using Kerlinger's (1973) distinction, is control. The investigator has at the very least manipulative control of one active variable, and if possible he can also exercise control by randomization through the assignment of subjects or treatments to groups randomly.

This part is divided into two sections: studies about students and studies about teachers. The studies reviewed in the first section, Students, are presented by grade levels: elementary, middle/junior high, secondary, and college. As we noted previously, we are unaccustomed to organizing research by grade level but that organization has turned out to be an acceptable solution to a difficult problem.

The trend toward multivariate research makes it increasingly difficult to discuss outcomes in traditional categories like achievement, simply because multivariate research results are reported in terms of interactions among many dependent or outcome variables. Thus, every multivariate study can be discussed under any category for which it has results. This condition, more than any other, led us to adopt grade levels as the most stable reporting category.

To bring more meaning to the results reported by grade level, we "invented" questions which have some relevance to classroom instruction. Each question is followed by a description of one or several studies. No pretense or assumption is made that the studies answer the question posed, but they are offered as possible clues.

Wherever possible, we have organized these questions within a framework of achievement, cognitive development, attitudes and perception, curriculum and instruction. MATRIX 2: EXPERIMENTAL RESEARCH is provided to help readers locate page numbers of discussions which relate to traditional areas of interest such as achievement.

MATRIX 2: EXPERIMENTAL RESEARCH

	Cognitive Development	Achievement	Attitudes and Perceptions	Curriculum	Instructional Methods	Basic Skills
Elementary Students	p. 40	pp. 40-41	--	--	pp. 39-40	--
Junior High/ Middle School Students	pp. 41-42	pp. 42-44	pp. 44-45	pp. 42-45	p. 45	p. 46
High School Students	pp. 46-47	pp. 47-50, 52	p. 51	pp. 50-51	pp. 51-52	p. 52
College Students	pp. 53-54	pp. 54-57	--	p. 57	pp. 54-59	pp. 57-58
Teacher Education	Teaching Behavior pp. 60-61		Attitudes p. 61	Competencies pp. 61-62		

Each cell contains page numbers where research on topics may be found.

Students

Elementary School

We begin this section by looking at an instructional method that varies the degree of teacher structure. Then we discuss studies related to cognitive development and, finally, studies that relate to achievement.

How does the degree of teacher structure affect pupils?

One of the major thrusts of experiments, in 1977, related to elementary pupils had to do with the influence that varied amounts of teacher initiated structure in the classroom had on pupils' behaviors. In a number of studies a single model developed by Matthews, Phillips and Good (1971) was used to measure quantitative changes in pupils' responses: the Teacher-Structured Learning in Science (TSLS) is contrasted with Student-Structured Learning in Science (SSLS); validity and reliability of the method have been described earlier than 1977.

Another characteristic of these studies is that they simultaneously assess several dependent variables within a single experiment, frequently leading to the reporting of mixed effects. The array of student behaviors observed has 12 cognitive and affective outcomes.

To generalize, most of these experiments show that student-structured learning in science promotes, for some pupils, greater achievement, problem solving abilities, motivation, attitudes, confidence, self-concepts, preference of structure, and independence: Penick and Shymansky (1977), Good et al. (1976), Allen (1977), McKee (1977), Abhyankar (1977), Crocker et al. (1977). However, many of these show mixed results and interaction effects with differences between genders, Piagetian stages, ethnic groups or other demographic variables (eg., McKee). Only one experiment, Hill (1977), shows a total lack of impact on creativity and self-perception in pupils' behavior by altering the degree of teacher structure.

Another approach to studying the effect that varied degrees of teacher-initiated structure has on children was conducted by Linn (1977). She reported that pupils who were given free choice in an enrichment program showed greater gains in logical/abstract reasoning when some direct instruction was combined with free choice.

A final study in this area was conducted by Sprague (1977). She reports that achievement was greater in classes where pupils were instructed to talk to each other or to the instructor during hands-on activities in science, than in classes where no instructions were given regarding verbalization. Interestingly, the gains in achievement showed up on the delayed-retention measure but not the immediate retention test. This result (a delayed effect) will be reintroduced shortly. However, a final point of interest on Sprague's study has to do with the outcome that was expected. We wonder whether peer interaction might be expected to have an even greater effect on cognitive development than on achievement.

The point that seems to be evident from this series of studies is that altering a single variable, in this case degree of teacher structure, does not produce a universally positive effect. Most of these effects appear to benefit some children and not others; and there appears to be a cancellation of effects in some cases, as indicated by statistical interaction effects.

On this point, Colin Power (1977) concluded after a recent critical review of one decade of interaction studies,

> ... many researchers who believed in the myth of universally effective teacher behaviors have either ignored or misinterpreted the results, or have left the field in search of new panaceas.... (p. 24).
>
> Attempting to understand the complexities and realities of classrooms is a long and difficult task upon which we have barely begun (p. 25).

No one knows better than those who conducted the research cited here how complex it is to study classroom interactions. We shall discuss this point further in the CONCLUSIONS section.

Can cognitive conflict produce long-term gains?

Previously, we noted in Sprague's study (1977) that peer interaction produced delayed but not immediate achievement gains.

In this regard, J. K. Johnson (1977) assessed the effect of cognitive conflict training on fifth-graders' concept of conservation of area. Two forms of cognitive conflict training were compared: peer interaction with conflict producing materials and arguments from their peers, and individual students using conflict producing materials without peer interaction.

Johnson found that both conflict producing procedures resulted in cognitive growth (i.e., achievement of conservation) on immediate posttest scores of conservation; but only the peer interaction cognitive conflict training produced gains in delayed tests of conservation.

What methods, sequences, programs, or activities produce the greatest achievement?

A second major thrust in experimental studies focused on achievement among elementary school students. Again, we find conflicting results among studies. If we look at teaching methods, we find that students learned as much in classrooms where indirect teaching strategies were used (lecture, discussion, questions) as with direct strategies (lecture only), according to Cottrill (1977). When Nevins (1977) altered the logical sequence of learning activities recommended by the science textbook publishers, she found no difference in achievement of concepts among third grade pupils.

Yet we find that other teaching methods do produce greater achievement. Wilson and Koran (1976) report that children who are asked to write their hunches rather than read hunches about discrepant events learn more; and Ferraro et al. (1977) found that differences in degree of structure of science materials (high/low) were related to recall for children, normal adolescents and mentally retarded adolescents.

Comparisons of curricula, programs and activities were also conducted in an attempt to find that one which produced greatest achievement by Glasser (1977), Hoover (1977), Vanek and Montean (1977).

Middle School and Junior High School

In this section, over 20 experimental studies pertaining to middle school and junior high school classrooms are discussed. We begin with studies that relate to cognitive development and follow with studies on achievement and curriculum, attitudes, instructional methods, and finally studies related to basic (3-R) skills. (Please see MATRIX 2: EXPERIMENTAL RESEARCH for page references to those areas of special interest.)

Can adolescents be trained to think more logically?

Two studies examined this question and results were reported indicating a positive response.

Howe and Mierzwa (1977) studied the effect of a series of six instructional lessons on the capability of eighth grade students to think logically on tasks requiring the control of variables. The lessons were presented over a time span of one month and the subjects were urban youth of low socioeconomic status (SES). The authors report that the lessons significantly increased the capability of logical thinking in these subjects and that the gain was retained over a six-week period. The lessons focused on the use of cognitive conflicts and the concept of the controlled experiment. No claim is made that the subjects moved from one Piagetian stage to another but only that the increased capability for logical thinking was demonstrated.

Wollman and Lawson (1977) investigated the capability of fifth and seventh graders from middle to upper-middle class suburban communities to control variables. Most of the subjects had demonstrated a pre-formal capability in this regard. The subjects were grouped into four developmental levels on the basis of four Piagetian conservation tasks. Each subject was trained individually in three or four 30-minute sessions over a four-week period. The training sessions consisted of physical, graphic-verbal and pure verbal experiences.

The authors reported that the experimental group significantly outperformed the control group on tasks which required the subjects to control variables. Differences were especially pronounced for the seventh graders. These studies indicate that specific training in certain types of formal reasoning can improve students' performance on problems requiring such reasoning.

Three studies (Ryman, Wright, Jeddeloh) dealt with capabilities of subjects to use specific processes of science. Ryman (1977) studied the effect of the Nuffield Project on the ability of 12 year old subjects to classify living organisms. The author concluded that the "Nuffield Method" was an important variable in subjects' achievements on classification tasks. Wright (1977) found no significant differences between the mean scores of seventh graders on a measure of process skills for experimental (exposed to the Science Curriculum Improvement Study) and control groups. Jeddeloh (1977) studied the effect of student chosen sequence of 20 lessons from the SCIS "Ecosystems" unit as opposed to teacher sequenced lessons. No significant difference was found between groups and their ability to use science processes. Readers will recall that Nevins (1977) also found altering sequence did not affect achievement of third grade students. Jeddeloh also concluded that the students' selection of an activity as a motivator for learning and positive attitude toward science was not related.

Fisher (1977) and Perrin (1977) examined other variables and their effect on cognitive learning. Perrin studied the effect of audio-visual variables on cognitive learning and found that the subjects exposed to normal sound significantly outscored those subjects exposed to "compressed sound." She also concluded that a larger screen produced better cognitive learning only on a delayed posttest. This latter finding may be linked to those reported by Sprague (1977) and J. K. Johnson (1977).

How successful are various science curricula in increasing student achievement?

The largest category of research related to middle school and junior high school students pertained to achievement.

Studies by Mulcare (1977), Greene (1977), and Griffin (1976) focused on student achievement as related to various aspects of junior high school science curricula. Mulcare studied the outcomes of two science programs, "Interaction of Man and the Biosphere" and "Interaction of Matter and Energy." Mulcare reports that the introduction of these two programs had a negative effect on the junior high subjects' raw scores for science achievement compared to similar scores for the four previous years. Also, the curricula had no effect on the subjects' rating of science as a desirable career compared to the previous four years. (The question of test validity is important here. We learned from early assessments of CHEM study the importance of test selection and norm groups, especially in the assessment of achievement.)

Greens examined the effect of reading levels of the modified ISCS Level III Environmental Science (ES) material. The difference of reading levels between the modified and original versions was not a factor in effecting the science achievement for the low-ability reading student using the ISCS materials. We are reminded here again of Raven and Thongprasert's study of the effect of conceptual complexity in reading materials.

Griffin reported that Interrelated Explorations in Science (IES) appeared to have no significant effect on student achievement and only a partial effect on student attitudes. IES emphasizes the ideas, processes and values common to the scientific enterprise utilizing independent study, gaming and value clarification activities.

Studies by Davies (1977), Jeddeloh (1977), and Meeks (1977) reported other additional variables which did not significantly improve science achievement.

Davies studied the effect of student selected mini-courses in their science program compared to conventional non-elective science courses and reported no significant differences in achievement between the two junior high subjects at different schools. Davies also found no difference in the students' attitudes about science for these two methods of instruction. Jeddeloh reported findings which supported Davies' findings.

Meeks studied the effect of embedded aids for subjects of three reading levels. A specific cluster of visual aids was embedded in separate passage of a science textbook. An example of an embedded aid was an attention-heightening device. No significant differences were found between the three groups. The question of crucial attributes for such embedded aids is, of course, at stake here.

Gabel and Herron (1977) and Rivers (1977) studied aspects of the ISCS curriculum. Gabel and Herron examined the effect of allowing students to pace themselves to achieve mastery learning versus the imposition of a deadline for completion of chapters in the ISCS materials. Over 1,000 students were studied. It was concluded that students who work alone had a higher learning rate than had those with partners and that no difference in learning rate occurred between students who were self-paced and those who had deadlines. Retention scores showed a significant difference favoring self-pacing.

Wright (1977) studied the effect of SCIS materials on the process skills and attitudes of seventh grade students. No significant differences were found between the SCIS experimental and control (traditional textbook) groups using a measure of process skills. As we will note later, other research indicates that teachers must specifically teach process skills if they expect achievement of them. Wright also reports that controls showed significantly better attitudes.

Does diagnostic testing promote greater science achievement for high school age students?

Two notable studies related diagnostic testing to achievement. Long et al. (1977) provided earth science teachers with performance objectives and diagnostic progress tests. Students were stratified on three levels of aptitude. Groups of students receiving diagnostic tests scored significantly higher than did control groups. A retention test, however, showed that initial differences measured were not retained after a two-month span.

Catanzano and Wilson (1977) assigned three testing contingencies to seventh grade students: no retesting, optional retesting and mastery retesting. Optional retesting and mastery retesting were found better for achievement; optional retesting was better for attitudes. Treatment difference was not related to anxiety.

Overall it would appear that some ongoing diagnostic testing will probably improve students' achievement in science without decreasing student attitudes.

Can choice of curriculum change students' attitudes toward science?

A study by Fraser (1976) revealed that students who experience the Australian Science Education Project (ASEP) showed favorable changes in their attitudes about science classes.

Three similar studies are reported which examine the relationship between a student's choice or freedom and the student's attitude toward science. The results of other studies on students' attitudes toward science have been included under other categories [see Burnette (1977); Fraser (1976); Flowers (1977); Jeddeloh (1977); and Mulcare (1977)].

Davies (1977) compared an elective mini-course science program with a conventional non-elective program and found no significant differences in student attitudes for the two programs. Gabel and Herron (1977) examined the difference in attitudes of students who had studied ISCS with deadlines and those who were self-paced. No significant difference was found in the two methods. The studies of Davies and Gabel and Herron tend to support one another and indicate that student choice is not a variable related to student attitudes about science. In this regard, the research on attitudes at middle school/junior high level is consistent with research we described earlier. (Keys and Omerod, 1976).

Catanzano and Wilson (1977), however, examined the effects of no retesting, optional retesting, and mastery retesting on seventh grade students and found optional retesting to be better for attitude. The three treatments were found not to be related to student anxiety.

<u>Are some modes of instruction more desirable than others for adolescents?</u>

Previous reviews of research have suggested that the search for a universally beneficial method is naive. Let us look at the research in this area for 1977.

Raven and Calvey (1977) investigated operative comprehension (Piaget) differences in students exposed to activity-oriented science programs and students exposed to textbook-oriented programs. The results indicate that eighth grade students in the activity-oriented program achieved higher scores on operative comprehension items than did the control group. No differences, however, were found for sixth grade students receiving the same treatment. The study utilized the Science—A Process Approach (S-APA) materials.

Flowers (1977) studied the effect of an individualized instruction based on programmed material compared with teacher-centered instruction and found favorable but not statistically significant results for the individualized approach. Yoder et al. (1977) examined the effect of sequencing in junior high science in the success of these students in high school biology. Students enrolled in a generalized science curriculum in grades seven through nine scored as well or better than did those having a specialized life science course in grade seven.

Other approaches to science instruction in junior high were studied by Goodyear (1977) and G. Johnson (1977).

Goodyear concluded that an open science classroom was more effective in facilitating cognitive growth than was a traditional science classroom. Johnson found that a consistent mode of instruction (all outdoor or all indoor) produced higher achievement than did mixed modes of instruction. On the surface this appears to contradict our common sense which tells us that occasional field trips can have a positive effect on early adolescent learning; however, on close examination, motivation, not achievement, might be the expected outcome for single or intermittent field trips.

Additional related studies by Fraser (1976); Gabel and Herron (1977), Rivers (1977) and Jeddeloh (1977) have been included in other categories.

Can science instruction improve basic (3-R's) skills?

A study by Rivers (1977) examined the association between the use of individualized, self-paced science curriculum materials of ISCS as a reading course and gains in reading comprehension and vocabulary skills of seventh grade students. The study employed two control groups (traditional science and ISCS science) and one experimental group (ISCS-Reading Course).

Teachers of the experimental group participated in a short workshop where they were given specific reading activities for students. These activities allowed informal assessment of student reading ability and vocabulary scores. Results showed a significant improvement in reading comprehension and vocabulary for both ISCS classes compared to the control group. Also students in the ISCS-reading classes made somewhat higher gains than did those in ISCS-science classes. No differences in vocabulary were found among the ISCS groups. A significant finding of this study is that most of the difference of gains between groups occurred for the students reading below grade level.

Summary

What have we learned from experimental studies involving early adolescents? It appears that early adolescence is a time when students' logical reasoning abilities can be enhanced by highly specific training. The data on achievement in traditional subject matter are mixed, showing that some methods or curricula affect attitudes while others do not. It appears that content achievement for these students can be improved by mastery learning techniques and diagnostic testing. However, overall the search for a universal method for all students appears very naive.

There is a strong indication that increased complexity of science tasks may prove to be much more of a barrier to achievement than is the level of reading. The evidence indicates that the junior high/middle school aged students are certainly at a crucial point in cognitive and affective development.

Secondary School

The experimental studies in this section deal with students and instruction in secondary or high schools. Over 40 studies are presented and discussed in the following order: those having to do with cognitive development, achievement, attitudes, instructional methods and, finally, studies related to basic (3-R's) skills. Readers will be able to find page number references to specific areas of interest by looking at MATRIX 2: EXPERIMENTAL RESEARCH.

What have we learned about the way high school students think?

To answer this question, a number of studies were conducted with high school students.

DeLuca (1977) designed and tested an electronic apparatus for its similarity to Piaget's first chemical experiment. DeLuca's tasks were randomly included in a series of five tasks administered to twelfth grade chemistry students. Statistical analysis indicated no differences among the tasks in their discrimination between concrete and formal operational subjects.

Bady (1977) developed tasks to study the ability of ninth grade, eleventh grade and college freshmen students to identify correlations in data and to test hypotheses. Results of typical correlational tasks showed a 40 percent success rate by college students, 15 percent by eleventh grade students, and 5 percent for ninth grade students. The subjects performed at a lower level on the hypothesis testing task.

Lawson and Nordlund (1977) investigated high school biology students using BSCS-Blue Version. The majority of these subjects performed below the formal-operational level on weight and volume conservation tasks. The results indicated that these students would probably encounter difficulty with the BSCS-Blue Version materials.

The surprisingly low percent of subjects passing the tasks administered by Bady and Lawson has been reported by other researchers in recent years.

Rowell and Dawson (1977a, 1977b) studied the ability of 61 ninth grade concrete operational subjects to make the transition to a full knowledge of density (including floating and sinking) which, according to Piaget's theory, requires formal reasoning. They emphasize that the study attempted to teach the idea of density rather than requiring this construction by individuals. The authors reasoned that this enabled a more concrete approach to be taken avoiding wherever possible the necessity for formal operational thought processes. Rowell and Dawson reported that 41 percent of the students finished the period of instruction with a full understanding of density.

Holliday, et al. (1977) studied tenth grade subjects who were low verbal performers. These subjects performed significantly higher when provided with picture-word diagrams of biological concepts than when provided with block-word diagrams.

How much imposed structure is desirable for high school science students?

A fairly strong argument for imposed structured learning is revealed by a review of the articles in this category. Evidence, however, has been obtained from relatively short-term observations. Certainly the research in this area will profit greatly if more long-term studies can be employed.

Beeson (1977), Kahle and Rastovac (1976), LaShier and Wren (1977), Lee (1977) and Power and Tisher (1976) conducted investigations which examined the relationship between imposed structured teaching and student learning.

Beeson reported a study in which tenth grade students received instruction on electric circuits using a hierarchy of concepts constructed from a task analysis procedure. The results of the study indicate that intellectual skills were best learned when they were connected in a hierarchical sequence. Beeson, however, also concluded that the hierarchy was mechanical rather than meaningful. Beeson also suggested that meaningful (generalizable and relatable to the subjects' experiences) learning in learning hierarchies is a field in need of much additional research.

Kahle and Rastovac examined the effect of advance organizers on the meaningful learning of carefully sequenced materials in biology classes. The advance organizer group showed significant improvement over the control group.

LaShier and Wren investigated the effects of student knowledge of pretest mathematics skills and exposure to a mathematics overview on IPS achievement and mathematical competency. LaShier and Wren interpreted that the superior gains of the experimental group were due to their knowledge of pretest results and instruction provided by the mathematics overview. This mathematics instruction provided the students with a concise computational instruction in each area of the pretest. The results of the experiment indicate that a diagnostic method which assists students with defined needs is successful in improving their scores on the IPS Achievement Test.

Lee examined the effects of kinetic structure on the acquisition of meaningful learning. Kinetic structure is a term defined as the serial linkage of verbal statements throughout a communication, which can be visually represented on a graph. The study showed that high structure was the greatest factor for producing greater knowledge acquisition and retention. The study was conducted with 212 ninth and tenth graders. The retention data were gathered seven days subsequent to the initial testing. The study also showed that visuals (35 mm slide versions of black and white line drawings from textbooks) were not an important variable.

Power and Tisher studied 15 science classes using the Australian Science Education Project (ASEP) materials. Video-taped classes were analyzed for student and teacher behaviors. The independent variable was the three levels of teacher structuring. The study revealed that more structuring resulted in more cognitive activity, more experimentation and less task—irrelevant activity.

Although the studies generally indicate that mastery learning and increased "kinetic structure" produce increased student learning, a study by Douglass (1977) produced contrary evidence. Douglass investigated the achievement of high school biology students as a function of the effects of instructional sequence and cognitive style. The instructional sequence had no effect on the level of achievement. Cognitive style of the subjects was determined to be either field dependent or field independent based on the Embedded Figures Test. The cognitive style was found to have a significant effect on achievement when general intelligence was ignored.

How does team teaching affect student achievement?

Jeffries (1977) studied over 3000 tenth grade biology students over a four-year period. Students were randomly assigned to one teacher for the full year or to four 9-week courses with different teachers. Significant improvements in achievement occurred for the team teaching approach.

Additional studies by Beeson (1977), Coles (1977), Even (1977), Lawson and Nordlund (1977), Leonard (1977), Loeb (1977), Rambally (1977), Rastovac (1977), Tamir (1976), and Williams (1977) included data on student achievement. These studies indicate the tendency for student achievement to be improved by increased imposed structuring of the learning experience, although some studies do not support this conclusion.

How does computer assisted instruction effect achievement?

Sperry (1977) studied the use of computer simulations to teach biology in an inner city high school. The study analyzed the effect of computer simulations on critical thinking, attitudes toward computer programs, and attitudes toward biology. The study concluded that (1) the computer simulated materials did not improve the students' critical thinking compared to students in regular biology classes; (2) the computer group significantly improved their attitudes about computer simulation over those of the control group.

Staniskis (1977) compared student biology content achievement between computer-managed instruction and non-computer-managed groups. Groups were identified as computer-managed-instruction- junior high students (CMI-JH), computer-managed-instruction- senior high students (CMI-SH) and non-CMI-SH. The subjects were cross-categorized as high or low using the California Achievement Test and Achievement Development Scale Scores (CAT/ADSS) for total reading. The study concluded that the CMI-JH group achieved significantly higher biology content achievement than did the other two groups. No significant difference between the CMI-SH and non-CMI-SH groups occurred for achievement. Within each group the high readers showed significantly higher content achievement scores than did the low readers. A discussion of the study reveals that the CMI-JH group followed the recommended CMI program closely. Students were permitted to progress at a rate equal to their ability. In the CMI-SH group the format was modified. Time constraints were placed on students and the sequence of modules was changed. The non-CMI group followed a conventional approach of lectures, periodic tests and group pacing.

How successful have various science curricula been in 1977?

Studies specifically related to CHEM Study, BSCS, IPS and Project Physics were reported. Even (1977) studied student achievement in CHEM-Study and non CHEM-Study classrooms. Achievement was measured using a 60-item posttest, a Scholastic Aptitude Test, the Inventory of Choices and a summary of educational plans. Aptitude and achievement scores showed substantial decline when a course based on CHEM-Study was implemented in place of a traditional curriculum used for eight years.

Rambally (1977) studied the relationship between teachers' attitudes toward science, interaction patterns, and achievement among twelfth grade students in the CHEM-Study program. The study revealed a direct relationship between teachers' attitudes about science and student achievement. No significant relationship occurred for student-teacher interaction and achievement.

Frigo (1977) studied the feasibility of integrating selected environmental management concepts into parts of the BSCS-Yellow version. It was concluded that this approach was not feasible. Tamir (1976) examined achievement scores of Israeli high school students using BSCS and found that scores for this group were significantly higher than for other students in non-BSCS curricula. Watkins (1977) assessed the cognitive style of students enrolled in the BSCS-Green version compared to a traditional biology program. The results indicate little or no difference in populations exposed to the BSCS curriculum or the traditional version and the subject's cognitive style, i.e., the mode of problem solving or inquiry. BSCS subjects, however, had significantly higher achievement scores than had subjects in traditional biology classrooms.

Additional studies by Lawson and Nordlund (1977) on the BSCS curriculum and LaShier and Wren (1977) on the IPS program were reported earlier.

K. D. Peterson (1977) examined a training program in science inquiry skills which was developed to enable high school students to acquire investigative strategies which are an integral part of science. The author defines science inquiry as the coordination of the processes of science in a systematic probing of the nature of objects and events of the environment. The experimental group was trained in science inquiry. One control group completed nine weeks of Project Physics and a second control group experienced a combination of science inquiry and Project Physics. The author concluded that the experimental group generally out-performed the Project Physics group on investigative skills. The author concludes that specific instruction in scientific inquiry skills was of functionally significant value for the subjects and that the group benefited from a blend of concrete materials and abstract verbal instruction.

What interventions appear to influence high school students' attitudes toward science?

Research by Coles (1977) focused on attitude as a function of teacher directiveness. Coles hypothesized that students would perform best and experience greatest satisfaction in classrooms when the delivery style of the instructor best matched the students' locus of control orientation. That is, the achievement and attitudes of externally controlled students were expected to be maximized in directive settings. It was concluded that there was no support for the hypothesis. The study was conducted with 15 biology teachers and 370 students and represents a significant effort to test this hypothesis.

Loeb (1977) examined the effect of group testing and individual testing on student attitudes toward science for nearly 300 students. The experimental group consisted of students taking regular quizzes within five groups of three to four students. The exams in these groups were answered in a cooperative manner while the control group took individual tests. In the second phase of the experiment, the treatment for the two groups was reversed. No significant difference between groups was found for test anxiety, attitude, or achievement, and student interest. The study also revealed that teams teaching may not be beneficial for students with intelligence quotients below 95. The team teaching approach definitely favored the students with average and higher I.Q.'s.

Williams (1977) conducted a similar study on first year biology students. The results of the study also indicated no significant difference for student attitudes toward biology for achievement in biology.

Martin and Bell (1977) concluded that behavioral objectives made a significant difference in the student attitudes toward instruction in a vocational science class. The students also performed significantly higher than did a control group on terminal achievement, critical operations and residual achievement. Their finding is consistent with the results of Manley's study discussed earlier.

What teaching methods appear to work best with high school students?

Leonard (1977) studied two instructional methods for biology laboratory investigations. The experimental group did investigations based on the Extended Discretion Model (EDM) which consists of (1) a task statement, (2) ongoing teacher review of student progress and (3) a list of student discretionary resources to complete the task. The control group consisted of students in a BSCS-Green version laboratory program. The study concluded that investigations should require more independent student work than, for example, do the BSCS investigations. The study also noted that different teachers utilized the EDM method differently and that teachers tended to show reluctance to allow students greater independence.

Rastovac (1977) examined the effectiveness of audio-tutorial versus teacher directed inquiry in promoting achievement. The results showed no significant treatment differences in achievement.

Santiesteban and Koran (1976) studied tenth grade students of low verbal ability who were taught using one of three instructional adjuncts: (1) advance organizers, (2) behavioral objectives, or (3) a set of adjunct questions. No significant difference in achievement was found for the three treatments.

Silbert (1977) investigated the effects of high and low structure educational environments on 67 students who differed in level of cognitive development (LCD) as assessed by Piagetian tasks. The study concluded that neither attitudes nor achievement of the low LCD group and the high LCD group were related to the degree of structure.

Evans (1976) investigated interactions that take place in oral teaching of high school and college students. The study revealed a high degree of teacher dominance in both settings and an infrequency of discussion by many pupils.

Additional studies related to this category by Balogun (1977), Coles (1977), Jeffries (1977), Martin and Bell (1977), Peterson (1977), Rambally (1977), and Williams (1977) are included in other categories in this section on secondary students.

<u>Can high school science courses improve students' basic skills?</u>

A study by Kincaid (1977) investigated the effectiveness of an inservice program for secondary teachers in teaching reading in the content areas. Mathematics, science, and social studies teachers received three days of training in selected skills and processes needed to help their students read content material. The study indicated that the teachers in the experiment group did in fact perceive themselves incorporating new experiences designed to improve student reading in each content area.

Summary

What have we learned from experimental studies involving high school students? It appears that the formal reasoning capabilities of secondary students as defined by Piaget are lower than one would expect by merely examining Piaget's theory, but this finding is not new.

The research generally indicates a fairly strong argument for imposed structured learning to improve achievement for high school students. There appear to be improvements in achievement when content material is carefully and logically sequenced.

Some researchers warn, however, that much "improvement" may be only mechanical and that generalizable learning is much more difficult to assess. Evidence is beginning to accumulate that concrete experiences coupled with structured learning may be more desirable.

College and University

In this section, the 1977 experimental studies pertaining to college and university students and classes are discussed in the following order: cognitive development, achievement, curriculum, studies related to improving basic skills, and computer assisted instruction.

Readers interested in any of these specific areas of interest will find page number references in MATRIX 2: EXPERIMENTAL RESEARCH.

What is the relationship between cognitive development and structured learning?

Mathis and Shrum (1977) studied biology students using an audio-tutorial center. Kinetic structure was defined as the serial order in which a subject is presented and the relatedness of contiguous discourse units in verbal communications. The study revealed that students attending tutorial centers with high kinetic structure performed significantly better on achievement tests than did those attending centers with low kinetic structure.

Thro (1977), in a parallel study, examined the relationship between content and cognitive structure. The study examined (1) the development of physics concepts in cognitive structure resulting from the content structure presented to the learner, (2) differences between cognitive structure and physics achievement, and (3) the relationship between cognitive structure and problem solving ability. Small samples (N = 19 and N = 11) were used to generate data. The results showed a positive relationship between the variables under investigation.

The influence of structured versus unstructured laboratory experiences in physics and students' understanding of the processes of science was studied by Spears and Zollman (1977). The structured traditional laboratory proved better in this regard than did an inquiry laboratory that covered identical experiments. Serlin (1977) conducted a parallel study and found opposite results. Serlin designed a laboratory experience that stressed activities which matched the mental stage of the students and the use of advance organizers. It was concluded that these methods were significantly effective in improving the students' science process skills.

Renner and Paske (1977) studied the relationship between content achievement and cognitive development gains among college students receiving concrete instruction and those receiving formal instruction. Gains for all groups using the concrete mode were made over the groups under formal instruction.

Moche (1977) studied the effects on knowledge acquisition of matching science subject matter communication structure to students' cognitive style. It was concluded that the type of structure a science teacher should use depends on the outcome objective. If the objective is recall of information, the subject matter should be presented in brief isolated blocks of equivalent to about one paragraph. If the objective is synthesis of relationships, then a cluster approach should be used where concepts are continually contrasted and compared. The results of this study indicate that the learning level of the student is directly related to the instructional level.

A study by Blake (1976) was conducted on the cognitive characteristics of the freshman population of elementary education students in Australia. The purpose of the study was to determine the success of a combined mathematics-science course of one semester in facilitating intellectual growth using an inquiry approach. The control group was taught science-mathematics in a traditional lecture format. Piagetian tasks were used to measure intellectual growth. The study concluded that neither method proved superior. Both groups showed marked intellectual growth which was not related to a standard intelligence quotient. Approximately only two percent of the population was fully formal operational (Piaget) after the one-semester course.

Other cognitive development studies were reported by Bunge (1977), Coldeway and Merrill (1977), Crawley and Shrum (1977), J. Johnson (1977), Lutz and Rigney (1977).

How does audio-tutorial instruction affect achievement?

Francis (1977) investigated biology achievement in an audio-tutorial program for non-science majors. The first phase of the study compared achievement between groups of students with audio-tutorial instruction and with lecture-laboratory instruction. The second phase compared achievement among high, medium and low science ability subgroups in the audio-tutorial group. The audio-tutorial group achieved significantly better than did the lecture group in the area of knowledge but not in the areas of comprehension, application or overall achievement.

Seal (1977) concluded that the audio-tutorial method was equally as effective as a conventional method. Retention scores for the two methods also showed no difference between the two methods.

Anthony (1977) made a comparative study of an audio-tutorial and conventional lecture method of instruction in a biology course for non-science majors. No significant difference was found between the two methods for student achievement and critical thinking.

Walsh (1977) compared the changes in achievement and attitude between a physical geology class using the Keller Plan or PSI and a control class using a conventional lecture-laboratory method. No significant difference in achievement occurred between the groups, but the experimental class showed significant improvements in attitude toward science compared to the control.

Butzow et al. (1977) examined the relationship between attitude and achievement in an audio-tutorial introductory chemistry course. The best predictor of success with the experimental program was the prior achievement, notably grade point average. The attitudes of students toward the course were not found to be related to their achievement.

The conclusions from this body of research imply that audio-tutorial instruction seems to be as effective as traditional means of instruction when growth in student achievement is measured. Research by Walsh (1977) and Thiele (1977), however, have demonstrated that audio-tutorial or self-paced methods can be used to improve student attitudes.

<u>How effective is mastery learning on student achievement?</u>

Several studies addressed this question. It should be noted that this question examines gains in student achievement if mastery learning or diagnostic learning is stressed. Research on this question provides important additional information about the merits of an audio-tutorial instructional system.

Putt (1977) studied an established course in introductory physics presented according to traditional and to the Keller method of instruction. The study specifically examined the mastery concept of self-paced learning. Putt concluded that time is the relevant variable determining mastery in an introductory physics course.

Rakitan (1977) also studied conventional learning strategies and mastery learning strategies. This study reported that discriminant analysis of cognitive and affective student traits was highly successful in placing students into modes of instruction which produced the greatest achievement.

A study by Hass (1977) examined the use of performance objectives on achievement and attitudes of non-science majors enrolled in biology. The students who used the performance objectives scored significantly higher on teacher-constructed tests than did students not using performance objectives. The use of performance objectives, however, did not enhance general biological achievement as measured by the Nelson Biology Test nor improve attitudes toward instruction.

Collins (1977) also studied the effect of the Keller approach and mastery learning on biology and pharmacy major freshmen and found measurable but limited short-term enhancement of scholastic achievement when compared with a standard audio-tutorial (non-mastery) strategy. Superior performance, however, tended to be limited to lower-order types of multiple-choice items.

A study by Waugh (1977) determined the effect of ongoing diagnostic tests. First year biology students showed no significant increase in achievement compared to the control. However, a second unit of diagnostic instruction for these students did produce significant achievement over the control group.

The results of these studies are not conclusive, but the tendency for mastery learning or diagnostic learning to produce higher student achievement than does non-mastery learning is indicated.

Which student characteristics are related to student achievement?

A difficulty with studies of students' characteristics is the problem of isolation and control of variables. For this reason it may be impossible to conclusively demonstrate a cause-effect relationship between student achievement and student characteristics. The studies below examined the correlation of these two broadly defined variables.

Elliott (1977) used a multiple regression analysis on the variables of physics pre-test scores, reading comprehension, support, conformity, independence, leadership, practicular mindedness, achievement and variety. Each of these variables was examined for its effect on physics achievement and on attitude toward an audio-tutorial approach and a lecture approach to instruction. The author concluded that the student characteristics of aptitude of physics pretest scores and support produced significant positive correlations with physics achievement for students in the lecture approach. None of the nine student characteristics was found to be significantly correlated with physics achievement or attitude for the audio-tutorial approach. Neither approach was superior in producing higher physics achievement or attitude.

As Butzow and Williams (1977) and Lyon (1977) concluded, the best predictor of science achievement is prior content achievement. Additional studies related to this category were conducted by Chuaphanich (1977) and Osborne (1976).

Is there a relationship between the teacher's style of questioning and students' learning?

An investigation of the effectiveness of three levels of questioning and biology achievement was reported by Merlino (1977).

Teachers' classroom questions were classified as high, medium or low using the Sander's taxonomy. Significant improvements in students' understanding of biological concepts occurred when higher levels of questioning were used.

Is the grading of homework necessary in upper level engineering classes?

Stephens (1977) studied students in an upper level engineering class and evaluated their homework assignments. Stephens concluded that students who had their assigned homework graded did not perform better than did students whose homework was not graded.

Additional studies related to the category of achievement/attitudes were conducted by Chapdeleine (1977), Chuaphanich (1977), Cooney (1977), Foster (1977), Gabel et al. (1977), Elliott (1977), Hanshaw (1977), C. Johnson (1977), Mamantov (1977), Osborne (1976), Reach (1977), Russock (1977), A. Smith et al. (1977), Stronck (1976), Suter (1977), and Thiele (1977).

What is the impact of curriculum change in college classes?

A study by Gadson (1977) examined the change in science attitude in college students enrolled in physical science due to the implementation of the Thirteen-College Curriculum Project (TCCP). A traditional physical science course served as a control. The findings indicated a significant improvement in the emotional, intellectual and scientific attitude for the TCCP group compared to the control group.

A model chemistry curriculum for the undergraduate biological sciences major was reported by Englin (1977). The author made an extensive review of the literature related to this problem and involved a variety of experts. A sequenced list of courses was developed. A number of important conclusions were reported related to the success of such a curriculum: (1) a substantial percent of college freshmen needed training at an abstract level before they could successfully deal with the rigor of the proposed curriculum, (2) college students could be trained to function at an abstract level through instructor-directed inquiry learning and laboratory manipulations of surrogate concrete concepts leading to abstract generalizations.

Additional studies relating to curriculum were reported by Craney (1977), Frangos (1977) and Jenkins (1977).

What is being done at the college level to improve students' basic (3-R's) skills?

Mirsky (1977) reported on a sophomore level course in geoscience at Indiana University and Purdue which was developed to teach written and oral reporting skills. Considerable improvement occurred during the one-quarter course. Other professors reported differences in written reports by the subjects as well. Subjects who have graduated recommend the course to current students.

Buckley (1977) studied the effect of integrating topics in science and algebra for remedial instruction. The experimental group received instruction that emphasized a close correlation of related topics in science and algebra. These were also sequenced so that the algebra was generated from the science topics. Science related problems were frequently utilized in the assignments for the experimental group. The control group covered the same topics in science and algebra but no attempt was made to interrelate course material. The study revealed that the experimental group significantly outperformed the control group on cognitive gains. No significant difference between the two groups occurred for attitudinal changes toward science and mathematics.

<u>What evidence is there that computers can play an important role in science education?</u>

The use of computers as an instructional system is an area of increasing interest to researchers. Several studies were conducted at the university level which analyzed various aspects of the question above. Studies by Cavin (1977), Cottrell (1977), Hilbert (1977), and Luce (1977) explored computer instruction as it relates to science.

Cavin compared the use of computer-simulated experiments in a college chemistry laboratory compared to conventional laboratory experiments. It was concluded that students who did the computer-simulated experiments performed significantly better than did the students in the conventional setting in some cases. Overall, however, the computer method did not show a clear advantage over the conventional method.

The study by Cottrell investigated achievement and attitudes of chemistry students using a computer managed instructional system with FORTRAN language. Again, the computer method showed no significant difference in the achievement of instructional objectives.

The results of studies by Hilbert and by Luce are somewhat contrary to those of Cavin and Cattrell. Hilbert's evaluation of the effectiveness of instruction augmented with computer interaction and peer assisted learning showed significantly greater gains for the computer group. The study by Luce also provided evidence in favor of a modified form of computer assisted instruction (CAI). The study employed a computer system based on units of instruction which are more comprehensive than the frame of traditional CAI. The data collected showed significant improvements in the users of this program.

The results from these studies seem to be mixed, but, based on these studies alone, computer assisted instruction methods appear to be at least as good as conventional methods. And, very much appears to depend on the specific kind of computer assisted instruction.

An additional study by Dunkum (1977) reviews the problems associated with computer assisted instruction in physics programs. The reader should refer to this non-experimental study for programs on the effective use of CAI and for future research questions.

A study of Berkowitz and Szabo (1977) examined the effects of mental ability upon the problem solving processes of individuals and dyads confronted by complex science problems of hypothetical reasoning. Results showed that dyads composed of two high mental ability students requested significantly more data than did high ability individuals. Apparently the dyads were doing more critical thinking and more hypothesizing than were individuals alone. Low ability dyads received significantly fewer data matches than did low individual and high-low dyads. The fact that high ability pairs of students achieved most may suggest the computer problems were too difficult to be stimulating to less able students.

<u>What have we learned from experimental studies involving college students?</u>

The research indicates that structured learning can be used effectively to improve achievement, especially if the subject matter is presented in a well designed and highly logical sequence. Typical audio-tutorial instruction, however, was found to be about as effective as conventional modes of instruction for achievement and attitudes. The inference is that only audio-tutorial instruction that is high in logical organization will significantly improve student learning. The evidence overall shows that students require a wide variety of modes of learning, and the search for one ideal mode continues. There is the usual evidence that concrete experiences, when coupled with logically structured abstract experiences, can produce high overall achievement for college students in science and perhaps mathematics. Mastery learning and diagnostic testing are found to improve achievement. Time is recognized as a significant factor in affecting achievement in this setting. Achievement of this type is also the easiest to measure. Continued evidence indicates that college students as a whole are surprisingly deficient in formal or abstract thinking. Computer assisted instruction provided mixed results. The evidence however indicates that computer assisted instruction which is high in logical organization and used systematically can produce high achievement.

Teachers

We begin this section by looking at experimental studies which were conducted to test methods of changing teachers' behavior, attitudes and competencies. MATRIX 2: EXPERIMENTAL RESEARCH will assist readers in locating pages which deal with specific areas of interest.

How can teachers' interactions with students be modified?

Kelsey (1977) conducted a performance based teacher education study with 27 student teachers. Variables investigated were students' cognitive statements, reinforcement patterns, effects of treatment on individuals, identification of individuals responding well and poorly, and performance criteria. The study employed a four-hour training session during which the student teachers learned to identify and classify cognitive and reinforcing verbal behaviors from audiotapes of their instruction.

The study concluded that these methods were effective in changing verbal behaviors of student teachers and that these teachers could learn to categorize and monitor their own verbal behavior. Furthermore, the monitoring and the setting of measurable goals as performance criteria with reference to baseline data was more effective in producing behavior changes in student teachers than was merely providing subjective feedback.

Lamb (1977) studied a module for training science teachers to ask a wide variety of levels of cognitive questions. The module included a question category system to be used by the teachers. A written programmed instructional sequence of 120 frames was designed to train teachers to use the system. The teachers then applied the system to audiotapes of classroom behavior. It was concluded that the experimental teachers who used this module asked a wider variety of questions than did groups without the module.

Yeany and Capie (1977) studied the effects of model viewing and instruction in teaching strategy analysis on preservice teachers' selection of science teaching strategies and on their attitudes toward the role of the student. The study concluded that the best method to bring about changes in attitude and in teaching style of elementary preservice science teachers was a combination of training in a science teaching strategy analysis and the use of videotaped model lessons.

Sunal (1976) investigated the effects of an elementary methods course on preservice teachers. An experimental group of students was involved in a campus-based field experience as well as in methods courses and student teaching. The major difference occurred in the ability of students with field experiences to more adequately model specific teaching roles when asked to do so.

Generally the studies indicate that teacher behavior can be adjusted to better and higher forms of questioning. Teachers can recognize desirable modes of interaction in their own teaching. Additional studies are badly needed to measure the long-range effects of such instruction. Additional studies related to this category were conducted by Rahn (1977), D. Smith (1977) and Vannan (1977).

<u>What techniques are most successful for changing teachers' attitudes toward science?</u>

Two studies addressed this question. Jaus (1977) found that an immediate microteaching experience for inservice teachers rather than curricular activities had a positive effect on the teachers' attitudes toward teaching process skills. The microteaching experience had a significant positive effect beyond those teachers who were competent in understanding the processes of science.

A study by Bergel (1977), however, produced mixed results for this question. Bergel concluded that the microteaching experience did not produce a significant increase in positive attitudes for preservice elementary teachers over a control group.

Apparently the microteaching method of introducing teachers to teaching science can be successful, but a positive change in teacher attitude cannot be assured. Apparently teacher attitudes are controlled by additional factors.

Other factors which may affect the attitudes of elementary teachers toward science were studied by L. Gabel (1977) and Kauchak (1977). Gabel concluded that a significant positive change in attitude toward the teaching of science but not toward the body of science was achieved as a result of a four-week workshop on modern elementary science curriculums. The teachers involved also served as model science teachers for preservice teachers. It is interesting to note that the preservice teachers did not change their attitude toward science or science teaching after observing the model teachers. Kauchak found that writing an essay, in a test situation, favorable to a particular topic resulted in an attitude change toward that topic. Santiesteban and Koran (1977) found that elementary school science students taught by preservice teachers trained to ask observation and classification questions showed a significant increase in frustration over a control group. Results such as these indicate a continued need for longitudinal research.

<u>How can teacher competence by improved?</u>

A study by W. Brown (1977) concluded that elementary teachers who were taught science process skills in a series of hands-on laboratory activities scored significantly higher on a paper-and-pencil instrument for science process skills than did a group not receiving these skills. This control group was also enrolled in an elementary science method course. Campbell and Martinez-Perez (1977) also concluded that preservice teachers may not acquire science processes in science courses and that instruction of relatively short duration is sufficient to significantly alter preservice teachers' knowledge of process skills. The work of Markle and Capie (1977) also indicates that the processes of science can be learned by elementary teachers in a physics course designed for the group.

The importance of these studies to teacher education is that the processes of science which are important to modern elementary curriculum have to be emphasized in a science course. They cannot be expected to occur automatically as a result of a prospective teacher enrolling in a science course.

The acquisition of science teaching competencies through psychological modeling was studied by Santiesteban and Koran (1977). Psychological modeling is defined as the tendency of individuals to imitate higher status persons, peer group members and other relevant models. Students observed a videotape of a teacher asking observation and classification questions of elementary students. The teaching skills of observation and classification were not verbally highlighted. A sound track of the video model was given to another group. The results suggest that both the video and audio models produced affective behavior more frequently than a no-model treatment.

A study by Henderson (1977) evaluated the success of resource teachers to the implementation of elementary science curricula. The findings indicate that classroom teachers not previously involved as science resource people can provide inservice education for their peers. It was also concluded that a four-week summer workshop can be an effective means of changing the resource teacher's attitude toward science and science teaching. The study also stressed the importance of providing experiences for the teacher which closely fit the actual responsibilities of the resource teacher. Furthermore, the principal's interest in such an experience is an important factor in the actual implementation.

Additional studies by White (1977), Fox (1977), Harvey (1977), and Wolfe (1977) were conducted in this area.

Summary of Teacher Education

The experimental studies in teacher education indicate that teachers, through training, are capable of diagnosing their own interactions in the classroom. This procedure proved to be an especially valuable technique in changing preservice teachers' teaching styles compared to subjective comments. Thorough diagnosis, however, requires considerable training and some teachers may be hesitant. And, preservice teachers who took part in field experience during a science methods course could model specific teaching roles adequately when asked to do so.

Microteaching can be an effective bridge to the field experience. The evidence indicates that teachers become proficient in successful science teaching by doing the teaching rather than by watching it. Model elementary teachers who were trained in a four-week workshop on modern science teaching techniques showed positive attitudinal changes to teaching science, but no change toward science. Pre-service teachers who observed these model teachers showed no positive change in attitude toward science or in teaching science.

CONCLUSIONS

Introduction

What have we learned from research in 1977? Quite a bit, we think. This part looks at the broad picture, combining ex post facto, survey, and experimental research. Our discussion and conclusions are organized into four sections which cut across grade levels and focus attention on traditional categories: cognitive development, achievement, attitudes and perceptions, and instruction.

In each of these sections, we have looked at the annual reviews of research from 1972-1976. These years represent an initial effort to look at the preceding five-year span of research. A more thorough five-year synthesis is now needed as a separate document.

The implications that we draw from the conclusions are presented in two final sections which are addressed to two audiences: implications for teachers, and implications for researchers.

Cognitive Development

Looking Back: 1972-1976

As we looked back at the research on cognitive development over the past five years, three facts became obvious. First, Piagetian theory has dominated the scene. Second, much of the Piagetian research appears to be repetitious. The majority of the studies were confirmations of Piaget's theory; only the numbers of adolescents who demonstrated formal reasoning patterns differed from Piaget's estimates. Nevertheless, we were positively impressed by the sheer number of studies and by the diversity of tasks and populations sampled.

The third fact to surface from the past five years of research is that little work has been done to show how Piaget's theory can help science teachers improve instruction. Most studies supply tests or tasks that can be used by teachers and offer student norms which may or may not apply to the teacher's local population. Little effort has been directed toward helping teachers know what to do after the tests have been scored. With this background, let's look at the research for 1977.

This Year: 1977

At the 1978 National Association for Research in Science Teaching (NARST) annual meeting in Toronto, 20 of the 70 papers listed titles related to Piagetian theory. Similar trends are reflected in the various journals that report research on science teaching. We interpret this wave of interest as evidence of readiness for a developmental theory that is easily understood, easily confirmed or tested by reality, and sufficiently broad to permit a great deal more research for clarification.

What were the major findings of Piagetian research during 1977? First, the major thrust must be described as demographic—meaning surveys which report the distribution, population density and other vital statistics about the performance of individuals on Piagetian tasks which require logical reasoning. Vital statistics include the relationship of logical reasoning to such factors as age, gender, social or cultural groups, and so forth.

On the surface, it appears that the majority of the demographic studies support findings already reported by others, but readers must dig deeper to find out which studies have really added a new dimension to our understanding. Examples of this latter group include studies by Karplus et al., Kraft, and Piburn, to name a few. The Karplus team, with its international survey involving thousands of adolescents in Europe and the United States, sets the stage for a new scale of demographic mapping. Their data relate to the testable hypothesis: Can differences in teaching influence the logical reasoning abilities of adolescents?

In a new direction, Kraft has shown the relationship of right-left brain hemispheric activity to the intake of information on Piagetian tasks and output of hypotheses for task solution. From this relationship, Kraft proposes that Piagetian tasks are an index of interhemispheric communication, and that Piagetian stages are the behavioral index of maturing neural fibres between the right and left cerebral hemispheres which facilitate the process. In our view, Kraft's research is of considerable significance because it brings us closer to understanding the connection between learning and physiological development.

A better understanding of the differences between sexes' responses to logic problems is offered by Piburn. This in-depth analysis shows that gender differences are problem-specific and not at all generalized as many have thought. Proportionality is one key area Piburn identifies for careful attention to differences.

What were other characteristics of Piagetian research in 1977? Very little research pertained to classroom instruction, meaning application of Piaget's theory. A study by Johnson is an example of the exceptions, however. Two forms of cognitive conflict training were tested experimentally in the classroom. Cognitive conflict combined with peer interaction proved to have greater long-term effect in promoting logical reasoning among elementary students than did the use of cognitive conflict materials with individuals working alone. Classroom teachers will find this study ready-made for implementation. It is on a par with the research reported by Albert (Herron et al., 1974) for exceptional applicability.

Finally, the combination of research by Hargrove, Harkabus, and Raven and Thongprasert suggests that logical reasoning ability may prove to be more closely linked to the logical complexity of science reading materials than to their reading levels determined by popular formulas or tests.

Conclusions

What conclusions are suggested by the review of this year's research in cognitive development? First and most obviously, Piaget's theory continues to dominate the research scene. As the total number of Piagetian studies has increased, so has the number of Piagetian demographers. Their interest resembles the ascending slope of a growth curve.

We conclude that the astonishing amount of interest in Piagetian surveys needs to be channeled to contribute to an enlargement of the theoretical horizon. For example, there are presently sufficient data from surveys to plot a more-or-less detailed demographic map which, though spotty in places, could be used to create a phylogenetic model. What do we mean by a demographic map and a phylogenetic model?

Foreign and U.S. survey data from the past several years of Piagetian research, if organized as demographers plot census data, would characterize the development of logical thought among people of many ages, languages, countries, cultural-social-economic backgrounds, from both technological and non-technological or non-industrial societies. Such demographic survey data could hint at the historical or evolutionary lines of development of logical thought among humans.

Piaget's model is ontogenetic in nature: it depicts the development of logical thought within the life cycle of a single individual. A phylogenetic model—if constructed from our present demographic surveys—could suggest the evolution of this human trait, behavior or capability called logical or abstract reasoning.

Our demographic search would need to be broadened if we were to develop a phylogenetic model, of course. How should we begin? By plotting our existing data first, identifying information gaps, and then gathering data to fill in the gaps. Perhaps we would need to poke around in old literature to find early or primitive examples of logical thought, not that living examples are extinct; but literature could serve as our "biological fossils," as could existing non-technological cultural groups.

Naturally, all of this implies time, energy and resources; but with the present corps of demographers at work now, it may be that all we need are the resources.

We readily recognize that on the one hand we argued earlier for Piagetians to devote more energy to the design of research which has built-in classroom applicability, while on the other hand we have just proposed the development of a phylogenetic model—which is theoretical. There is room for both, obviously. We also admit that the proposed model perhaps belongs elsewhere; but we shall explain the reason for this example in the section entitled Implications for Researchers.

What other conclusions are suggested by the review of this year's research in cognitive development? Obviously there is still much new ground to cover. We refer now to a broad cognitive development framework.

There were so few studies which explored alternative theories about cognitive development that we found little to discuss in a comparative way. Moreover, it was impossible to contrast cognitive development research with research based on theories of learning (eg., Skinner or Ausubel) or theories of instruction (eg., Gagne), simply because studies based on these theories were not sufficient in number. One could interpret some of the Piagetian research in terms of Skinnerian theory, but of course that is not our task. We conclude the research base needs to be broadened theoretically. What might be done?

We interpret the interest in Piagetian research as evidence of widespread interest in theory, and that people do like to have their research contribute to some larger intellectual pursuit. We suggest that the lesser interest in competing theories may owe to their lack of clear example (eg., protocols of responses), field testing methodologies (eg., analysis of protocols), and perceived (not real) narrowness which precludes the desire to conduct more research for clarification of the theory. In our view, university faculty members with appropriate backgrounds might be encouraged to describe how interested researchers could broaden the theoretical base of research in cognitive development.

Achievement

Looking Back: 1972-1976

Achievement has been a frequently researched area of science education. It would seem that achievement should be one of the easiest variables to measure. Yet it is not. The evaluation of achievement is characterized by a diversity of definitions including "recall of information," "application of knowledge," and "meaningful learning," to name only a few. The higher the level of the achievement (Bloom's Taxonomy), the more infrequent measurement has been.

The wide diversity among studies of achievement over the past five years suggests the need to organize achievement research around existing or new theoretical models. Authors of past summaries have all indicated the importance of such theories for useful and continued research in science education, and we concur.

It also makes sense to assess achievement over relatively long periods of time; yet very few such studies have done so. For example, modern elementary science curricula have been employed for several consecutive years in various locations throughout the country, but there is very little information about students' long-term achievement from these programs.

The research from prior years emphasizes the importance of the teacher's effect on student achievement. Proper questioning patterns were generally found to be an important variable. Behavioral objectives and similar aids to instruction generally appear to improve achievement. Such objectives appear to be especially helpful for lower ability students. Past studies of mastery learning and diagnostic testing have shown a slight tendency to improve achievement over traditional modes. The variables of these studies are, however, extremely complex. It must be emphasized, again, that most studies have only measured short-term achievement of extremely small increments. The best predictor of achievement is still prior achievement in similar subject matter areas.

This Year: 1977

Overall the majority of studies for 1977 indicated that greater structuring of specific learning experiences increases achievement in those specific areas. Diagnostic testing and mastery learning generally tended to produce higher achievement than conventional modes of instruction. A problem with these studies as with previous years is that the measured achievement is short term and specific to the experiences, while retention studies are too infrequent.

Continued research on the value of concrete experiences for college students indicates that these experiences provide meaningful and necessary connections to the abstractions of science.

The value of audio-tutorial methods and computer assisted instruction has been studied. Research reports mixed results on these modes of instruction over conventional modes when achievement is the dependent variable. Research suggests that these modes of instruction can be relatively successful if the subject matter is systematically and logically presented. This requires considerable work on the part of the instructor.

Evidence was presented which indicates that the complexity of a science concept can be important, in addition to the reading level in which the concept is described. This finding suggests that authors and teachers should be able to analyze the complexity of science concepts in determining their appropriateness for students, and be able to provide alternatives. We shall discuss this point further in Implications for Teachers.

The evidence, according to Eisenhardt's study, suggests that students begin to improve their attitude toward science only after some achievement has been attained. These results have important considerations for future studies of achievement and attitudes.

The research for 1977 generally indicates that logical sequencing of science activities improves content achievement, although studies by Douglass and Nevins provide evidence to the contrary, indicating that adult-imposed logical sequencing does not necessarily improve achievement. The entire issue of sequence as an instructional variable deserves more attention.

Taken as a whole, the 1977 research indicates that no one science curriculum is clearly superior to others in providing increased achievement, using present measurements of achievement. Yet, local situations appear to have a significant impact on the success of various science curricula. It is generally assumed that when there are significant differences in favor of a particular science program at a local site, differences are due to the uniqueness of that particular site, the motivation of the teachers, or the closer similarity between the achievement test and one of the programs over the other. This point will be discussed further.

Conclusions

What conclusions do we draw from achievement research? First, the overwhelming evidence from the past six years of achievement research shows that highly specific instruction produces highly specific achievement. This finding surprises no one; but what is surprising is that we continue to compare students' achievement from two different programs as though both programs were designed to produce the same effect in achievement. We still appear to believe that one program will produce more—rather than different—achievement, and we pass this belief on to teachers and administrators.

Second, the results of achievement research from 1972 to 1977 demonstrate the urgent need for systematic long-term assessment of achievement. Other reviewers have pointed out the need for a theoretical framework, a view we wholeheartedly endorse; but the presence of a theoretical framework alone is not enough. Our failure to gather cumulative data is very costly in terms of research dollars and impact.

Attitudes and Perceptions

Looking Back: 1972-1976

The number of attitude studies conducted over the past five years has remained relatively stable, generally less than 30 per year in science education. A brief consideration of the research in this area reveals that some persistent methodological problems plague researchers. Yet in spite of these problems, we applaud the efforts of all who have worked to quantify this qualitative behavior called attitude.

It appears that attitude research has attracted both creative pioneers, who work from a theoretical base, as well as those who want to try designing their own test. For this latter group most of the innovation seems to end with the design of instruments themselves, leaving the experimental design of the research studies very much the same: Does A produce better attitudes than B?

While most of the attitude studies are believed to have locally beneficial results (the favored program or method usually wins), reviewers of research complain that these studies add little to the development of a theoretical base or construct for attitudes.

Beyond the five annual ERIC reviews with their sections on attitudes, two major reviews of attitude research have taken place during the past five years; both of these reviews were described by Mallinson in 1975 and were conducted by Gardner and by Omerod and Duckworth.

From the reviews by Gardner and Omerod and Duckworth, which cover more than 700 studies, Mallinson reflects the authors' conclusion that "no one has really gotten a handle" on the issue of attitudes. We shall react to this conclusion later.

Against this background, the findings of attitude research in 1977 are presented next.

This Year: 1977

One main thrust of attitude research in 1977 dealt with the relationship between attitudes and instruction, with the implication that a particular curriculum or method led to an attitude change. We point this out simply because studies of the relationship between attitude and other variables such as achievement were generally less common, or in the case of cognitive development, were absent.

What did we find out about the relationship of attitude to instructional programs or methods? On the surface, it appears that nothing is new: approximately 20 studies showed that a specific curriculum or method produced a change in attitude and approximately 10 studies showed no attitudinal effect.

This surface appearance with its "cancellation effect" has often been interpreted to mean there are no universally beneficial approaches, strategies, programs and so forth. This view is probably based on the assumption that any group of individuals requires differences in treatment.

As we dug beneath the surface of these attitude studies, however, it occurred to us that there may be some critical or key elements, perhaps few in number, which are essential if we wish to encourage positive attitudes or if we need to prevent or treat some negative attitudes.

These key elements may exist to some degree in parts of several or many programs or methods. The essence of the elements may still elude us but that does not preclude their existence. To illustrate the point, let us look at some examples.

First, a much stronger argument can now be made for saying that achievement creates positive attitudes and probably not the reverse, as many of us have thought. Eisenhardt's data are massive in this regard (over 70,000 students) and cannot be ignored in future discussions.

Clues about the characteristics of classrooms where students have very positive attitudes (upper 25 percent) come from students' own descriptions of their 80 classrooms where instruction "moves at a slower pace; is more goal-directed, is less difficult, and where there is a better physical environment and less favoritism" (Manley). Additional support for specificity of performance objectives producing positive attitudes comes from Martin.

We do not ignore contrary evidence which shows no correlation between college students' attitudes and achievement (Butzow), that high school students' attitudes are not affected by the degree of teacher structure (Silbert), or that use of behavioral objectives does not influence attitudes (Hass).

Instead, we interpret these no-effect findings to mean that the particular instructional curricula, programs, strategies or methods used in those specific studies are indeed lacking in the key elements which _do_ produce differences in attitudes among students.*

If we are to search for some key elements which _do_ influence attitudes, then we must look closely at those programs or strategies which have the impact we seek, and attempt to isolate the key elements in them.

Rather than ignore negative data, we propose that researchers also try to abstract from no-effect studies the common features or non-key elements. In this manner we could progress in our search for the key elements to attitude changes.

There is a second thrust that seems to be suggested by the 1977 studies of attitudes. The line of reasoning goes something like this: (1) Science teachers perceive science as being more difficult than other school subjects, while school counselors do not; these same teachers see science students as being different (Wolff).... (2) Science teachers treat students in their classes differently, initiating more interactions with students for whom they have higher expectations (Sayavedra).... (3) Teachers and students do not have

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*We acknowledge that measurement errors could account for differences in results, but argue that if errors of measurement could be eliminated we might isolate the key elements all the more quickly, if they exist.

the same perceptions of their interactions (Heiting), or.... (4) of their science program (Oriedo), ... (5) Science teachers grade more severely than their non-science colleagues, and their grading is positively correlated with lower enrollments in subsequent or more advanced classes (Adkins).

As we attempt to look at these findings in relation to the discussion of Eisenhardt's findings that improved achievement precedes positive attitude change, we are led to suspect that science teachers may fulfill their own prophesy: science is harder and those who succeed are different, perhaps because they have been treated differently.

What about the students who recognize that they have not achieved or those who feel they have not achieved because they receive lower grades? According to Eisenhardt's findings, these students are likely to be the candidates for negative attitudes.

When we consider Manley's description of the 80 positive-attitude-producing classes, the descriptions sound like an environment in which students are achieving: instruction is slower paced, more goal-directed, less difficult, and there is less favoritism. Is this possibly a model for students of average ability?

We cannot describe our line of reasoning as a conclusion. However, we suggest that it would be possible to explore the validity of the reasoning in a longitudinal study where individuals worked as a team on various aspects of the problem and followed a population of students over time.

Conclusions

Now we return to our major concern. Attitude research is chaotic, we believe, because we have allowed it to become so. We continue to look for cause-effect relationships on a hit-or-miss basis; we should not complain about a little confusion.

Perhaps a medical analogy would be useful: when a microbiologist wants to develop a treatment for a new disease, the first step is to isolate a pure strain of the disease-causing organism. A later step is to systematically test all known antibiotics or possible combinations of chemicals to find a treatment or cure.

It appears that we have not attended to the first step very well: isolating the attitude we want. Do we generally agree that a positive attitude is circling "happy faces" in elementary school, signing up for science classes in high school, selecting science as a major at the university, or any of a number of other behavioral indicators? The fact that so many attitude tests exist (and continue to be developed) suggests that we have not isolated the behaviors we are after.

With regard to the latter step, we aren't doing very well either as evidenced by our hit-or-miss approach to research. It would make sense to get organized if we wish to find a way to treat "Bad Attitudes" or encourage good ones. Our hit-or-miss comparisons of attitudes, produced or not produced by programs A, B, C and so forth, have allowed many to conclude that any new program can win a popularity contest or that there is no reason to believe in universally beneficial treatments of attitudes.

We do not conclude that any single teaching method or curriculum will be found to create universally positive attitudes. But we do think that, as researchers, we ought to be able to determine whether there are some elements which influence attitudes positively or negatively, and then perhaps develop ways to promote positive attitudes on an individual basis, and ways to treat those negative attitudes which somehow develop.

To carry our medical analogy to its logical conclusion, our present efforts to find a curriculum or teaching strategy which promotes positive attitudes for entire classes of students might be compared to releasing a vaccine in a room full of people in the hope that everyone would acquire immunity.

What might be done to advance attitude research? In our view, a series of conferences on this subject and perhaps a specialized journal would accord the recognition due the problem and the pioneers in this area of research.

Instruction

Looking Back: 1972-1976

A review of the summaries of research in science education for previous years generally indicates that improvement in teachers' interactions with students can affect the students' achievement and attitudes. The extent to which a teacher is aware of the content and technique relevant to a learning experience appears to directly affect student achievement. Likewise the more positive the teacher's response to this awareness the greater will be the student achievement. Warm, supportive teacher behavior appears to help concept learning and reduce risk taking in inquiry modes of instruction.

These findings reinforce this view that a conscientious positive improvement in the teacher's performance can produce corresponding desirable results in students. Much of the research over the past five years might be described as "fine tuning:" it maps specific effects of teacher behaviors on specific groups of students.

This Year: 1977

The evidence from the year's research on instruction again indicates that the interaction of the teacher with the students influences student behavior. To cite one example, research in 1977 by Kadlecek demonstrated that open-minded teachers caused students to model open-minded thinking.

It appears that time spent on improving teaching performance in such areas as questioning strategies and logical content delivery has desirable results for students. The continued search for a best teaching behavior for all classrooms reappears here again. Continued research will profit greatly by identifying optimum teacher behavior for specific settings and specific student needs.

The evidence from 1977 indicates that curriculum innovations show mixed results. In light of the previous comments perhaps this is not surprising. The capability of the teacher generally affects the success of a curriculum. However, an interesting study by Orgren indicated that a mandated curriculum can affect high school science teachers' behaviors. This four-year study demonstrated lasting changed behavior in the direction of the design of a curriculum which emphasized student activity investigative behavior. It appears generally that curriculum designers who include special materials to educate teachers on the exact use and significance of materials and strategies will have a much better chance of attaining their objectives.

The studies by Howe and Mierzwa (1977) and by Wollman (1977) indicate that significant improvements in the ability of students to think more logically about science-related problems occur after the students have undergone relatively short-term instruction on specific tasks. Conversely, general experiences in activity oriented science did not improve the students' abilities to use specific science processes.

Other studies concluded that diagnostic testing and mastery retesting do improve student achievement. These results tend to reinforce the idea that specific skills can be learned best by students studying specific related tasks.

The research for 1977 overall indicated that mastery learning and diagnostic testing can improve student performance in science.

Evidence from 1977 research supports the importance of kinetic structure as defined by O. R. Anderson and the use of advance organizers as defined by Ausubel.

Overall the research of 1977 indicated that instruction which provided logically sequenced information or information which possesses high kinetic structure will improve learning. The importance of the research of Piaget in this regard is to assure the instructor that the content of the structure must be equal to the cognitive ability of the learner.

Additional research by Linn (1977) reported evidence on teacher structure. It was found that students who were given free choice in an enrichment program showed greater gains in logical/abstract reasonings when some direct instruction was combined with free choice. Perhaps these ideas hold the makings of an instructional model or paradigm of the future.

Research in 1977 on instruction pointed out that a high percent of oral instruction occurs in high school and college settings. This, of course, is not surprising. Additional research, however, shows clearly that oral instruction is definitely directed to students of high ability. An interesting point is that many teachers in these settings believe they are treating students equally.

Heiting (1976) demonstrated that teachers' perceptions of their interaction with students in science classrooms significantly differ from those of their students. Again these results indicate the importance of the awareness on the part of the teacher. The evidence for 1977 suggests that teachers are capable of recognizing and classifying their own interactions in the classroom if provided with proper training. Additional research also showed that teachers are capable of changing their behavior—at least temporarily, in the classroom.

Additional research for 1977 focused on individual instruction including computer assisted instruction, programmed instruction and audio-tutorial instruction. It is recognized that good individual instruction also involves taking account of the personality and aptitude of the learner.

In looking back over the research on instruction, we are reminded of a parallel in the energy problem facing our nation and the world. It is a complex problem. Various sources of energy are available for use and some forms are yet to be discovered. Which form should be used depends on local and national needs. People debate over which form is safest, most economical, and so forth. No one person can supply an answer nor does any single energy source suffice. Answers to the problem, however, are vital and demand ongoing study. Perhaps through careful collaboration and fact seeking, we can cooperate to find the satisfactory solutions for general and local needs.

Conclusions

As one examines the research over the past five years and present, the need for testing a theory of instruction becomes obvious. Such a theoretical framework is essential if future researchers are to make collective and comparative studies of instruction. We shall refer to this point in Implications for Researchers.

Research reveals that the teacher is important in affecting the outcome of the instruction with students. Such a statement is redundant at best, but it is important. It indicates that there is more to science instruction than simply "transferring information."

Teachers have been able, with proper instruction, to recognize deficiencies in their questioning behavior. These teachers have been able to make important improvements in this respect according to short-term measurements.

The research for 1977 generally supports the hypothesis that instructional information should be logically sequenced to maximize learning. Some research, however, indicated that sequencing was not important. It has been our observation that some textbooks, for example, may appear to be organized into chapters which progressively build on previous chapters. Yet, on closer examination, the actual linkage between chapters may be slight or non-existent. In fact teachers may use chapters from some texts in mixed orders or even omit chapters. Even within chapters there are often gaps in the logical sequencing of the subject matter of science. The structure of science is rather like a web of facts, concepts, conceptual schemes, and theories. Perhaps logical sequencing can only be accomplished for small parts of this web. Additional research of the problem of logical sequencing as it relates to instruction is warranted.

Implications for Teachers

What are the implications of this year's research for teachers? The primary implication is that student learning basically proceeds in the direction of the teacher's objectives. Obviously the formation of these objectives by the teacher is of paramount importance. If teachers wish students to use and understand the processes of science, they must have experiences which directly relate to these processes. If the teacher decides that a certain concept of science is important, then the teacher must plan for appropriate experiences. If a new curriculum is imposed on a teacher, and the teacher has a neutral or negative attitude, there is evidence that students will share the teacher's attitude. The evidence indicates that an open-minded teacher can promote open-mindedness in students.

Clearly then, some teacher behaviors or models can produce corresponding behaviors in students. This is not to say that a teacher must constantly dominate instruction. Rather, it implies that it is the teacher's responsibility to provide the desirable setting. Current research indicates that student-structured learning and teacher-structured learning are both needed.

The research in 1977 in science education also indicates that teachers' perceptions of the classroom and the students' perception of the classroom are often quite different. Evidence was also presented that students for whom teachers have high expectations receive considerably more teacher contact than students for whom low expectations are held. Thus it is the responsibility of the teacher to be aware of the potential for differences in perception or expectations and to act appropriately.

Evidence from 1977 research and prior years indicates that activities which contain logically connected links of information influence achievement. The success of these connections appears critical in teacher-imposed settings. The research also suggests that the complexity of a science concept can be a barrier to understanding the concept just as reading level can be. Teachers need to look beyond the reading level of written material to an examination of the concept itself in making decisions about appropriateness. However, teachers will probably need training in order to analyze the cognitive complexity of concepts or to know how to provide critical linkage between concepts. Thus, the implications for teachers also apply to teacher educators.

Implications for Researchers

The most serious problem facing the research profession in this last quarter of the twentieth century, in our view, is how to deal with the knowledge explosion that has been brought about by the trend toward multivariate research.

The introduction of more elegant statistical procedures, which are now commonplace, has given us more information for our research dollar and, at the same time, overwhelmed our traditional system for reviewing and synthesizing research results. Very simply, we are living (or researching) in a multivariate age while we are still trying to synthesize and communicate in a univariate language.

What is the evidence of this problem? To illustrate, we have identified 35 studies in Table 1. This includes all of the experimental studies in elementary science education conducted in 1977, as stored by ERIC. (Ex post facto studies and surveys have been excluded.)

In the third column from the left, readers will find the list of dependent—or outcome—variables reported by each author. About one-third of these studies have multiple outcomes. To save space, we have not listed the array of demographic variables which were also controlled in each study; instead we have simply used an asterisk (*) to indicate studies which controlled multiple demographic variables (as indicated by their ERIC abstracts). Over half of the studies have multiple demographic variables.

Only a moment's thought is needed to get a sense of the problem. Every study with multiple variables—dependent or independent—could be reported or synthesized within a group of studies focused on that one variable. The study by Crocker et al., for example, could be discussed, reviewed or synthesized under achievement, attitudes, locus-of-control, self-concept, task preference, and grade level (elementary) as well as several other demographic variables.

The complexity of the problem is only partially related to the number of repetitions that might be necessary. The other factor contributing to the problem is that multivariate research typically shows interactions among dependent variables. An example might be: Method A produces positive attitudes in all black male elementary students, negative attitudes in white males of upper elementary grades only, and neutral attitudes among all females of both racial groups, regardless of grade. Achievement patterns might differ from attitude patterns among these same subgroups. While it is quite easy to describe such interactions for a single study, synthesis of several studies is difficult.

Readers are accustomed to univariate communication: reporting, reviewing and synthesis. They expect to find some rather clear implications from traditional research categories like achievement or attitudes; and would be overwhelmed by a computer search that "opened the flood gates" with all of the studies which listed achievement as one of several descriptors.

It appears to us that other reviewers have faced this problem in research review and synthesis just as we have. We found no immediate or easy solution, but suggest there are many parallels between this problem and other similar problems faced in science.

What is the consequence of not attending to the problem—of not "getting our house in order"? When we reflect on the amount of information that will be lost, the thought of not keeping track of the results reminds us of the reaction of many adolescents faced with Piaget's combinatorial task with five colorless liquids. When asked to find the combination of chemicals that will yield a yellow color, students who are unaccustomed to combinatorial logic are overwhelmed by the possibilities and lose track of the number of combinations they have mixed.

The overriding implication for research is that we must face the fact that we have entered a multivariate research age, that we are still attempting to communicate in a univariate language, and now we must reevaluate our priorities and processes of communication, if we expect to make use of or keep up with the new knowledge that is being produced by our research technology.

There is a second problem which has concerned researchers for much longer than the one we have just described: it is the general lack of theory among ~~many~~ research studies. More recently, there is a related concern about the decline in basic or theoretical research itself.

It may appear to be a tradition among research reviewers to express concern about the lack of theoretical foundations, models or rationales among the studies they review (Novak, 1972; Rowe and DeTure, 1973; Herron et al., 1974; Mallinson, 1975; Renner et al., 1976). But their concern is genuine, not simply a tradition. How is it that a profession which rates "application of research findings" among its highest priorities can at the same time consistently dispair over theoretical matters? There may be a clue in the following event.

While NARST members were attending the 1977 annual meeting in Cincinnati, Fred N. Kerlinger (1977) spoke of his concern about the decline in basic research, and talked about the deleterious consequences of the pragmatic-practical notion that research should have "pay-off" and be "relevant" to classrooms, as he delivered his presidential address at the AERA annual meeting in New York City.

The pragmatic-practical view that research should pay off and be relevant is a major obstacle to research influencing educational practice in the long run, Kerlinger argued, as he cited strong empirical evidence which showed clearly and unmistakenly that basic research has been much more important than applied research in its ultimate impact and influence on modern applied clinical (medical) practice. In other words, if you want to increase the influence of research on medical practice, invest in basic research—not applied research. Can we assume there is a parallel in educational practice?

Perhaps in our eagerness to have research be more applicable to science classrooms, we have fostered more applied research than basic research by encouraging our graduate students to search for immediate solutions to educational problems. A quick glance at the bibliography of the present review may suggest a greater popularity of applied research.

Likewise, through federal funding requirements and selective criteria, we appear to foster a climate where applied research predominates and where basic research, aimed simply at understanding phenomena, is a luxury that must be supported by private foundations or out of one's own pocket.

If in fact there is a serious decline in basic, "pure," or theoretical research, as Kerlinger has suggested, the push-pull toward applied research is certainly understandable in the context of the economic pressures of the 1970s for accountability by the Congress, government funding agencies and local school districts.

But an alleged decline in basic research cannot fully explain the apparent lack of theoretical bases or frameworks over the past five years of research, for even applied research can have a theoretical basis. We must ask ourselves why this problem persists. How does the training of graduate students perpetuate this weakness in research that we ourselves have recognized? A brief review of several textbooks on research methods reveals that study materials on the role of theory in research are available. What needs to change? What incentives are needed? What standards of excellence shall we enforce? These and similar questions deserve attention before another year goes by and another annual review of research goes to press.

What other problems need to be addressed by researchers? Several challenges were described earlier in CONCLUSIONS. To repeat, there are critical needs for longitudinal studies, integration of efforts through team approaches to problems, and systematic study within theoretical frameworks. An example based on these three critical needs was cited in an earlier section entitled Cognitive Development (Phylogenetic model). There may also be a need for new, more specialized research journals directed, for example, toward attitude research or cognitive development or for conferences called specifically to focus on these same or similarly narrow areas of research.

We have talked about the problems that we face as researchers or at least as they appear to us. But that does not mean we view the science education research enterprise negatively or think it is in trouble. On the whole, we were impressed by what we read and found many fine examples of excellence in research. And while there are clearly areas which need to grow, there are also ample signs of growth within the profession. In our view, 1977 was a good year!

TABLE 1: EFFECT OF MULTIVARIATE STUDIES ON RESEARCH REVIEW AND SYNTHESIS

Includes all (35) experimental studies about science education in elementary schools in 1977

Author	Independent Variable*	Dependent Variables	Statistical Result
Studies Where Achievement is One Outcome:			
Carroll	*Biology Concepts	Achievement	Mixed
Cottrill	Direct/Indirect Approach	Achievement	NSD
Crocker et al.*	Teacher Structure	Achievement Attitudes Locus of Control Self-Concept Task Preference	Mixed
Delaini	Use of Docents	Achievement	SD
Dickson	Teacher Training in ESS/SCIS	Achievement Attitudes	NSD
Ferraro et al.*	Content Structure	Achievement	SD
Glasser	*LAP Curriculum	Achievement	Mixed
Hoover	SCIS/EIS,	Achievement	NSD
McKee	*Teacher Structure	Achievement Problem Solving Cognitive Develop. Motivation/ Attitude Confidence	
McLaughlin	*NASA-SSEP	Achievement	SD
Nevins	Learning Sequence	Achievement	NSD
Schilling	*Lessons/Individual/ Grouping	Achievement	Mixed
Sprague	*Student Verbalization	Achievement	Mixed
Swanson	Individual SAPA	Achievement Attitudes	Mixed
Vanek & Montean	*ESS/Laidlaw	Achievement Attitudes Cognitive Develop.	NSD
Wilson & Koran	Hypothesis Training	Achievement	SD
Wuhl	Individual vs. Group Field Depend./Independ.	Achievement	Mixed

*Studies have multiple demographic variables (eg., age, gender, I.Q.) controlled but unlisted to save space; only treatment/independent variable is listed.

TABLE 1 (continued)

Author	Independent Variable*	Dependent Variables	Statistical Result
Studies Where Attitude is One Outcome:			
Abhyankar	*Teacher Structure	Attitudes	Mixed
Bath	*Open/Closed Classroom	Attitude Self-concept Persistence	Mixed
Crocker et al.	*Teacher Structure	Attitudes Achievement Locus of Control Self-concept Task Preference	Mixed
Dickson	Teacher Training in ESS/SCIS	Attitudes Achievement	NSD
Hofman	SCIS/Textbook	Attitudes	NSD
Jaus	Active Science	Attitudes	SD
McKee	*Teacher Structure	Attitude/ Motivation Achievement Problem solving/ Cognitive Develop. Confidence	SD
Shann	USMES	Affective/ Cognitive	Mixed
Swanson	Individual SAPA	Attitudes Achievement	Mixed
Vanek & Montean	*ESS/Laidlaw	Attitudes Achievement Cognitive Develop.	NSD
Studies with Variables Other Than Achievement and Attitudes:			
Allen	Teacher Structure	Disruptive Behavior	SD
Deyermond	*ESS units	Cognitive Development	SD
Edwards	Token Reinforcement	Productivity	SD
Esler et al.	*SCIS	Reading Readiness I.Q.	SD
Hill	Teacher Structure	Creativity Self-perception	NSD

TABLE 1 (continued)

Author	Independent Variable*	Dependent Variables	Statistical Review
Iatridis	Curriculum	Curiosity	SD
Johnson	Cognitive Conflict	Cognitive Develop.	SD
Linn et al.	Free Choice/ Direction	Cognitive Develop.	SD
Mansfield	*ESS	Verbal Skills	SD
Penick & Shymansky	*Ability/Teacher Behavior	Student Behavior	Mixed
Quinn & Kessler	Inquiry	Language Development	SD
Swift	*BSCS/ESSP	Listening Skills	Mixed

SUM EFFECT OF OVERLAP AMONG 35 STUDIES ABOVE WHEN ONLY DEPENDENT VARIABLE IS REVIEWED

Achievement	=	17 studies	
Attitude	=	10 studies	(5 new; 5 repeat)
Cognitive Development	=	7 studies	(4 new; 3 repeat)
Self-Concept	=	6 studies	(1 new; 5 repeat)
One/Two-of-a-Kind	=	10 studies	
Total Original (35)	=	50 studies to be reviewed/ synthesized	

*STUDIES IN THIS SECTION ARE 10 PERCENT OF TOTAL NUMBER TO BE REVIEWED.

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Za'Rour, George I. "Identity Versus Equivalence in Weight Conservation." Science Education, 61(4):541-547, October-December, 1977.

APPENDIX A: OTHER PAPERS

Evaluation

In the area of evaluation, a number of important contributions to research were made in 1977. In this section, research focused primarily on the development of an evaluation process or instrument, as opposed to an emphasis on evaluated outcomes, and included papers which dealt with teaching and attitudes performance (Capie and Butts, 1977; Colbert, 1977; Jones, 1977; Munby, 1977; Moore, 1977; Okey, 1977; Yeany and Capie, 1977); federal programs and funding (Vandette, 1977; Welch, 1976); science processes (Torrence, 1976); cognitive development (Ruud, 1977); student interest and achievement (Carlson, 1977; Ferguson, 1977; Hofstein et al., 1977c; Lawrenz, 1977) and curriculum (Salmon-Cox, 1967).

Theoretical Models and Constructs

Reviewers of research have often commented on the lack of theoretical substance to studies. Occasionally, however, a few researchers focus their attention on the creation of a theoretical model or construct. Such papers have an important place in research, and in 1977 the following topics were considered: learning (Good, 1977; Lowell, 1977; Mallach, 1977; Treagust and Lunetta, 1977), science teaching (Lorenz, 1977; Sweeney, 1977), scientific literacy (Gabel, 1977a; Gibbons, 1977), and the terms "involvement" (Butzow and Williams, 1977), "creativity" (Van Norren, 1976), "discovery and inquiry" (Kornbau, 1977), "view of science" (Munby, et al., 1977).

History

Research in the area of history has always been rare (Mallinson, 1975 review) but 1977 is exceptional. Two studies fall into this category. Wood (1977) studied the relationship between social factors and the development of high school chemistry curricula between 1850 and 1939. (Readers are referred to studies reported under SURVEYS of programs for research related to this topic; see Streitberger, 1977 and others.) Herron's study (1977) reports data on declining enrollments in U.S. school science classes, based on selected years between 1889 and 1974.

Curriculum

Finally, there were research papers on the development and evaluation of curriculum. Several papers generally looked analytically at the development of a specific course of instruction often with an emphasis on its theoretical framework (Clipsham, 1977; Finegold, 1977; Novak, 1977; Searles, 1977).

Readers will find Welch and Willson's paper (1977) on the evaluation of alternative systems for implementing curriculum change is of special interest. Additionally, Bredderman's (1977) survey and evaluation of elementary school science program adoption is of interest.

APPENDIX B: INTERNATIONAL REFERENCES OF RESEARCH IN SCIENCE EDUCATION

(Also listed within Bibliography)

Australia

Blake, Anthony John Dyson (1976)

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Canada

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Kagan, Martin H. and Pinchas Tamir (1977)

Kenya

Igambi, Levi Libese (1977)

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Balogun, Taju Adedokun (1977)

Onyike, Innocent Ozurumba (1977)

Puerto Rico

Ortiz Plata, Georgina (1977)

Scotland

Wilson, James M. (1977)

Thailand

Raven, Ronald J. and Kingfa Thongprasert (1977)

Subhadhira, Suphasinee (1977)

Terapigiltra, Somsuke (1977)

Tongsookdee, Mungkorn (1977)

U.S.S.R.

Buravikhin, V. A. (1977)

Dobrzhitskii, B. (1977)

Gloriozov, P. and V. Ryss (1977)

Goloborod'ko, M. and F. Sokolova (1977)

Miagkova, A. (1977)

Razumovskii, V.; V. Usanov; and L. Khizhniakova (1977)

Volkov, K. N. (1977)

Combined

Karplus, Robert et al. (1977)

APPENDIX C

ABSTRACTS PERTAINING TO SCIENCE EDUCATION FROM U.S.S.R.

SOVIET EDUCATION
prepared by Janice Cruz

Volkov, K. N. "Certain Problems in the Development of Pedagogical Science Under the Tenth Five-Year Plan." Soviet Education, 19(3):16-34, January, 1977.

Purpose: To find out about the origin of research problems, factors upon which formulation of research problems depend, the way they reflect demands of practice that urgently require elaboration of the pressing problems of education and upbringing.

Method: Pedagogical science department of USSR Ministry of Education studied this question at scientific research institutes of pedagogy of the ministries of education. There are 15 of these scientific institutions with staff personnel of 1,534.

Results Drawn from Data: 77 percent of scientific problems under study are advanced by institutes themselves. A greater share of topics are proposed by rank-and-file research associates. Because of palnning from "below," plans of institutes are often overloaded with relatively unimportant problems that are repeated from year to year, duplicate the problems studied at other institutions, and are sometimes remote from the real needs of a republic's system of public education.

Question Which Arises: How can disparity between practical needs and pedagogical science be overcome?

The article indicates several possible ways to deal with this problem. Most of the article is devoted to describing the "plan-order" practice of USSR Ministry of Education for dealing with research priorities and some of the areas where research is especially needed.

Buravikhin, V. A. "Science and Education." Soviet Education, 19(3):86-96, January, 1977.

Science and technology are advancing at a very great pace. The problem has arisen in education in the field because even though research has shown ways to solve problems, results of this research have ~~not~~ filtered down to the schools. Schools need to be able to incorporate these results in their practices.

The article also discusses some of the research resources available and some of the ways to use these resources to help alleviate the problem.

Miagkova, A. "Studying the Basics of the Science of Living Nature." Soviet Education, 19(8):5-23, June, 1977.

This article discusses some of the new scientific discoveries in the field of biology, how these have been incorporated into the curriculum, the quality of textbooks, teachers, printed materials, and instructional materials. It also covers what pupils know, what they have difficulty learning, and the results of some testing of pupils' knowledge. This information is used to indicate ways the curriculum should be changed or improved to help pupils learn more effectively.

Razumovskii, V.; V. Usanov; and L. Khizhniakova. "Ways to Make Physics Teaching More Effective." Soviet Education, 19(8): 24-32, June, 1977.

This article discusses five specific areas relating to the teaching of physics: (1) the attainments of the new physics curriculum, (2) the ways the new physics curriculum is not being fully realized, (3) the shortcomings of students according to test results, (4) the ways to overcome student shortcomings, and (5) the ways to use materials and examinations most effectively.

Gloriozov, P. and V. Ryss. "The New Chemistry Curriculum and the Task of the School." Soviet Education, 19(8):33-46, June, 1977.

This article is very much like the Razumovskii article except that chemistry is the curricular area discussed. Gloriozov describes the new chemistry curriculum, the results of the work under the new curriculum in grades seven, eight, nine and ten, and the ways the teaching of chemistry in secondary schools could be improved.

Goloborod'ko, M. and F. Sokolova. "Bringing Out Interdisciplinary Relationships in the Teaching of Physics and Chemistry." Soviet Education, 19(8):47-51, June, 1977.

Pointed out in this article are the ways interdisciplinary relationships in physics and chemistry can be brought out under the new curriculum and the roles of teachers and principals in bringing this about.

Dobrzhitskii, B. "On the New Fourth-Grade Nature Studies Course." Soviet Education, 19(8):52-58, June, 1977.

Described in this article are the methods proposed by teaching methods specialists for teaching nature studies courses, the results of tests given to children taught by these methods, a summarization of the shortcomings of pupils' knowledge based on test results, the factors explaining the shortcomings, and the ways of improving teaching methods to overcome these shortcomings.

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