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ABSTRACT

Abstracts of most of the papers, symposia, and poster sessions presented at the 59th conference of the National Association for Research in Science Teaching (NARST) are provided. Subject areas addressed include: instructional practices in secondary school science; research on computers in science learning; teacher's professional knowledge and conceptual changes in students; factors influencing student science achievement; contexts of science learning; research on classroom and school environment; student attitudes; secondary science teacher education; computer applications; assessments (of test material); the Second International Science Study; process-product studies in middle school science classes; logical thinking in science; alternatives in science education; developments in style and purpose of research on the learning of science; science process skills; computer oriented programs; undergraduate science education; administration of science programs (a policy perspective); meta-analysis of research on the effectiveness of "new" science curricula; cognitive development; student concepts in science; teachers' perceptions and interests; science and writing (linking research with classroom models); issues related to sex differences; science textbooks; preservice science teacher education; science education in non-traditional settings; science teacher education program evaluation; students' misconceptions; college science teaching; systematic representation of biology knowledge; science curriculum implementation; science careers; technology in science education; goals and issues; and other areas. (JN)

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ABSTRACTS OF PRESENTED PAPERS

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San Francisco, California

March 28-31, 1986

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PREFACE

The SMEAC Information Reference Center for Science, Mathematics and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the 59th annual conference in San Francisco, California, March 28-31, 1986.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts. Special recognition should be given to Dr. James Barufaldi and the NARST Program Committee who obtained the abstracts and organized the program.

Many of the papers will be published in journals or made available through the ERIC system. These will be announced through Resources in Education, Current Index to Journals in Education, and other publications of the ERIC system.

Patricia E. Blosser
Stanley L. Helgeson
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A STUDY OF SECONDARY SCHOOL SCIENCE TEACHING PRACTICES

James J. Gallagher

This paper is an overview and summary of a two-year study of the nature of secondary science teaching and the forces which shape it. Special emphasis has been given to developing rich descriptions of teaching practices and interactions among teachers, administrators, and external agents.

The method used was ethnographic which allowed (a) the acquisition of descriptive data on science teaching practices and (b) examination of factors which have shaped them. Data include written field notes of observations of over 700 class periods in five middle and high schools in two districts. Field notes also have been prepared on numerous informal conversations and formal interviews with teachers and administrators in these two districts.

A set of assertions regarding these two major points has been formulated. These assertions include statements about the nature and quality of instruction in secondary school science, the interactions between teachers and students, interactions among teachers and between teachers and administrators, teachers' role perceptions, the character of the implemented curriculum and other pertinent issues. In each case, there has been an attempt to enrich our descriptions of observable events and to seek data about the forces which shaped those events.

This paper also includes descriptions of methods used, and it encapsulates a wide array of findings which have emerged from the extensive data base acquired during the study. Further, implications of this research for teacher educators, school officials, and other researchers are discussed. More focused analyses of specific issues arising from the study are included in the five additional papers comprising the symposium.

TARGET STUDENTS IN THE SCIENCE CLASSROOM: A CASE STUDY

David A. Cline

This is a report of a case study of a physical science teacher and his methods of pacing instruction in one ninth grade class. When conducting the lesson, the teacher relied upon a limited number of students for answers to questions, especially questions which served as transition points, from one

topic or point to the next. In the literature, these students on which the teacher relies for pivotal actions are called the steering group or target students. This report describes one teacher's use of target students and examines possible reasons for the patterns that the teacher used in calling upon students. Through a qualitative analysis, the teacher was found to be calling on a limited number of students in the class. Of those students there were two subgroups: those receiving basic questions, and those students who received questions requiring a higher level of sophistication of thinking.

This report also examines three other findings of the study: (1) the teacher's perceptions of the target students in the science class, (2) possible reasons for certain students being target students, and (3) types of questions that students received. The teacher's perceptions provided an interesting paradox. Although the teacher was observed on several occasions calling on a very few students in a class period, he routinely denied calling on these students more than others. When the teacher was interviewed about certain students who had been identified as targets, there appeared to be few links such as prior acquaintance that would cause them to receive more attention than others. Several of the target students were not included on the teacher's list of the most able students. As with the questions that the students were asked, it seemed that a few of the target students received questions of a higher level of sophistication. The average student in the class, when asked a question, was asked a factual recall question, but target students were asked application, synthesis, or analysis questions. The teacher claimed to be oblivious to this difference.

This article lends support to the work of Gallagher and Tobin done in the United States and Australia on target students. The implications for science teaching are important. First of all, science teachers who depend on target students to answer the bulk of the questions during a lab session are reinforcing the myth/truth that science tends to be an elitist subject in which each further advanced class of study skims the top students from the previous class until there are but a select few that remain.

The second implication is that teachers who rely on such a strategy for instruction are in effect managing time, but not teaching. These teachers provide tasks which are worked on by the class and then reviewed by the few. Teachers with target students do not acquire information about the achievement of the entire class, but only about the accomplishment of the few target students.

The final section of this report presents the views of the observed teacher. When the teacher was asked to describe his questioning patterns, his perception was that he was being equitable to all students. When the teacher was shown transcripts and frequency diagrams representing questioning patterns to target students his reaction was that the information was not representative of a typical class even though data had been collected tri-weekly during a period lasting sixteen weeks. The report of this study ends with an analysis of the behavior of the teacher from his point of view which contrasts observational data and perceptions of the teacher.

THE DECONTEXTUALIZATION OF MIDDLE SCHOOL SCIENCE:
AN ETHNOGRAPHIC STUDY

Armando Contreras

Although it has been said that no human act is decontextualized, in this ethnographic study it has been shown that secondary school science is highly out of context. The researcher conducted intensive classroom observations in a large ethnically-diverse city school for about a year. Three science teachers were systematically observed during their actual teaching for one hour a week. Formal interviews, together with informal conversations with teachers, were carefully recorded and analyzed. Ethnographic vignettes describe several instances of actual classroom teaching that clearly indicate that not only the science content (as presented in the textbook and in classes) is decontextualized but also that the process of doing science itself is often out of context. Teachers commonly deal with concepts and theories in a way that no link exists between what is taught in the classroom and the student's experiential world exists. For example, teachers often teach the concept of ice melting point in the context of the classroom without making reference to what is going on in the world outside of school. This discrepancy is highly visible when an experiment of this type is conducted, for example, on a warm and sunny day in spring when plenty of snow is melting in the school's surroundings. Or students may be taken to camp to perform activities far away from their own cultural environment. The rationale of having these activities is rarely made explicit to students.

In addition, teachers often refer to the processes of doing science without linking these processes to the scientific content embedded in the curriculum and to the student's daily life.

MIDDLE SCHOOL SCIENCE TEACHERS' PERCEPTIONS OF THEIR INSTRUCTIONAL ROLES

Okhee Lee

The general questions addressed in this study were (1) how do middle school science teachers perceive their instructional roles and (2) how do they go about improving their instructional effectiveness? The nature of these questions suggested an ethnographic approach which allowed description of behavior and investigation of what lay behind observed actions. The data sources included observation of middle school science classrooms, interviews and informal conversations with teachers, and a series of three workshops with a group of sixth grade science teachers in a middle school in which the researchers worked as participant-observers.

We observed that most middle school science teachers perceive themselves to be subject matter specialists and believe that their primary role is to present information and organize learning activities. However, they do not view their roles as including diagnosis and remediation of students, and leave the responsibility for learning the subject matter almost entirely to the students. The teachers' failure to diagnose and remediate students' difficulties in learning the subject matter was revealed through the ineffective use of (a) seatwork, (b) homework, (c) questioning students to check understanding, and (d) lack of feedback to students' responses. As organizers and presentors of information, we observed general characteristics of (a) poor organization and planning, (b) narrow and routinized teaching strategies, (c) absence of advance organizers and summaries, and (d) inattention to instructional objectives.

The reasons for these situations appeared to be lack of communication about teaching among teachers, teachers' over-rating of their own teaching competence, allocation of too little time for planning and preparation for instruction, and teacher autonomy.

The consequences of the situations were limited preparation for teaching, a narrow repertoire of teaching activities used routinely, use of time during seatwork and films by teachers for clerical work, curriculum and teaching methods adapted to student preferences, decrease in cognitive demand placed on students, heavy emphasis on vocabulary development, over-reliance on text books, and the emergence of highly motivated and high achieving target students who dominated science classes. From the experience of having workshops with the teachers, we noted that teachers enjoyed talking about teaching with others and improved their teaching practice through this sharing of ideas. This suggests the importance of teachers' interaction with other teachers, administrators, and researchers as a vehicle for developing a sense of professionalism as well as improved teaching effectiveness.

HIGH SCHOOL SCIENCE TEACHERS' ROLE CONCEPTIONS AS REFLECTED IN THEIR DAILY CLASSROOM PRACTICES AND DISCUSSIONS

Ribhi Abu Isneineh

This paper attempts to discover and describe the salient common factors constituting four high school science teachers' role conceptions. In a year-long ethnographic study, two researchers worked as participant-observers in various science classroom settings at an urban high school. Teachers in charge of these classrooms were interviewed on issues related to their classroom practices in general and their role conceptions in particular. As they interpreted observations and other data sources, the researchers took a symbolic, interactionist view. Assertions regarding teachers' role conceptions were made. Maintaining a sense of groupness in their classes through planning and organization of learning activities, presenting information through text assignments supplemented by copied materials, bargaining with students for high enrollments in science courses, and minimal disciplinary problems were the three major elements reported. Implications of these teachers' practices were highlighted and specific implications for teacher education were discussed. Contrary to curriculum designers' expectations, high school science teachers often lowered cognitive demands on their students. Also, they tended to avoid involvement with students' problems in learning subject matter content. The paper offers suggestions regarding possible factors contributing to high school science teachers' role conceptions such as (1) their role models, (2) educational background, (3) socialization by peers, and (4) job protectionism.

RESEARCH ON COMPUTERS IN SCIENCE LEARNING BEYOND
FRENCH LICK SPRINGS

Patricia E. Simmons
John S. Krajcik
Vincent N. Lunetta
F. Gerald Dillashaw

Robert D. Sherwood
Camille Wainwright
Eugene D. Gennaro
Carl F. Berger

Although research in Computer Assisted Instruction (CAI) currently lacks a well-developed literature and experimental foundation, the number of papers relating to CAI at the 1985 NARST convention at French Lick Springs increased substantially over those presented at the 1984 meeting. This symposium will begin with a general critique of those papers. The general critique will point out that conclusions drawn in the CAI papers were excessively broad, given the limitations in experimental treatments, in the software, and in the criterion measures. Too many generalizations about the effects of instructional software have been made after studying software that was inadequately documented, narrow in scope, and of less than optimal quality. Furthermore, the learning environments in which the instruction was embedded was often neither controlled nor described with precision.

Subsequently, presenters of selected 1985 papers will critique their own individual papers focusing upon important implications for research on CAI in the future. The final phase of the symposium will be a discussion of research implications drawn from the critique, the symposium presentations, and the comments of reactors.

DEFINING AND OBSERVING INSTRUCTIONAL
STRATEGIES FOR CONCEPTUAL CHANGE TEACHINGTheron Blakeslee
Charles W. Anderson

Three categories of effective instructional strategies for conceptual change teaching are synthesized from a small body of previous research. These strategies include presenting information, using scientific phenomena, and questioning. Strategies for presenting information include contrasting students' naive conceptions with scientific conceptions and emphasizing goal conceptions. Using scientific phenomena includes the use of everyday and discrepant events. Questioning strategies include asking for explanations, applications of scientific conceptions to various phenomena, probing for clarification or amplification of explanations, and asking students to make predictions about phenomena.

A classroom observation system incorporating coded information about teaching strategies and lesson content, detailed descriptions of actual instruction, and analyses of information sources and written assignments is described in detail.

Analyses of classroom observations include descriptions of the extent to which teachers use the identified strategies, process-outcome analyses relating the use of teaching strategies to student achievement, and process-process analyses relating experimental treatments (workshops, materials, workshop plus materials) to the use of conceptual change teaching strategies. Results of the descriptive analyses are presented.

TEACHERS' UNDERSTANDING OF STUDENTS' SCIENTIFIC
THINKING: ITS INFLUENCE ON PLANNING AND TEACHING

Robert Hollon
Charles W. Anderson

The influence of knowledge of students' scientific thinking on teachers' planning and teaching practices was investigated in middle school life science classrooms.

Thirteen experienced seventh grade science teachers were observed as they taught units about photosynthesis, cellular respiration, and matter cycling. The teachers were randomly assigned to three treatment groups: Group A received training workshops which provided them with general information about the nature of students' scientific thinking and misconceptions interfering with learning; Group B received teaching materials designed to explicitly contrast students' misconceptions about photosynthesis and cellular respiration with scientifically acceptable theories; Group C received both training workshops and materials.

Detailed descriptions of instruction and student pre- and posttest data were collected in each classroom. Interviews designed to assess each teacher's orientation toward teaching and learning of science, knowledge of teaching strategies designed to overcome students' misconceptions were administered before the study and after each unit was completed.

Analysis of presently available data suggests that the teachers possessed a wide range of content knowledge and approached the teaching of science from a variety of perspectives, but had little knowledge of students' patterns of scientific thinking. Most were unaware of the existence of misconceptions about photosynthesis, cellular respiration, and matter cycling held by their students.

Knowledge of students' scientific thinking is an important variable which may act to limit teachers' ability to teach science effectively. Teachers who do possess knowledge of students' misconceptions develop this knowledge mostly on their own. Present pre-service and professional development programs are not providing teachers with essential information about the nature of their students' patterns of scientific thinking.

ALTERNATIVE STUDENT CONCEPTIONS OF MATTER CYCLING IN ECOSYSTEMS

Edward L. Smith
Charles W. Anderson

A large body of research with science students across a variety of topics has documented the existence of conceptions that differ in fundamental ways from those taught in science courses and the tendency of these conceptions to persist despite instruction on the scientific alternatives. Cognitive theory and empirical research on science teaching and learning have elucidated how the interpretive role of naive conceptions helps explain this problem. Further, recent research indicates that knowledge of common student naive conceptions and strategies for addressing them can enable teachers and material developers to be much more effective in helping students understand scientific theory.

The purpose of the research reported here was to develop the necessary knowledge base on student naive conceptions of matter cycling in ecosystems in a form useful for both curriculum development and classroom teaching.

An initial pool of items was developed including prediction and explanation of relevant everyday phenomena. Comparisons of student and expert answers were used to define a set of contrasts between student and expert knowledge. Both pre- and post-instruction responses are used in order to identify contrasts which represent critical barriers to learning.

Schemes were developed for descriptive coding of student responses and relating student response features to scores reflecting the amount of evidence supporting the inference of student belief in a particular alternative on a given contrast. The sample was 303 seventh graders in 17 classes of eight different teachers. Data for four teachers (110 students) represent pretest results while that for the other four teachers (193 students) represent posttest results.

The overarching idea for this topic is that the matter making up organisms originated in the environment as simpler materials and eventually returns in that form, available for recycling. Rather than thinking of the biological processes as involving the same matter undergoing a series of changes, students think of these processes as events involving fundamentally distinct entities. While some materials are recognized as being used or produced, they are often viewed as being created or destroyed rather than being converted into other materials. Even when students are aware of important ecological relationships such as the indirect dependency of organisms on all other organisms in food chains for food, these may be viewed as a sequence of related events rather than as the same matter undergoing a series of transformations. This kind of contrast is reflected in the naive and scientific conceptions of specific portions of the matter cycle.

Consistent with the large body of student conceptions research, this study implies that modifications in teaching practice are necessary if the majority of students are to come to understand the scientific conception of matter cycling in ecosystems. Teachers and curriculum developers acquiring knowledge of the contrasts described above is an important step in the improvement process.

IMPROVING COLLEGE SCIENCE TEACHING: PROBLEMS OF CONCEPTUAL CHANGE AND INSTRUCTORS' KNOWLEDGE

Charles W. Anderson

This paper describes a combined research and development project with two purposes. The first purpose was to develop effective techniques and materials for teaching for conceptual change in college non-majors' physical and biological science courses. The second purpose was to develop effective ways of communicating to instructors about those techniques and materials.

The project focused on five topics in the biological and physical sciences: respiration and photosynthesis, evolution by natural selection, ecology, light, and heat and temperature. Each topic was taught in one of two non-majors' courses taught at Michigan State University. One course focused on biological science, the other on physical science. The students in both courses were primarily juniors and seniors majoring in elementary education.

The project involved three types of activities. First, tests and clinical interviews were developed which served as the basis for the development of detailed descriptions of student conceptions of each topic. This portion of the project revealed that, for each topic, there were major conceptual problems that were not being adequately addressed by the instructional methods then in use. Second, new teaching techniques and materials were developed for each topic, field tested, and revised in the light of experience and student posttest results. Third, teacher's guides were developed for each unit. Each teacher's guide included (a) an introductory essay, (b) a diagnostic test designed to reveal student misconceptions, (c) student handouts and masters for overhead transparencies, (d) laboratory activities, and (e) problem sets.

Results of posttests administered during each term of the project indicated that student understanding of the scientific conceptions improved appreciably over the course of the project. Thus, the first of the project's purposes was achieved.

We were less successful in achieving the second purpose of the project. The instructors (whose degrees were in science rather than science education) used the materials from the project with some success. However, they showed

little interest in the teacher's guides or in the research base for the materials. In the main, they continued to act as if successful teaching depends on organized study and theory building only in the realm of science, not in the realm of pedagogy.

The results of this study indicated that there was plenty of room for improvement in the teaching of non-majors' science courses at Michigan State University, and that practical techniques could be developed that markedly improved teaching effectiveness. It is probable that these results can be generalized to many other universities.

However, the teaching habits and belief systems of instructors who teach such courses may be a barrier to improvement. If instructors pursue organized programs of study and knowledge acquisition only in the realm of science, then they are likely to be relatively uninterested in improvements that are essentially psychological or pedagogical in nature.

AN ANALYSIS OF FACTORS USED TO PREDICT SUCCESS IN
THE NEW YORK STATE REGENTS BIOLOGY COURSE

Anthony Galitsis
Harold Friend

The purpose of this investigation was to determine which data can be used best to predict success in New York State Regents-credit biology courses. The first part of the study investigated the correlation between Biology Regents Examination scores and Ninth Grade Algebra Regents Examination scores. The second part examined the possibility that more than one factor must be used to predict biology achievement. Ninth year grade point average, ninth grade reading scores, and Ninth Grade Algebra Regents Examination scores were correlated with Tenth Grade Biology Regents Examination scores.

The students involved in the first part of the present study were selected from two New York City public high schools located in Queens. "High School One" consists of students from a lower middle-class socio-economic background with a population mix of 55 percent white, 27 percent Hispanic, 17 percent black, and 1 percent Asian. "High School Two" consists of students from a middle socio-economic background with similar percentages of white and black students, but with 13 percent Hispanic and 15 percent Asian.

The permanent records of all eleventh graders who were part of the sample were checked in order to compare each student's score on the Ninth Grade Algebra Regents Examination with the score on the Biology Regents Examination.

There appeared to be a relationship between the Ninth Grade Algebra Regents Examination scores and the Biology Regents Examination scores, but the relation was of limited value.

In order to obtain a more accurate predictive tool to enable high school personnel to successfully place students into biology classes, the second part of the study investigated the possibility that achievement on the Biology Regents Examination may be predicted from a student's Ninth Grade Algebra Regents Examination score, ninth year reading score, and ninth year grade point average.

Of the 200 students from "High School One" and 243 students from "High School Two," 189 from the former and 225 from the latter composed the sample for the investigation. The 29 students omitted had not taken the 1982 reading test, which was essential to the correlation. Since both schools are part of the same system and the sample was administered the same standardized examinations, the data from the schools were merged. An important finding is that the ninth year reading score correlate was the lowest recorded. One must question the validity of using reading achievement tests as the sole criterion for student placement.

A multi-regression equation using grade point average, reading score, and Ninth Grade Algebra Regents Examination score appears to be a helpful tool for placing students into Biology Regents courses. The grade point average and Ninth Grade Algebra Regents Examination scores were better predictors of Biology Regents Examination scores than were reading scores alone. This indicates that placement should not be based solely on reading level.

THE EFFECT OF TEXTUAL-AID, IN-CLASS HOMEWORK ON ACHIEVEMENT IN ADVANCED BIOLOGY

Robert H. Evans
Nancy R. Oakley

Although teachers often use homework assignments to help students learn, there is little evidence, particularly in science education, that homework contributes to increased achievement. This study measured the effects of one kind of homework, the textual aids which are supplied by an advanced biology publisher, on student achievement. These aids, which consist of completion and true and false questions, were alternatively assigned to two advanced biology classes. To control for external variables, such as the amount of time spent on the work and the circumstances under which it was done, homework was defined as a task, and completed during successive class periods.

Achievement was measured with a pre-test administered three months before the four chapters used in this study were read and with a post-test at the end of the two-day study period. Both tests are provided by the publisher for this textbook and correlate with the chapter learning objectives and textual aids. All materials were only used in the classroom.

The analysis treated the two classes as wholes, with mean scores for the pre and post tests serving as the bases of comparison. The main analyses were correlated T-tests between the scores on the post-tests of the textually aided and non-aided sessions. They showed no significant differences between achievement levels. In addition, an analysis of covariance, using the pre-test scores as the covariants, was done for each chapter. For three of the four chapters, the adjusted post-test scores showed no significant differences between the two groups. For one chapter, the F was 4.20 with a probability of <0.046 , indicating a significant difference between the adjusted means of the textually aided and non-aided groups.

These results generally suggest that no significant increases in achievement scores accrue from using the text aids written for this advanced biology text. However, the significant difference for one of the four chapters may indicate the potential for such an effect under certain circumstances. Several hypotheses may explain the positive effect in that instance. One may be that students use the textual aids more effectively after discovering their value from immediate post experiences. The instance of significant increase in achievement occurred at the only point in this study where a class used textual aids consecutively. In all other cases, the students had not used the textual aids for the previous chapter they had studied.

Another possible explanation for the significantly different result is that the material of that chapter (the nervous system) was more of a challenge for students than the contents of the other chapters (nutrition, circulation and respiration). Since the textual aids were highly correlated with both the learning objectives and author tests for the chapters, these aids may have been useful advance organizers for difficult or unfamiliar material.

A COMPARISON OF THE EFFECTS OF TWO INSTRUCTIONAL SEQUENCES INVOLVING SCIENCE LABORATORY ACTIVITIES

Glenn C. Markle
Jerry E. Ivans

The purpose of this study was to address three questions: (1) Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions learn those concepts better than students who have the concepts introduced through textbook readings or teacher lectures followed by verification labs? (2) Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions retain those concepts better than students who have the concepts introduced through textbook readings or teacher lectures followed by verification labs? (3) Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions have a stronger preference for science than students who have the concepts introduced through textbook readings or teacher lectures followed by verification labs?

A review of the literature revealed findings (Renner and others) that indicated the sequence of instruction in which laboratory activities were used to introduce concepts increased achievement and attitude for science. However, the evidence is based on studies that involved major revisions of the curriculum which makes implementation difficult for most teachers. This study attempted to determine if typical textbook laboratory exercises (verification labs) could improve achievement and retention if they were used to introduce new concepts (directed discovery learning labs).

The information processing theory suggests that laboratory activities may help students develop a stronger cognitive structure by establishing mental images for students that provide a route to long-term memory. The implication is that existing textbook laboratory activities used as directed discovery learning labs (DDL) to introduce new concepts should result in greater achievement and retention than verification labs. Greater achievement and retention should have a positive effect on student preference for science.

The sample population consisted of one hundred and three seventh grade earth science students enrolled in six homogeneously grouped classes in a suburban junior high school in Cincinnati, Ohio, during the fall quarter of 1984. The families in the attendance area of the school are predominately white and middle class. Two science teachers instructed three classes, one high ability class and two general ability classes.

The results of the study indicated that students did experience greater achievement and retention when directed discovery learning labs were used to introduce new concepts when compared to the same laboratory activities used as verification labs.

THE ACCULTURATION OF SCIENCE STUDENTS: A PREREQUISITE FOR
SCIENTIFIC LITERACY IN ANY DECADE?

Cathleen Loving

The purpose of this study was twofold. First questioned was the extent to which scientific literacy, as defined by the science education community, is an achievable goal. Next, an examination of science education literature was conducted to determine whether two antecedents, functional and cultural literacy, are considered part of the goal for science education. There is a growing body of work on the periphery of science education supporting more historically-linked, culturally-based curricula. The extent of science education's commitment to such a linkage was a major focus of this study.

Methods employed were essentially those of an analytical philosophical study. Included in the examination were books, articles, and curricula generated since the birth of Project Synthesis. In addition, recent works dealing with literacy in general and with learning theory were examined. In each case, the question raised was: To what extent does this data source support or promote the acculturative aspects of science education?

Results suggested possible conflicts between science education's views on literacy and those in the surrounding scholarly community. Examination of the goals of Project Synthesis and of the subsequent curricula generated seemed to reveal an ahistorical, acultural view of science. At the same time, the body of research from cognitive psychologists suggested the importance of common "context effects," or prior knowledge for effective learning of new concepts. And from those doing recent scholarship on general literacy was evidence that having adequate skills and processes in reading, writing, and numeracy without seeing a connection between language, numbers, and life is meaningless.

The implications for science education are that without a common knowledge of science linked to some common culture, perceptions and expectations for the future will differ greatly among the seemingly literate people. The result might be failure to have real communication among the members of a technologically specialized society. Scientific literacy appears to require the acculturation of science students, in order to produce decision-makers who speak the same language and have similar images of what past societies did to solve their problems.

AN ANALYSIS OF THE RESEARCH ON LEARNING IN SCIENCE EDUCATION

Donna Berlin
Arthur L. White

The purpose of this research was to determine and describe the nature and focus of contemporary studies on science learning. The learning context is viewed as an interaction among the characteristics of the learners, the learnings, and the learning environments. Learning is perceived as the changes within the learner as these relate to cognitive processing of information and/or structure of knowledge.

Search profiles were developed to identify research on the learning of science, mathematics, and social studies in terms of learners and learning environments. Each "hit" was further identified as belonging to one of seven categories. These categories were 1) learners, 2) learnings, 3) learning environments, 4) learners and learnings, 5) learners and learning environments, 6) learnings and learning environments, and 7) learners, learnings, and learning environments.

The results of these classifications relative to science as compared to the other content areas are as follows:

1. The number of studies which focus specifically on the learnings is relatively low in science as compared to mathematics education.
2. The number of studies which include all three factors of the learning context (learners, learnings, learning environments) is relatively low for research in science education.

Research efforts should be directed toward the development of models of learning applicable to science education. These models for science learning may be combinations or modifications of existing models or the result of the development of new models. These models should accommodate new knowledge about learning and incorporate and integrate the benefits of advanced technology into the learning process. Research should facilitate the translation of theoretical and empirical knowledge into efficient practice in the science classroom.

PROBLEM-SOLVING AND KNOWLEDGE-BASED LEARNING IN SCIENCE

George J. Pallrand
Daulat Husain
Neil Moyer

This paper reports on research into the manner in which the novice or non-expert uses knowledge to solve simple problems in kinematics. A knowledge base is provided in advance and at various junctures during the problem-solving sequence. What aspects of this knowledge are selected for use in conjunction with or in place of that previously held by an individual is at issue. How in a highly formalized domain, such as physics, is knowledge assimilated and used in solving problems?

A related aspect of the research involves the use of computer simulation as medium for presenting knowledge and examining the subject's presentation of the knowledge. A series of related problems of increasing difficulty were presented sequentially. The immediacy of the computer response enabled subjects to examine an array of situations in a brief period of time. The graphic representation provided visual expression of the relationships being considered.

Ten graduate students served as subjects. They were practicing teachers with several years of experience. These subjects volunteered from a graduate level course related to the teaching of mathematics at the junior high school level. Their academic backgrounds were general and included at least one course in physics. The physics course had not, however, been taken within the past three years. Each subject participated in the problem solving sequence individually.

The most general findings concern the subjects' failure to use the knowledge provided in attempting to solve the problems. Subjects appeared to make initial moves or probes that appeared to be arbitrary. They did not appear to use the knowledge provided in their initial moves. This knowledge was used to rationalize the positions they had taken. Subjects also tended to use knowledge acquired incorrectly at the next level in the sequence. Once a relationship was established, subjects felt compelled to use the knowledge whether it was related to the problem at hand or not. A number of responses normally accounted for in terms of misconceptions could be explained in terms of the failure to isolate or coordinate variables. Given sufficient opportunity to use the simulation, most subjects were able to solve approximately half of the problems.

Education has traditionally emphasized an expository approach. Concepts are broken down and presented as component parts. Once the components are known, it is assumed that the learner understands the concept as well. Research, such as that reported in this paper, indicates that this may not be the case. Greater attention needs to be given to the development of intellectual schemas into which knowledge can be interpreted and organized.

SCIENCE AND TECHNOLOGY RELATED GLOBAL PROBLEMS: A SURVEY
OF SCIENCE EDUCATORS IN DEVELOPING COUNTRIES

Rodger W. Bybee

Science educators in developing countries evaluated global problems related to science and technology. Educational issues associated with teaching about the global problems were also assessed. This research was intended to provide information about certain aspects of the Science-Technology-Society (S-T-S) theme as a conceptual organization for science education programs. Seventy science educators representing twenty-seven developing countries completed the survey. This response was approximately 75% of the original sample. The science and technology related global problems ranked highest were: world hunger and food resources, population growth, human health and disease, energy shortages and water resources. Generally, these problems would be worse by the year 2000. Science educators indicated they were slightly or moderately knowledgeable about global problems and their primary sources of information were: professional journals, books, newspapers, and weekly magazines. Science educators estimated the public's knowledge of global problems as slight. Science educators generally indicated the following concerning global problems and education:

1. It is very important to study these problems in schools.
2. Emphasis on global problems should increase with higher educational levels.
3. There is public support for including global problems in school programs.
4. The science and social studies related to global problems should be integrated into one course.
5. Courses including global problems should be required for all students.
6. Developing countries are in the early stages of implementing programs including global problems.
7. There is a clear trend toward the S-T-S theme in school science programs and it will be very prominent by the year 1999.
8. The most significant limitations to implementing global problems into school programs are economic, personnel, political, and social.

A SURVEY OF BIOLOGY TEACHERS' OPINIONS ABOUT THE TEACHING OF
EVOLUTIONARY THEORY AND/OR THE CREATION MODEL IN THE UNITED STATES

Frank Affannato
Daniel Sheldon

A national poll of high school biology teachers in public and private schools throughout the United States was conducted in March of 1984. Four hundred and sixty seven of the nine hundred and ninety nine polled responded.

Analysis of the results indicated that 4.9% of the respondents believe that evolution should be excluded from a high school biology class and 53.1% of the respondents believe that the creation model should be included in a high school biology class; 19.7% of the respondents believe that a high school biology class can be taught without reference to evolutionary theory, and 15.2% of the respondents believe that the creation model and evolutionary theory are equally scientific explanations. The majority of the respondents believe that the specific content of a biology course ought not be determined by federal or state legislative bodies and should be determined by the biology teachers themselves; 94.1%, 93.6%, and 87.6% respectively. Only 41.5% of the respondents believe that the teaching of the creation model in a high school biology class violates the students' Constitutional rights which guarantee the separation of church and state. Most teachers felt that they were prepared to teach evolutionary theory and unprepared to teach the creation model; 79.9% and 37.0% respectively.

A Chi-square test was performed to determine whether there were any connections between various educational and personal effects in the respondents' backgrounds (such as degree held, courses taken, school size, geographic area, sex, and religious preference) and their expressed opinions on the questionnaire. It was determined that increased educational levels (BA/BS, MA/MS, or doctorate) had little effect on the opinions of the respondents. It was also determined that there was little effect due to specific courses that had been taken (either as an undergraduate or after certification), with the exception of courses in evolution. It was determined that there was a very significant effect on the opinions of the respondents due to their personal religious preferences: with the opinions of those who preferred one of the more conservative and/or fundamentalistic groups varying greatly from the opinions of those who opted for more liberal religious groups such as Roman Catholic, Jewish, "mainstream" Protestant (such as Episcopalian, Presbyterian, Lutheran, or Methodist), "liberal," or no preference given.

In summary, the religious preferences of the respondents has had a more profound effect on their opinions than has their educational preparation for their chosen profession.

WERE THE 1950s LIKE THE 1980s?:
A STUDY OF SCIENCE LABORATORY EQUIPMENT IN NORTH DAKOTA HIGH SCHOOLS

Betsy Ann Giese

Proposals for improving current science teaching are often similar to actions taken during the late 1950s and early 1960s. Federal funding for science equipment in schools has been suggested in the 1980s. Such funding was first available under Title III of the National Defense Education Act (NDEA). Congress appropriated NDEA Title III funds from 1958 through 1976. The current situation should be studied to determine if past actions are still appropriate.

The purpose of this study was to learn (a) the extent of similarities between the 1958-1959 school year and the 1984-1985 school year in the quantities of science laboratory equipment in North Dakota high schools and (b) teachers' perceptions in 1984-1985 about laboratory equipment needed, but not available, to teach science in North Dakota high schools.

Questionnaires were mailed during the 1984-1985 school year to all of the 230 public high schools in North Dakota. Questionnaires were returned from 213 schools, for a response rate of 93%. The median size of the responding schools was a total of 74 students in the ninth through twelfth grades. Data from these questionnaires were compared to results of a study directed by Charles L. Koelsche and Archie N. Solberg in 1958-1959. (Koelsche presented those results in 1960 at the Thirty-Third Annual Meeting of NARST).

The 1984-1985 survey done for this study gave evidence that, in general, North Dakota high schools are better equipped to teach laboratory sciences in the 1980s than they were before the acquisition of equipment with funds from NDEA Title III. Larger increases in quantities of equipment occurred in schools with fewer than 200 students in grades 9-12 compared to schools with 200 or more students in those grades.

The increase in sizes of North Dakota high schools between 1958-1959 and 1984-1985 was very slight and, therefore, does not account for the increases in laboratory equipment.

For each of the 65 equipment types studied, the mean number of pieces of equipment per school in 1984-1985 was higher than in 1958-1959. The largest increases in those means were the 38.0 fold increase in spectrometers and the 16.5 fold increase in molecular model kits. The smallest increase in those means was the 1.4 fold increase in siren/color disks.

In the 1984-1985 survey, the proportion of schools in which equipment was rated as poor was 3.4% for biology, 3.5% for chemistry, and 21.1% for physics equipment. In the 1958-1959 survey, the comparable proportions were 47.7% for biology, 40.9% for chemistry, and 72.8% for physics equipment.

The following types of equipment were listed most frequently by teachers in 1984-1985 under the question about their current needs for new equipment: balances, water stills, oscilloscopes, microscopes, incubators, and models. The reason most frequently selected by teachers for needing equipment was to implement activities not previously done in their schools.

The results of this study indicate that there is not as great a need in North Dakota now for federal legislation funding school science laboratory equipment as there was in 1958 when the NDEA was passed.

RESEARCH ON CLASSROOM AND SCHOOL ENVIRONMENT

David F. Treagust
Darrell L. Fisher
Renato A. Schibeci
Barry J. Fraser

The past two decades have seen a sharp increase internationally in the assessment and investigation of perceptions of psychosocial characteristics of classroom and school environments. The purpose of this symposium is to report salient findings from three separate research programs in science education which are extending and consolidating past work on classroom environm^{ts}.

"Validity and use of a Classroom Environment Instrument for Higher Education" (Treagust, Fraser) extends a strong tradition of research in elementary and secondary schools to the higher education level by describing the validation and use of a new instrument, the College and University Classroom Environment Inventory (CUCEI). The CUCEI assesses students' or instructors' perceptions of Personalization, Involvement, Student Cohesiveness, Satisfaction, Task Orientation, Innovation, and Individualization. Administration of the CUCEI to 372 Australian and American students in 34 classes and to 20 instructors attested to the internal consistency reliability and discriminant validity of the actual and preferred forms with either the individual or the class mean as the unit of analysis, and supported the ability of the actual form to differentiate between the perceptions of students in different classrooms. A research application suggested that the nature of the classroom environment affects outcomes. Another research application suggested that both students and instructors preferred a more favorable classroom environment than the one actually present, and that instructors viewed classroom environments more positively than did their students in the same classrooms.

"Assessment of Teachers' Perceptions of School-Level Environment" (Fisher, Fraser) begins by overviewing several instruments for assessing school environment (as distinct from classroom environment), giving particular attention to Moos' (1981) Work Environment Scale (WES) which assesses Involvement, Peer Cohesion, Staff Support, Autonomy, Task Orientation, Work Pressure, Clarity, Control, innovation, and Physical Comfort. Administration of a slightly reworded version of the WES to 114 science teachers in 35 high schools revealed KR-20 reliability coefficients ranging from 0.60 to 0.85. The WES has now been cross-validated with a larger sample of elementary and high school teachers responding to both an actual (N=599) and a preferred form (N=543). Analyses of these data attested to the internal consistency reliability and discriminant validity of both the actual and preferred form of the WES with either the individual teacher or the school mean as the unit of analysis; as well, each scale in the actual form differentiated significantly between the perceptions of teachers in different schools. The third section of

the paper presents evidence that, in comparison with elementary school teachers, high school teachers perceived their school environments as being characterized by more work pressure, less clarity regarding school rules and policies, less innovations, and worse physical surroundings.

"Effects of Classroom Environment on Science Attitudes: A Crosscultural Replication in Indonesia" (Schibeci, Fraser) reports two pilot studies involving the development of a four-scale Indonesian version of the test of Science-Related Attitudes and an Indonesian classroom environment instrument with eight scales. When these two instruments were used with another sample of 250 Indonesian biology students, findings of statistically significant associations between environment and attitudes replicated much prior work in science classrooms in developed countries. For example, more favorable science-related attitudes on several scales were found in classes perceived as having more personalization, participation, investigation, and order and organization.

A COOPERATIVE STUDY OF SCIENCE ATTITUDES AND INVOLVEMENT
IN SCIENCE ACTIVITIES OF U.S. AND JAPANESE MIDDLE GRADES STUDENTS

Charles R. Coble

This study was a cooperative endeavor between science educators at East Carolina University in North Carolina and Hiroshima University in Japan. The primary purpose of the study was to measure the reasoning skills and integrated science process skills of students in grades 7, 8, and 9 in both countries. These variables were correlated with measures of student attitudes toward science and involvement in science-related activities in and out of school. A total of 3,291 students in North Carolina and 4,397 Japanese students participated in the study. They were not randomly selected, but were selected from a wide range of school systems.

This portion of the study attempted to answer the following questions:

1. Is there a relationship between student activities and measures of student attitudes toward science?
2. Is there a relationship between student activities and integrated process skills?
3. Is there a relationship between student activities and logical thinking skills?

Instruments used in the study were: the Attitude Toward Science Scale (ATSS) adapted by William Spooner from a scale developed by Lewis R. Akin; a student questionnaire was developed jointly by the Japanese and American researchers to assess involvement in science-related activities; the Group Assessment of Logical Thinking (GALT) a 12-item test of logical thinking skills developed by Roadrangka, Yeany, and Padilla; and the Test of Integrated Process Skills (TIPS II) developed by Burns, Wise, and Okey. This consists of 36 items designed to measure five integrated process skills.

Most all correlation coefficients were statistically significant. This is not surprising, given the large population of students participating in the study.

The data from the science attitude scale showed that North Carolina students had a more positive attitude toward science than did their Japanese counterparts at all three grade levels. There was a definite decrease in their scores from the seventh to the eighth grade, which would reflect the difference from the elementary school to the junior high school.

AN ASSESSMENT OF INTEGRATED PROCESS SKILLS
OF JUNIOR HIGH SCHOOL STUDENTS

William E. Spooner

The development of thinking skills is well recognized as an important goal of American education. The philosophy and objectives of science education strongly support this goal. However, too often science achievement in our schools is measured at the lowest level of recall which largely excludes higher level thinking skills.

The purpose of this study was to assess North Carolina middle grade students' integrated science process skills and to examine the relationship between these skills and formal operational processes.

A sample of approximately 3,300 middle grade students were administered the Test of Integrated Process Skills II (TIPS II) and the Group Test of Logical Thinking during the fall of 1985. A similar study with these instruments was simultaneously conducted in Japan.

The results from these tests are as follows: The overall mean score on the TIPS II was 17.34 with a standard deviation of 6.22. The maximum score on the TIPS II is 36. Coefficient alpha for the TIPS II was .82. No significant differences in scores were found to exist between male and female students. There was a progression of scores from the 7th to the 9th grade. The 7th grade mean was 16.09 and the 9th grade mean was 19.12. The most difficult subscale item was identifying variables. Only 42.2 percent of students gave correct responses. In comparison, Japanese students scored the highest on this subscale. In addition, the mean score for Japanese students was significantly higher.

A moderately strong relationship was found to exist between the integrated process skills on the TIPS II and logical thinking skills as measured by the Group Assessment of Logical Thinking (GALT), ($r=.64$, $p=.0001$). This relationship is consistent with other studies using these tests. How the two types of skills are related is not presently understood. The GALT test results indicate that only 10% of NC middle school students are functioning at the formal operational stage. In comparison, 32% of the Japanese students are functioning in the formal mode.

There appears to be considerable room for improvement of North Carolina students' understanding of formal thought and science process skills. This study adds support to the need for additional research on appropriate classroom activities to enhance the reasoning and process skills of the middle grade students.

A STUDY OF THE LOGICAL THINKING SKILLS OF
JUNIOR HIGH SCHOOL STUDENTS IN NORTH CAROLINA AND JAPAN

Floyd E. Mattheis
Charles R. Coble
William E. Spooner

The basic purpose of the cooperative research project was to study the level of reasoning skills in junior high school students in Japan and North Carolina (grades 7, 8, and 9). Students in this age bracket are characteristically in the process of making the transition from concrete operational thinking to formal thought, according to the ideas of Piaget.

The formal thinking abilities studied in this project were measured by the test Group Assessment of Logical Thinking (GALT). The data also produced subscores on six different reasoning skills--proportional, conservational, combinatorial, identifying and controlling variables, correlational, and probabilistic logic. During November 1984, this test was given to approximately 3,300 students in North Carolina and 4,500 students in Japan. The data were analyzed, and charts were developed to summarize the data for all three grade levels by developmental level--concrete, transitional, and formal.

Additional analyses of the data are available for both groups by grade level and sex. The data showed that the Japanese students had a significantly higher percentage of students in the transitional and formal levels for all three grade levels. In addition, there were some interesting similarities and differences in the various subscores for these groups.

The main difference occurred prior to the seventh grade, so the implication is that the Japanese schools must be doing something right during the elementary school years. The elementary school science program is one that basically includes the components that science educators in the U.S. would agree are aspects of a good science curriculum in any country. In effect, it seems that the Japanese have been able to do a better job of implementing an excellent elementary school science curriculum. However, the items tested on the GALT are not limited to the science curriculum. Proportional logic, probability, combinatorial logic, and controlling variables are all considered to be important topics of study in mathematics. The challenge for educators in North Carolina is to include more direct experiences for students in the elementary school that involve learning activities including proportional reasoning, probabilities, controlling variables, correlational logic, combinatorial logic, and conservation. Further research is needed to study the similarities and differences in the logical thinking skills that North Carolina and Japanese students exhibit during their years in senior high school.

STUDENTS' PERCEPTIONS AS PREDICTORS OF ACHIEVEMENT IN
INTERMEDIATE LIFE SCIENCE CLASSES

John Mergendoller
Martin Packer

Students' perceptions of their classroom activities and the instruction they receive are important elements of the learning of science. In this study empirical test was given, in a natural setting, to the causal model that students' perceptions mediate the relationship between their academic ability and their learning in life science classes. Students in 11 seventh-grade life science classes (n=213) completed four science-related measures at both pretest and posttest: a Life Science Questionnaire, a Nature of Science Survey, a Science Process Survey, and a Feelings toward Science Survey. These measures tapped relevant components of scientific literacy. The first assessed knowledge of science content; the second and third tapped understanding of science as a process of reasoning. The third addressed attitudes towards science, and covered feelings towards science classes, vocational and educational intentions, feelings about science in general, interest in science activities. Students also completed the Ideas About Science Survey, whose items covered a wide range of topics, and which solicited students' detailed report of their perceptions of teacher behavior, instructional activities, and the curriculum. Multiple regression was used to examine the relationships between outcome scores, pretest cognitive and affective scores, and students' perceptions and their learning-relevant self-reports. Attitude measures accounted for approximately 15% of the variance in cognitive outcome scores, with attitude to science classes and to science activities in general showing the strongest relationship. Understanding of science process was also predicted by students' perceptions of the quality of their teacher's explanations, and of the teacher having positive expectations. For most of the students' learning-relevant self-reports, the pretest attitudinal measures were better predictors than the pretest ability measures. Between 4% and 17% of the variance on these perception measures was predictable. Reported difficulty, and interest in laboratory-related activities were the two perception measures showing the strongest relationship to the attitudes towards science expressed at pretest. In each case, attitude towards science classes was the attitude measure with the most predictive value. In several analyses, attitude towards science classes predicted as much of the variance in outcome scores as did pretest ability.

PROJECT LEO STUDIES OF ATTITUDES, PERCEPTIONS, AND PREFERENCES
OF HIGH SCHOOL CHEMISTRY STUDENTS WHO HAVE EXPERIENCED THREE
QUANTITATIVELY-DEFINED SCIENCE LEARNING ENVIRONMENTS

Charles C. Matthews
Dorothy M. Schlitt
Mohammad AbuNejmeh

The purpose of this Project LEO study was to investigate high school chemistry student perceptions of three different science learning environments and their attitudes toward, perceptions of, and preferences for science in general, chemistry, and learning chemistry. Subjects were 48 students enrolled in two sections of a high school general chemistry course.

Data were collected over a nine-week period utilizing a modified version of the Science Curriculum Assessment System (SCAS) for coding classroom behavior and SCAS-derived protocols for interviewing subjects on student perceptions of chemistry, the learning of chemistry, classroom behavior, and on student preferences for the three environments. Finally the Scientific Attitude Inventory was used to obtain student attitudes toward science after experiencing each of the three science learning environments.

Repeated measures design analyses were used to investigate student perceptions of and preferences for learning chemistry and their attitudes toward science. Chi-square analyses were used to investigate the accuracy of student perceptions of classroom behavior. Finally, correlation analyses were used to investigate the relationship between student attitudes toward science and their grade point average in science courses.

The results indicated the following:

1. Student perceptions of chemistry and of learning chemistry showed significant differences subsequent to experiencing each of the three different science learning environments.
2. A significant difference existed between student perceptions of classroom behavior and observed classroom behavior.
3. No significant relationships were found between student attitudes toward science and their grade point average in science courses.
4. No significant difference was found in student preferences for three different science learning environments.
5. No significant difference was found in student attitudes toward science subsequent to experiencing the three different science learning environments.

AN ANALYSIS OF NATIVE AMERICAN STUDENT ATTITUDE TOWARD SCIENCE

Gerry D. Haukoos

Success in science results from a variety of experiences and characteristics, some come from within the individual while others are in the environment. One such characteristic associated with student achievement is attitude toward the fundamental activities of the science discipline. Initially, investigators of attitude and achievement hypothesized that attitude influenced achievement, yet summarizing reports show a higher correlation for achievement causing attitude. In a broader sense, achievement in science seems more closely related to interest in science or even a larger and more powerful attitude system, attitude toward school.

Native American students have not been successful achievers in either science or in school. There is an emerging pattern where native children are falling behind at an alarming rate and as high as 60% drop out before reaching 12th grade on some reservations.

The purpose of this study was to survey attitude toward science by native students enrolled in the primary school system serving the Rosebud Sioux Reservation of South Dakota. The objective was to not only survey students but also to analyze components of attitude to provide some notion of native student perception of the nature of science.

Subjects for the study were Native Americans enrolled in grade 8-11 in Todd County Schools on the Rosebud Sioux Reservation and an exemplary group of similar age and grade but non-native paper presentors from the South Dakota Junior Academy of Science.

All students were administered the Science Attitude Inventory (SAI) in a two-treatment design using the Mann-Whitney U test for significance. Purpose of analysis was to determine if differences existed between native and exemplary scores for attitude toward science.

Analysis of overall values and subscales from the SAI indicate a difference between native students and the exemplary population. Such differences were so great that 11 of 12 subscales revealed difference at least at $\alpha = 0.05$ level. Results of the study seem far more complex than attitude toward science or school alone. Even though these factors were exhibited in this study and in public school data, achievement seems to be more closely related to factors in the culture. These factors need to be addressed in researchers' analyses of the culture for components of traditional science. Once identified, development of a new and improved focus in science can occur among the Native Americans.

EVALUATION OF A TEACHER INSERVICE TRAINING PROGRAM IN PHYSICAL SCIENCE

Frances Lawrenz

As the numbers of science teachers decline, more emphasis must be placed on making those who remain as effective as possible. One approach to this goal is to provide inservice training. This study presents the results of a comprehensive evaluation of a teacher training program that incorporates the "train master teachers to train other teachers" approach espoused by the NSF in their teacher enhancement program. The effectiveness of both the master teacher training institute and the local teacher training classes was assessed qualitatively through observations, interviews and questionnaires and quantitatively through pre and posttesting on attitudes toward teaching, attitudes toward science and science content knowledge.

Nineteen master teachers were trained in the summer institute. Subsequently they offered local classes to over 300 of their colleagues. Both the institute and the local classes were designed to present physical science content and activities for use in the classroom. The pre and posttesting showed that the summer institute participants became significantly more favorably inclined toward laboratory oriented science and that the teachers in the local classes significantly improved their attitudes toward science and became less in favor of strictly structured science classes. Both groups also improved in science content knowledge. The summer institute participants were mixed in their opinions of the institute. Most, however, felt the science content was too difficult and that they needed more time for planning their local course. The teachers in the local classes viewed their classes quite positively. They felt that the classes were interesting and understandable and that their participation had had a significant effect on their teaching and their students.

SECONDARY SCIENCE EDUCATION LIBRARY RESOURCES AT NEW ENGLAND'S TEACHER EDUCATION PROGRAMS

Lloyd H. Barrow

The purpose of this study was to compare secondary science education resources of graduate and undergraduate teacher education institutions in New England. A 72-item mail survey was sent to library directors of New England institutions. There was a 75% return rate from the 56 teacher

education institutions that prepare secondary science teachers. Prepared programs from SPSSX were utilized for data analysis. Of the 42 responding institutions, 19 had graduate education programs.

Differences were found between indexes and journals in graduate and undergraduate New England libraries. Significant differences were found for education indexes, science indexes, science education journals, and non-science education journals. There was no significant differences for science journals. Library resources available for preservice secondary science education were inadequate, with the exception of science reference books.

The lack of science education and non-science education journals could reflect the priority given to education and/or educational research at these responding institutions. Another concern is the low priority given to education and science indexes at many New England institutions. Consequently, many graduates are unacquainted with the current resources that could be utilized to improve their teaching skills and update their science content information. Science educators should ascertain the quality of their library's resources for promoting research. If any of the above resources are lacking, they should be requested, thereby facilitating the preparation of future secondary science teachers.

THE EFFECTIVENESS OF A NARROW FIELD ACADEMIC SCIENCE MAJOR IN PREPARING STUDENTS FOR A BROADER CONTEXT TEACHING ASSIGNMENT

Roger G. Olstad
Andrea V. Marrett

Secondary science education students typically major in narrowly defined academic fields. Such preparation may not be adequate for the broader context teaching assignments often given students teachers or first year teachers. The National Teachers Examination Specialty Area Tests for Biology and General Science or Chemistry, Physics and General Science were administered according to students' declared majors to all final quarter, secondary science student teachers at a major university. It was presumed the tests were a measure of academic competence. Average scores on both exams were in the 85-86th percentile. Students seem to acquire the expanded training and knowledge needed for assignment in the broader context through selection of electives or as peripheral experiences within their major.

THE DEVELOPMENT AND CONCURRENT VALIDATION OF COMPUTER-BASED PIAGETIAN ASSESSMENT INSTRUMENTS

Charles R. Barman

The purpose of this investigation was to determine whether a computer-based test could serve as an alternative to the personal interview technique in assessing levels of cognitive growth theorized by Jean Piaget. Two computer-based instruments were designed for use on an Apple microcomputer. One instrument was developed to assess concrete operational reasoning patterns, while the other examined formal operational thought.

Concurrent validation of each computer instrument was established by comparing the computer tests to corresponding personal interviews. This comparison was achieved by randomly selecting 50 subjects from second, third, and fourth grade (Group A) and 50 subjects from fifth, sixth, and seventh grade (Group B). Group A was asked to respond to the computer items designed to assess concrete operational reasoning. These subjects were also personally interviewed, using the same Piagetian tasks found in the computer items. The same procedure was used with Group B. However, they were given the computer items and corresponding personal interview that assessed formal operational reasoning.

Based on the results of this investigation, a computer-based assessment could be a reasonable alternative to the personal interview technique in identifying cognitive reasoning patterns.

This conclusion was determined through a matching of subject responses to each computer item and its corresponding personal interview. Probability values were established for the total number of matches observed in each computer item/personal interview comparison. Nine comparisons were significant at the .01 level, while one was significant at the .05 level. In addition, a percentage of consistency was calculated for the proportion of matches for each computer item and its corresponding interview. The percentage of consistency for all ten computer items ranged from 68% to 100%.

THE INSTRUCTIONAL EFFECTIVENESS OF GRAPHICALLY-REALISTIC
COMPUTER-GENERATED MATERIAL ON STUDENTS OF
DIFFERENT PRIOR-KNOWLEDGE LEVELS

Daryl Adams
John W. Shrum
Russell H. Yeany

This study investigated the instructional effectiveness of graphically-realistic computer-generated instructional material as compared to a traditional method of instruction. A software package from Scott Foresman was chosen as an example of a recent, sophisticated, and high-quality computer program ("Adaptation," 1985).

A test was developed to cover the five objectives listed by Scott Foresman in their software package on adaptation. The test and objectives were submitted to a seven member panel of science educators to assess content validity. They were asked to assign a number to each item that indicated its validity: 3=High Validity to 0=No Validity. This test was found to be highly valid ($X=2.4$) and reliable ($\alpha=0.89$) and was used for both the pretest and posttest.

A total of 111 students enrolled in five classes of biology at a medium-sized (enrollment approx. 1100) rural high school in northeast Georgia were selected for this study. Two intact classes ($n=42$) were designated as control classes. All students were pretested and the score was used to establish three prior-knowledge levels. In examining the pretest data, no significant differences between the two groups were found in any of the three prior-knowledge levels for either the entire pretest or any individual section.

The students classified as low prior-knowledge showed a significant ($p=0.03$) difference in the mean scores of the overall posttest. The control group performed better on the test by 10.3 points.

The results of the tests were also examined using a paired t-test. Individual pretest and posttest scores were examined to determine if either group (experimental or control) made significant ($p<0.05$) gains because of the treatment. All three prior-knowledge levels in both experimental and control groups showed a significant gain for the entire test.

Gain scores were also computed for both experimental and control groups. The gain scores were compared using analysis of variance to determine if one group's gain score was significantly different ($p<0.05$) from the other. For low, medium, and high prior-knowledge students, there was no significant difference for the gain score on the entire posttest.

We can conclude from the results obtained in this study that superiority of the software package, as tested, was not supported by the data. It was not seen as being more effective than a teacher using the lecture/discussion method of instruction.

A VALIDITY AND RELIABILITY STUDY OF A COMPUTER SIMULATION DESIGNED TO TEST FOR CONTROL OF VARIABLES

Richard Borst

The purpose of the study was to assess concurrent, predictive and construct validity and test-retest reliability of a computer simulation designed to test for control of variables as described by Inhelder and Piaget.

The sample consisted of 75 secondary students. Each subject was tested using four instruments: the computer simulation, the Pendulum Task of Inhelder and Piaget, the Lawson Classroom Test of Formal Thinking, and the American Chemical Society (ACS) Test of High School Chemistry.

Statistical analysis was done by correlating the computer simulation scores with the results of the Pendulum Task, the Lawson total score, the five Lawson Test Subscores, and the ACS Test scores. The computer simulation was administered twice to 26 subjects and the scores were correlated in order to assess the test-retest reliability. The opinions of a panel of experts, all of whom had previously published in the area of cognitive development, were sought to establish consistency of the computer simulation with the Pendulum Task. Sex bias was investigated by analyzing the difference in variance of male and female computer simulation scores.

Significant correlations were found between the computer simulation and the Pendulum Task ($r=.70$). Groups of concrete and formal subjects also exhibited a significant variance in computer simulation score ($p<.01$). Significant correlations were found between the computer simulation score and the Lawson total score, the control variables subscore, and the combinatorial reasoning subscore ($r=.45$, $r=.51$, and $r=.34$) respectively. Spearman rank-order correlation coefficients were calculated and the results were $\rho=.90$, $\rho=.79$, and $\rho=.88$ for the same three relationships.

The test-retest correlation was $r=.81$. Male and female groups of subjects exhibited a significant variance in computer simulation score. The one-way ANOVA yielded an F ratio significant at the .05 level.

On the basis of the panel's evaluation and the statistical relationships between the computer simulation and the Pendulum Task, it may be concluded that the technique has a degree of construct validity with the Pendulum Task. Concurrent validity can be established on the basis of the non-parametric correlations. The results also indicate a high degree of test retest reliability. Gender bias was also demonstrated.

READABILITY OF MULTIPLE-CHOICE SCIENCE ITEMS

Steven J. Rakow
Thomas C. Gee

Multiple-choice science tests are a common method of assessing students' knowledge in a variety of subject areas. Yet, determining the extent to which items measure students' understanding of the subject content (for example, science knowledge) rather than the students' ability to read items is very difficult.

The concern about the reading appropriateness of multiple-choice items becomes especially important when considering the procedures of the National Assessment of Educational Progress. In order to make comparisons of ability between thirteen and seventeen-year-olds, the National Assessment gives both of these age groups the same multiple-choice items. However, without an appropriate measure of the readability of these items, it is impossible to say whether the differences in performance observed between the two age groups are due to differences in their science ability or to differences in their reading ability.

The purpose of this study was to investigate the readability of a set of multiple-choice items. The sample was composed of 60 thirteen-year-olds and 60 seventeen-year-olds. The sample at both age groups was stratified into low, medium and high reading levels on the basis of their standardized reading scores. Six NAEP items were randomly selected. A group of reading experts examined the items and determined key reading skills that were necessary for students to understand in order to answer the questions. Each student was individually interviewed. During the interview, the student read and answered each question while the investigator recorded any reading miscues that the student made. In addition, the students were asked the series of reading skill questions.

There was no significant difference between the thirteen and seventeen-year-olds in their ability to answer the science questions. There was a significant difference in their ability to answer the key reading skill questions. This reading ability, as well as students' standardized reading achievement, was correlated with ability to answer the science questions. Finally, miscue analysis was not effective in predicting students' ability to answer the questions. Thus, while the results support the validity of NAEP's procedure of administering the same item to thirteen and seventeen-year-olds, these items do not appear to assess the kinds of higher level thinking skills that are required by the key reading skills questions. If higher level thinking skills is a goal, then the types of questions used to assess the skill must be carefully examined for readability considerations.

CONTENT VALIDITY OF THE 1985 MICHIGAN DEPARTMENT
OF EDUCATION PILOT SCIENCE EXAMINATION

W. L. Yarroch

An alternative measure of the content validity of a portion of the 1985 Michigan Department of Education Pilot All Student Assessment Science Examination was made through comparisons of:

- 1) student answers to objective items on the examination,
- 2) student answers to essay items prepared as an equivalent to the objective test items, and
- 3) clinical interviews with examinees designed to ascertain their knowledge and understanding of the objective and essay test items studied in #1 and #2.

Particular attention was paid to student responses to objective examination items that were correct for the wrong reason and wrong for the wrong reason. A quantitative estimate of item content validity was made using data from these observations. Suggestions are made for improving the content validity of the studied items.

The study demonstrates that the traditional technique used to ascertain content validity is not the best determiner of content validity in this instance. A more useful approach is one based on the examinees and their interpretation of what test items measure. State-wide all-student assessments in science are well meaning, but caution should be observed in interpreting the results unless a high degree of content validity can be assured.

THE DEVELOPMENT OF A TEST OF COMPUTER LITERACY
FOR SCIENCE TEACHERS

James D. Ellis
Paul J. Kuerbis

In this study the authors are developing an instrument to measure the computer literacy of science teachers. This instrument is part of ENLIST Micros--an NSF funded project developing a curriculum for training science teachers to use the computer for instruction. The instrument is based on the

essential competencies for computer literacy for science teachers developed and validated for this project. The instrument will be used to evaluate the effectiveness of the ENLIST Micros curriculum at developing those essential competencies in science teachers.

A ten step procedure is being used to develop the Test of Computer Literacy for Science Teachers (TCLST). The procedure is criterion-referenced tests. The first step was accomplished by the development and validation of the essential competencies in computer literacy for science teachers. A pool of 74 items were prepared for the 19 competencies by the writers and project co-directors. The items were reviewed by 12 experts in educational computing in the sciences who evaluated the item-competency congruence and the technical quality of each item. The test is being piloted with over 200 preservice and inservice science teachers in 10 sites. The results of the pilot will be used to establish the reliability of the instrument and its construct validity and decision validity.

The TCLST will be one of the evaluation instruments used with the ENLIST Micros curriculum. It also can be used as a diagnostic test by universities and school districts to determine if science teachers have previously achieved computer literacy and therefore do not need a course on computer literacy or as a posttest to determine mastery after instruction in a course on computer literacy. Also, the test will be a valuable tool for researchers in science teaching interested in a measurement of computer literacy in science that could be a variable in a variety of studies--as a covariate in implementation studies, as an outcome measure for studying approaches to training teachers, or as a covariate in efficacy studies of computer-based instruction in science.

SECOND INTERNATIONAL SCIENCE STUDY--A MULTI-NATIONAL REPORT

Willard J. Jacobson
John Keeves
Pisarn Soydhurum
Delores Hernandez
Josefina Fonacier
Pinchas Tamir
Rodney Doran
Michael Connelly
Robert Crocker
Heidi Kass
Menahem Finegold

This is the first report on the Second International Science Study at a meeting of professional science education researchers. The survey research problems, procedures, findings, and implications for science teaching will be discussed by representatives of several of the countries engaged in the study. Some of the problems involved in international studies, such as the selection of comparable populations and the development of internationally accepted instruments will be discussed. Some of the results, such as the finding in several countries that the 1983 students did better on common items than comparable students did in 1970, will be described. Each nation's representative will present some of their most important findings. Each of the national representatives will be asked to reflect upon their studies, problems encountered, and implications for science education in their countries.

FOCUSING PRECOLLEGE SCIENCE CURRICULA: A DISCUSSION
OF FIVE ORIENTATIONS

Richard Duschl

The improvement of science education curricula is a significant concern of science teachers, science teacher educators, and educational researchers. This symposium is organized to present a structured dialog on the implications different curriculum orientations have for the design, implementation, and evaluation of precollege science curricula. The basis of the dialog will be Eisner's 'Five Orientations to Curriculum':

- a) Curriculum as Technology (Ron Good)
- b) Personal Relevance (Robert Yager)
- c) Development of Cognitive Processes (Anton Lawson)
- d) Social Adaptation and Social Reconstruction (Rodger Bybee)
- e) Academic Rationalism (Richard Duschl)

Adopting any one orientation or combination of orientations over others has significant implications for 1) what science content is included or excluded in the curriculum, 2) what would be the goals of K-12 science education, 3) the environment and educational climate that is created, 4) the types of and the quality of learning opportunities that would exist, and 5) other assets and liabilities associated with the design, implementations, and evaluation of curricula.

Recent discussions concerning the direction precollege science education should take have focused on providing a definition of science education. The issue seems to be whether or not science education should abandon the strong ties with the academic structures of the disciplines of science and replace it with an approach which emphasizes the symbiotic relationships amongst science-technology society. Such discussions have served the purposes of raising the consciousness of science education curriculum writers and researchers and of focusing attention on a critical issue. However, such discussions have yet to address the range of issues operant in the design, implementation and evaluation of curriculum. The principal objective of the symposium is to explore topics in science, science education, and curriculum that hold special significance for the preparation of science curricula at the precollege grades. The adoption of Eisner's five orientations to curriculum provides a basis for extending the existing dialog by supplying a theoretical framework for comparing and contrasting the merits of the different orientations outlined by Eisner.

RELATIONSHIPS BETWEEN TEACHER PERFORMANCE, STUDENT
PERCEPTIONS OF THE LEARNING ENVIRONMENT AND
PROCESS SKILL ACHIEVEMENT

Antonio Bettancourt
Steve Byrd
Kenneth Tobin

This process-product study was designed to investigate relationships between teacher performance, student perceptions of the learning environment, and science achievement. A content analysis of the Learning Environment Inventory (LEI), which was used to assess student perceptions of the learning environment, indicated that a number of the items were not valid measures of the scale to which they were assigned. Factor analysis of each of the 15 scales provided support for the logical analysis. As a consequence, the items for the LEI were separately considered from the viewpoint of whether or not they were theoretically related to teacher performance or to science achievement. Those items that were so related were factor analyzed in order to investigate the underlying structure. A strong factor, defined by nine of the LEI items, was identified. On the basis of the magnitudes of the factor loadings the factor was named student perceptions of teacher management (SPTM). The internal consistency reliability of the nine items was 0.8. Because of the theoretical and empirical support for the SPTM scale and the questionable validity of the original LEI scales, the SPTM scale was used in all analyses in this study.

The results of the study indicated that six of the seven teacher performance measures were significantly related to SPTM. Each relationship supported the research hypotheses of this study.

THE RELATIONSHIP OF TEACHER PERFORMANCE
TO SCIENCE PROCESS SKILLS
ACHIEVEMENT OF STUDENTS

Michael Padilla
Linda Crohin
William Capie

The purpose of this study was to investigate the relationship between science teachers' teaching performance and their pupils' achievement on an integrated process skill unit.

All seventh grade science teachers (N=40) in a large Georgia school district which includes schools in suburban Atlanta and more outlying rural areas were involved in the study. Data were collected on one class of students for each teacher (n=1240).

Each teacher taught a prepared two-week unit focusing on science problem solving or process skills. The unit consisted of objectives, unit directions, materials, handouts and ten lessons which focused on conducting a science experiment. The lessons were presented to the teachers in a predetermined order, but teachers were encouraged to reorganize them as appropriate to their teaching style and their pupils' learning habits. This type of individualization made the unit more like a real teaching experience in that the teachers were asked to deal with questions of pacing, unit content and order.

All students were administered the Group Assessment of Logical Thinking (GALT) as a pretest in order to equate learner ability. During the unit each teacher was assessed three times with the Teacher Performance Assessment Instruments (TPAI), once by a peer teacher, a second time by a school administrator, and lastly by a state employed assessment expert. Each of the assessors was specifically trained to use the TPAI. At the end of the unit the teachers all administered the same post test composed of 40 multiple choice questions, provided by the researchers.

The revised TPAI consists of eight broad competency statements broken down into 30 indicator statements which are further divided into 120 descriptor statements. Each descriptor represents a specific, observable teaching behavior. Observers respond to each descriptor statement, indicating whether or not the acceptable form of the behavior was observed during a given lesson. These descriptor data were then aggregated to form indicator scores which were in turn aggregated into decision-making competency scores.

A teacher effectiveness index for each teacher was constructed in order to study the relationship between TPAI scores and learner achievement. GALT, given as a pre-test, was used to generate expected post-test scores for each learner using regression techniques. The difference between the observed and expected post-test scores was considered to be a teacher effect. The class mean of these teacher effect values was used as a teacher effectiveness index for each teacher. Correlations were then computed between various components of the teacher's TPAI score and this effectiveness index.

Correlations between student achievement and teacher performance were above .30 for 12 of the 92 classroom performance descriptors. Four descriptors had correlations of .40 or greater with student achievement. Descriptors correlating highly with student achievement included the use of demonstrations and/or examples to illustrate content and reinforcement of learner participation.

Four of the 23 indicators correlated significantly with achievement. Values for these correlations ranged from .36 to .42. These four indicators were associated with efficient use of time, provision of a favorable learning environment, matching instruction to learners, and helping learners develop a positive self-concept.

Correlations between competency scores and student achievement ranged to .41 for the competency which is associated with organization of time, space and instructional materials. The competency which deals with maintaining appropriate classroom behavior also correlated significantly with student achievement.

THE DEVELOPMENT OF A MIDDLE GRADES INTEGRATED SCIENCE PROCESS SKILLS TEST

Linda Cronin
Michael Padilla

The objective of this project was to develop a reliable multiple choice test of the integrated science process skills appropriate for middle school students from grades six to eight (ages 12 to 14). Most instruments currently available focus on measuring all science process skills or were created for use with teachers. The few integrated process skills that do exist are geared primarily for upper level secondary school students. No suitable test of integrated process skills has been developed for middle school students. This research is an effort to develop just such an instrument.

In light of this need, the investigators began to develop the Middle Grades Integrated Process Skills Test (MIPT). The following criteria were outlined for the test:

- (1) An emphasis on the skills associated with experimenting, i.e. identifying researchable questions, formulating hypotheses, identifying variables, designing an experiment, recording data, and interpreting data.
- (2) A multiple choice, four option format.
- (3) An average test readability below the seventh grade level.
- (4) Test length that permits completion within one class period (45 minutes or less).

- (5) A wide range of difficulty of items addressing each identified skill.
- (6) Content free test items.

Objectives for each of the identified process skills were written and refined. A pool of related test items was collected from various sources, including other existing process skill tests. Potential MIPT items were selected from this pool and matched to the seven MIPT objectives. These selected items were then modified for inclusion in the MIPT. Additional new items were written for objectives lacking a sufficient item pool.

From this pool of modified and new items, the 40 items judged to be the best measures of the skills identified were chosen for inclusion in the test. All items were subjected to a readability analysis and an average grade level of 6.1 was obtained.

One thousand one hundred and fifty four seventh grade students were administered the MIPT test as the conclusion of a ten day unit on experimenting. Student test score data from this field trial were used to establish test reliability and to compute item difficulty and discrimination indices. Scores ranged from 6 to 40 correct ($X = 27.14$, $s.d. = 7.69$) with a standard error measurement of 2.73. The overall reliability (KR 20) of the MIPT was .89. Item difficulties ranged from .24 to .89, with an average value of .63. Point biserial correlations (discrimination indices) showed 39 of the 40 items above .30, with an average value of .43. All incorrect alternatives had point biserial correlations in the zero or negative range.

These results indicated that most items were functioning quite well and that the MIPT could serve as an item pool for teachers and researchers looking for a means of evaluating integrated process skill performance of middle school students.

THE GALT: A MEASURE OF LOGICAL THINKING ABILITY OF
GRADE 8 STUDENTS AND A PREDICTOR OF SCIENCE
AND MATHEMATICS ACHIEVEMENT

Betty L. Bitner

A convenience sample of 147 eighth grade science and mathematics students in Arkansas was administered the Group Test of Logical Thinking (GALT). The sample consisted of four different sections of eighth grade students, i.e., one algebra, one 8-1, three 8-2, and one 8-3. The lowest ability eighth grade students, those in the basic level, resource room, or self-contained special class, were excluded because of their general sub-average intellectual functioning ability. The GALT was used to investigate the relationship between the GALT scores and students' course grade and SRA scores in science and mathematics, to determine whether the GALT is a predictor of science and mathematics grades, to measure the reasoning ability of these eighth grade students, to compare the performance of the four sections of eighth graders on the GALT, and to determine gender differences in reasoning ability. It was found that the GALT correlates significantly with both course grades and SRA scores in science and mathematics. Also, the results on the linear regression indicated that the GALT is a predictor of science and mathematics course grades. The distribution of students by reasoning levels as measured on the GALT was 5% formal operational, 33% transitional, and 62% concrete operational. The results of the one-way analysis of variance comparing GALT scores for the four sections of eighth graders indicated significant differences among the sections. On the one-way analysis of variance procedure, significant gender differences were found for only two of the twelve test items, one measuring conservation and the other measuring combinatorial reasoning. The results of this study seemed to indicate that the GALT can be used to predict achievement in science and mathematics and is a valid instrument for measuring logical thinking.

RELATIONSHIPS AMONG SUPERSTITIOUS BELIEFS,
SCIENCE PROCESS SKILL AND LOGICAL THINKING
ABILITIES OF PHILIPPINE STUDENTS

Joseph P. Riley, II
Laurena G. Chuapoco

Research into possible relationships among science education related variables and non-science or superstitious beliefs has received little

attention in the United States. This can be attributed in part, to the assumption that superstitious beliefs of American students do not pose any serious threat to science learning. In countries where scientific literacy of the general population is relatively low, the influences of superstition can work at cross purposes to the goals of science education. This investigation explored relationships among science process skill achievement, superstitious beliefs and logical thinking abilities of Philippine high school students. The existence of an inverse relationship between science process skills and superstitious beliefs provides research support for the inclusion of process skills in the curriculum and provides a possible mechanism for altering students' non-science beliefs.

FACTORS WHICH INFLUENCE STUDENTS' PERFORMANCE ON A FORMAL REASONING GROUP TEST

Reuven Lazarowitz
Michal Shemesh

The study examines the effects of Piagetian-like tasks' characteristics on reasoning patterns of different age group students. The tasks were taken from a formerly developed and validated test which measures students' reasoning skills in six cognitive operations: conservation, proportions, control of variables, probability, combinatorials and correlations. Subjects were 7th, 9th, and 12th grade students, enrolled in two urban schools.

Three different 3 x 2 factorial research design experiments, with three levels of student age and two versions of the test in each experiment, were set up for this study. Experiment 1 tested the effect of task presentation (video-taped demonstrations versus paper-and-pencil tasks with illustrations). Experiment 2 tested the effect of questionnaire format (multiple-choice versus essay answers) and Experiment 3 tested the effect of the numerical content (integer ratios like 1:2, 1:3 versus noninteger ratios 2:3, 3:5) on different age group students' responses.

Analysis of the data indicated that method and format had an effect only on young students' performance, while numerical content had an effect on the majority of the students, in all grades. The only students who were indifferent to numerical content changes were the formal reasoners. The implication of these findings to science education in general, and to cognitive level assessment in particular, will be discussed.

FAMILY INVOLVEMENT IN SECONDARY SCIENCE HOMEWORK ACTIVITIES

Richard Rezba

Although parents have been involved in their children's education in secondary science in many traditional ways, the recent trend to increase parental participation in new ways has occurred mainly at the elementary grade level. Using a non-traditional kind of homework (short, simple, and interesting science activities), can similar family participation in science be encouraged by teachers at the secondary level?

The purpose of this study was to: 1) involve secondary students and their parents in take-home science activities and to solicit information about their participation, 2) to determine the effect of a novel kind of homework on homework completion behavior, and 3) to test the relationship of several variables, e.g., grade level, on the percent participation of students and their parents.

Twenty-four pre- and inservice teachers in urban, suburban, and private schools and 878 secondary students and their families were involved in the study. As homework, students were given an activity to conduct at home and encouraged to involve family members as participants or observers. An accompanying questionnaire was used to gather data from both students and their parents. Conventional frequency statistics were used to analyse the responses from both students and participating parents that included number and kinds of family members involved, problems encountered, reasons for enjoyment, and interest in further take-home activities. Analyses of variance were used to test the relationship of several variables to the percent participation of students and parents in the homework activities.

Of the 878 questionnaires sent home by the teachers, 531 (60%) were returned by the students indicating their completion of the assigned activity. Of these students, 320 of them (60%) reported that their parents also participated in the activity. In 37% of these family groups, both parents participated; in 44%, only the mother participated; and in 16%, only the father participated. Forty-eight students (9%) involved a sibling in their activity but not parent. The remaining 163 students (30%) completed their assigned activity alone.

Analyses of variance revealed no significant differences in percent participation of students per class when compared by grade level or effect of homework activity on students' grades. However, significant differences were found when compared by type of school--urban, suburban, and private. The percent of parent participation varied enormously by class (0% to 92%). While analyses of variance revealed no significant differences by grade level, analyses did reveal significant differences by type of school.

The results of the study indicate that parents of secondary science students can be involved in the science instruction of their children through the teachers' use of take-home science activities. Furthermore, their reaction to this involvement is overwhelmingly positive. Anecdotal data from parents, e.g. "...my child is doing homework for the first time this year," and from teachers suggest that take-home science activities might entice some students into doing science homework who ordinarily would not do so.

PARENT-CHILD INTERACTIONS IN A FREE-CHOICE LEARNING SETTING

Lynn D. Dierking
John H. Falk
John J. Koran
Mary Lou Koran

The focus of this study was to analyze family behavior during visits to a natural history museum. The study was an extension of an earlier ethnography of family behavior in one participatory exhibit in that same natural history museum. That ten week pilot study revealed two major categories of family behavior: 1) educative behaviors and 2) management behaviors, and three "types" of families: 1) educative, 2) non-educative and 3) rule-enforcing.

This study was expanded to analyze family behavior during the entire visit. The major questions to be addressed were: 1) Are these same "types" of families observed when families are followed during their entire visit and data are collected utilizing a coding instrument? 2) Is their behavior different from exhibit type to exhibit type (i.e. traditional case exhibit vs. walk-through exhibit vs. participatory exhibit)? and 3) Does the age and/or sex of the parent or children affect the interactions observed? It was hypothesized that different family types would be observed and that their behavior would be affected by the type of exhibit with which they were interacting. It was also hypothesized that age and sex differences would be observed.

Fifty-six families were followed during their visit and their behavior coded. The frequency data were tabulated and analyzed utilizing generalizability theory and cluster analysis. The major findings indicate that there are different "types" of families but that they are not distinct groups. Management behaviors were observed in equal frequencies for both groups but what was different was their family learning style. There seem to be two major "types": 1) the Guided Learning Family and 2) the Independent Learning Family.

These family types can be envisioned as occupying different ends of a continuum of family behavior and correspond to the educative and noneducative types originally described in the pilot study. This new conceptualization (Guided vs. Independent), however, recognizes in a nonjudgemental fashion, that families may interact in very different ways that can not necessarily be described as good or bad, just different.

These data also suggest that family behavior is affected by exhibit type; however, the differences observed were not as significant as had been hypothesized. It is very possible that these three exhibit types (traditional case exhibit vs. walk-through exhibit vs. participatory exhibit) were not significantly different enough to be perceived as distinct behavior settings by visitors. Perhaps if differences had been more salient, the effect on family behavior would have been more evident. These findings should be useful to both museum professionals designing exhibits and researchers interested in how families learn together.

PHILOSOPHICAL ASSESSMENT OF ANDRAGOGY AS AN ALTERNATIVE TO PEDAGOGY FOR ADULT SCIENCE EDUCATION

Preston Prather
John W. Shrum

Philosophical research methods were used to examine the adult segment of lifelong science learning and to identify curricular and instructional needs related to issues in science education for adults. The study indicated that the traditional pedagogical approach to formal education, based on the assumption that the purpose of education is to transmit the knowledge and skills that youth need to function for the rest of their lives, is no longer adequate for the educational needs of modern society. The literature review revealed a consensus among adult education theorists that an alternate educational technology will be required to accommodate lifelong learning.

An analysis of the adult segment of the student body encompassed by the emerging trend toward lifelong learning indicated that an alternative curricular and instructional approach is especially needed to accommodate the science learning needs of out-of-school adults. Studies on labor trends reported that millions of skilled laborers and factory workers are finding their training obsolete in a rapidly changing, science-technology oriented employment arena.

Millions of workers faced with job obsolescence have produced the largest potential clientele for science learning in the history of science education. But this study revealed few options for a basic science education open to

out-of-school adults. A review of adult education theory indicated that a student-centered approach will be necessary for adult science education. The study also revealed that andragogy, an adult education technology developed in North America and Europe over the past half-century, may accommodate the unique instructional needs of out-of-school adult science students. A survey of curriculum theory revealed models of student-centered curricula that may be compatible with adult science-learning needs. Speculative analysis of these observations produced a general compilation of teacher-characteristics that appear appropriate for adult science education.

A comparison of the basic applicability of pedagogy and andragogy to student-centered science instruction was conducted; and the merits of compatible curricular models were examined. Recommendations for research in these and other areas of adult science education, concluded the report.

ATTITUDE CHANGES OF TEACHERS INVOLVED IN A PROJECT FOR THE
IMPROVEMENT OF PHYSICAL SCIENCE INSTRUCTION IN
RURAL ELEMENTARY SCHOOLS

Karen L. Ostlund
Dick E. Hammond

The purpose of this study was to explore changes in teacher attitudes toward their perceived competencies in teaching science after participating in a project which provided opportunities to acquire important concepts and information in the physical sciences and to develop effective instructional strategies for teaching those physical science concepts to elementary level students. The participants attended four concentrated workshops, hosted three on-site visits from university science educators, developed practical instructional units, and shared their accomplishments with a variety of audiences.

The questions asked were:

- (1) Do elementary classroom teachers' attitudes toward their perceived competencies in teaching science change in a positive direction following participation in this project?
- (2) Which components of the project were perceived as the most helpful by participants?

The subjects of this study were 30 elementary level classroom teachers, i.e., teams of three (3) elementary teachers from ten (10) rural school districts. A pre- and post-opinionnaire was designed to measure the attitudes of elementary teachers toward their perceived competencies in the areas of content, curriculum and methodology in the physical sciences. One-way analysis of variance was used to analyze the 43 statements on the opinionnaire. Additionally, at the conclusion of the project, each participant responded to a questionnaire addressing issues regarding the quality of project content as well as the value of that content for their professional roles.

The results of this study indicate that coordinated efforts between rural school districts and universities to improve science teaching in the elementary schools need a greater emphasis on helping teachers organize their thoughts and activities around concepts in science. A combination of activities including inservice workshops, on-site visitations by university personnel, and developing instructional units for dissemination contributes to improvement of attitudes toward perceived competencies in teaching elementary science.

AN INSTRUCTIONAL IMMUNOLOGY LABORATORY SIMULATION

Antoinette Hodapp
Joseph Faletti

The primary instructional tool for training students to do science as opposed to simply understanding its results is the teaching laboratory. Unfortunately, in some biological sciences such as immunology, there are many dangers, costs and inconveniences which get in the way of the problem-solving behavior that a laboratory exercise teaches and which often lead to the elimination of labs. One possible solution is to abstract out the essential problem-solving component of laboratory work eliminating the time constraints, live animals, manual use of laboratory equipment and dangerous substances by simulating the behavior of the devices and materials in a computer. This requires that significantly different kinds of knowledge be represented in a computer than typical expert systems or intelligent tutoring systems. A basic prototype and design for a knowledge-based computer simulation of the materials and facilities in an instructional immunology laboratory have been constructed. The program contains knowledge about the behavior of the various types of equipment, biological materials, chemical reagents and procedures used in an immunology laboratory, along with the reactions when they are mixed or used with each other. The current state of knowledge about the mechanisms of immunology turns out to contain significant gaps which sometimes make the accurate prediction of results difficult to simulate. The methods developed might be more successfully applied to better understood areas of biology or chemistry. They also represent a significant step on the road to a laboratory tutorial which can explain itself.

THE RELATIONSHIP OF THE SCIENCE PROCESS SKILL OF PREDICTION TO FACTORS INVOLVED WITH THE USE OF BIOLOGICAL COMPUTER SIMULATIONS

Derrick R. Lavoie
Ron Good

The science process skill of prediction is important for the progress, learning, and teaching of science. It should, therefore, be included as a natural part of any science curricula which are process or inquiry oriented. Review of the science education literature revealed very few studies dealing with the acquisition, teaching, or assessment of prediction skills. It is clear that research is needed to initially understand the process or mechanism

of prediction so that, ultimately, it can be effectively incorporated into the science curriculum.

This research need gives impetus to this study whose general purpose will be to describe, in detail, the patterns and strategies of thinking associated with making predictions about science systems in biology. Information processing, which has been shown to be quite useful in studying how people think, will provide the theoretical framework.

Naturalistic qualitative research methods will be employed for data collection. Initially, Piagetian interviews assessing formal schema of proportion, combination, and probability will be administered to randomly selected high school biology students until six formal and six concrete subjects have been identified. Clinical "think aloud" interviews will then be used to collect verbal data from each selected subject while they make predictions at early and late stages of a three-stage learning sequence. Computer simulations in ecology ("Evolut" by Conduit; "balance" by DEE) will provide a good prediction environment.

All prediction "think aloud" interviews will be video taped and analyzed using qualitative techniques of verbal protocol analysis. Encoded transcripts of each prediction episode will be compared and discussed relative to early and late stages of the learning sequence (low vs. high knowledge), Piagetian cognitive stage (concrete vs. formal), and success at making predictions (poor vs. good). Additionally, an effort will be made to develop diagrammatic paper models of the prediction process.

As a result of this research the nature or thought processes of prediction concerning computer simulations in ecology will become clearer. A research base will be established from which more fruitful research on prediction can be conducted. The data may also prove useful for computer modeling of the prediction process. Lastly, the information gained from this study could lead to effective teaching, learning, and assessment procedures centered around the science process skill of prediction.

TEACHERS' EXPERIENCES IN IMPLEMENTING THE EQUALS PROGRAM: A QUALITATIVE STUDY

Catherine R. Conwell
Richard B. White

The EQUALS program provides an innovative approach for solving the problem of the underrepresentation of females and minorities in mathematics and science courses and careers. One component of the EQUALS program is the inservice

training program for K-12 science and mathematics teachers, counselors and administrators. The training provides instructional strategies to encourage cooperative learning; curriculum materials to promote problem solving and skills in spatial visualization; and classroom activities that emphasize a hands-on approach to understanding math and science concepts. To date, the EQUALS inservice training has been implemented in the Charlotte-Mecklenburg Schools during the school year 1984-85 and again in 1985-86. While the inservice training is respected and strongly supported, program proponents have not been able to describe fully the changes in teacher practices and attitudes which develop from the EQUALS training. The purpose of this research is to describe in detail the outcomes of the training from the perspectives of participating teachers.

A qualitative research approach termed emergent naturalistic design (Guba and Lincoln, 1981) is used. The purpose of the approach is to discover and characterize the experience of involved respondents. The outcome is detailed description of various respondent perspectives.

The primary benefit of this research should be the enhanced professional development of teachers. They should experience development through:

1. opportunities to improve their own problem solving skills;
2. new curriculum materials and methods which improve their student's problem solving skills;
3. a heightened awareness of the importance of math and science to their students' future careers;
4. involvement in research efforts which evaluate the intervention activities aimed at attracting and retaining young women and minorities in math and science; and
5. exposure to how math and science are being used in a range of career fields.

Ultimately, the benefits of this research will reach all the students of the EQUALS teachers, but especially the female and minority students. The EQUALS project attempts to:

1. increase students' awareness, interest and understanding of the importance of science and math in their studies and work;
2. improve students' ability and confidence in learning science and math; and
3. encourage students to persist in elective science and math courses.

Finally, this research may aid society as a whole by providing a talent pool sufficient to meet the present and future needs for a scientific and technical workforce.

THE IMAGISTIC PROCESSING SYSTEM: A COMPONENT OF A MODEL
FOR COMPETENCY IN MATHEMATICAL PROBLEM SOLVING

Sandra Judith Costello

A summary of the historical roots of problem solving is followed by a brief discussion of imagery. A model for competency in mathematical problem solving is introduced that provides for interactions among four representation systems: verbal/syntactic processing, imagistic processing, formal notational processing, and a planning system. Two mathematical problems and their solutions are used to demonstrate application of the model.

AN EVALUATION OF THE SIMULATION: THE FACTORY

E. L. Shaw, Jr.
James P. Okey

The purpose of this study was to evaluate the effect on achievement by the simulation "The Factory." The instructional treatments compared were the computer simulation and conventional classroom instruction.

Specific questions addressed in this study were:

1. Does the simulation increase achievement if used as an instructional strategy?
2. Does the simulation enhance the problem solving strategies of fifth grade students?
3. Does the use of the simulation result in enhancement of visual discrimination?

Outcome data were and will be collected from two fifth grade classes. Topics covered in this study included similar and opposite attributes, sequence of events, problem solutions, and certain process skills such as observing, inferring, hypothesizing, and testing. The students worked on the simulation as a class with the teacher operating the microcomputer and simulation. The study lasted ten days.

The following answers to the research questions appear to be tenable based on achievement collected and to be collected during the investigation.

1. The use of simulation will result in higher achievement than conventional classroom instruction.
2. The problem solving strategies will be enhanced as the result of the simulation.
3. The use of the simulation will result in higher achievement on a visual discrimination than conventional classroom instruction.

CALIFORNIA SCIENCE TEACHERS LEARN TO SERVE AS COLLEAGUE/MENTORS

Rita W. Peterson

The nation's critical shortage of science teachers in the K-12 schools has led many school districts throughout the United States to design mentor teacher programs as a means of addressing local shortages of science teachers. In some mentor teacher programs, veteran science teachers are being asked to serve as mentors not only to newly credentialed science teachers but also to an unusual cadre of newcomers to their field, including pre-credentialed science practitioners from industry and cross-over teachers who are credentialed to teach other subjects but find themselves teaching science. This is not an easy task for the best and busiest science teachers who are asked to be mentors.

California serves as a good example to illustrate the extent of the critical shortage of science teachers and the concomitant emergence of mentor teacher programs. State Department of Education data show a current annual requirement for 1,600 teachers of science and mathematics, while only about 300 enter the profession each year. During 1984-85, the California State Department of Education invested \$30.8 million (to support 3% of the teachers in the state) in mentor teacher programs in school districts throughout the state.

Yet even though mentor teacher programs have mushroomed throughout the country, very little research is being conducted to document the effectiveness of mentor programs which assist those who teach science, and thus ultimately to improve science teaching in the classroom.

In 1983, the National Science Foundation funded a 3-year project (\$547,000) called the UCI Science and Mathematics Mentor Teacher Project. The purpose of the project is to update the academic background of 150 outstanding science and

mathematics teachers, and to prepare them to serve as colleague/mentors in their local school districts in Orange and Los Angeles Counties of California.

As part of this project, the author is conducting a three-year ethnographic study to document the strategies used by mentor teachers of science, and to describe the characteristics of effective mentor teachers. In this presentation the author will describe the results of the first year of the three-year ethnographic study, and will guide a discussion of the difficult issues and challenges involved in preparing science teachers to serve as mentors. Participants in the session will receive a pre-publication issue of a handbook for mentors called M is for Mentor.

THE GENETICS TUTORIAL PROJECT: COMBINING EDUCATIONAL RESEARCH,
EXPERT SYSTEMS AND INSTRUCTIONAL SOFTWARE

James Stewart
Michael Streibel
Angelo Collins
Ken Koedinger

In this presentation we will describe and demonstrate how research on learning and problem solving in transmission genetics is being combined with advances in the development of expert systems to create an Interactive Genetics Tutorial Project. The project draws upon research on how experts (Ph.D. geneticists) and novices (university and high school-students) solve realistic genetics problems. This research has become the starting point for the development of a computer program designed to help students learn genetics content and problem-solving strategies. The project has three innovative components: a genetics PROBLEM GENERATOR program; a CONSULTING TUTOR program; and an interactive video and graphics component. The GENERATOR presents students with realistic problems and permits them to generate unlimited experimental data and infer inheritance patterns from it. The TUTOR interacts with students, based upon their problem-solving approaches, to help them achieve meaningful genetics problem-solving skills. In addition the TUTOR will contain still visuals of phenotypic information and moving visuals and computer generated graphics of meiotic processes to help students develop a conceptual understanding of genetics problem-solving strategies.

DEVELOPMENTS IN STYLE AND PURPOSE OF RESEARCH
ON LEARNING OF SCIENCE

Richard F. Gunstone
Richard T. White
Peter J. Fensham
Russell H. Yeany, Jr.

Recent years have seen a substantial growth in research that probes children's ideas about natural phenomena. This symposium places the research in a context that enables comprehension of how it informs and influences the practice of science education. To this end, past, present, and future styles of research are discussed. The predominant style of past research has been based on elaborate experimental designs and complex statistical analyses of data. These studies helped focus concern on questions about individual learning which the studies did not seek to answer, e.g. why does the learning resulting from a particular treatment vary between individuals? What is understanding and how can it be assessed? Such questions lie at the heart of current probing of children's ideas. One other form of previous research is addressed - that being work on children's ideas undertaken in the 1930s and 40s. The failure of this work to influence science education, or even to survive, is considered in ways which assist an understanding of the nature of present research on children's ideas. Three issues of importance in the present probing of children's ideas are considered: the mutually beneficial interactions between research and practice; the extent to which implications for practice have been derived from the research; and the ways in which the research links with the broader field of cognitive psychology. These issues have influenced the development of the research. From this present context, future developments in the research field are described. These focus particularly on research on the strategies used by learners, and on the continued growth of interaction between research and practice. In the latter case, the importance of exchange of roles (researchers becoming teachers, teachers becoming 'action' researchers) is considered. Neither of these developments is specific to science education, although both are developing from it.

DECISION-MAKING, LOGICAL REASONING, AND OTHER FACTORS
RELATED TO STUDENT SUCCESS ON THE NURSING STATE BOARD EXAMINATION

Carol Bierman

A study was undertaken to determine the criteria which most effectively distinguished between success/failure on the State Board Test Pool Examination for registered nurse licensure. Various selected cognitive and non-cognitive variables were used as independent variables. Relationships were determined between the dependent variable and achievement scores (reading, writing, and mathematics), cognitive variables such as logical reasoning tasks and grade point average, decision-making style, and demographics. Some of these variables were chosen in an attempt to relate the nursing process with the State Board Test Pool Examination. A stepwise multiple regression analysis was performed to predict performance on the State Board Test Pool Examination for registered nurse licensure. College grade point average, negative rational decision-making style, and the achievement variable, verbal ability (reading) contributed significantly to the multiple regression for predicting performance on the State Board Test Pool Examination. Approximately 46% of the variance was explained by these variables. The fact that negative rational decision-making style appeared as a significant predictor pointed to the State Board Test Pool Examination being a rather dogmatic examination requiring more dependent decision-making style on the part of test takers.

THE MONTHLY FLUCTUATION IN PERCEPTUAL/READING ACCURACY
IN FEMALE COLLEGE STUDENTS

Thomas R. Lord
Kathleen Taylor

Numerous investigators have found a cyclic patterning of chemical, physiologic and psychological events in women during their monthly menstrual cycle. Among the fluctuations, sensory sensitivity to visual stimuli has been found in naturally cycling women but not in men or females using oral contraceptives. This study was undertaken to find if a women's perceptual/reading accuracy was influenced by her monthly cycle, and, if it was, did it place her at a disadvantage in visual accuracy in the classroom?

Using the Stroop phenomena to measure perceptual accuracy, several dozen students from a small suburban two-year college were randomly sampled. Males

were included in the sample to both act as a control and to establish a mean score for their sex. Tests were run on the population for four consecutive weeks. The data from the tests were examined both as a function of sequential measures and as a function of the menstrual cycle.

The results indicate that a woman's perceptual/reading accuracy is lowest during her period. This is followed by an increase in visual sensitivity to ovulation when it levels out to remain elevated for the remainder of her cycle. This would suggest that women are at a perceptual disadvantage for learning for almost two weeks during the month. Interestingly, at no point during the study did the control group of male students score higher on the test than the females. This supports the claim that women are more accurate than males on tasks that involve perceptual/reading accuracy.

HARDWARE AND SOFTWARE DEVELOPMENT OF HIGH TECHNOLOGY SCIENCE INSTRUCTION: A CASE HISTORY OF THE INTERACTIVE VIDEODISC SYSTEM

William H. Leonard

A marriage of computer and television technologies has evolved into an exciting new learning system: interactive videodisc instruction. The development of the hardware components of a specific interactive videodisc system, the development of two instructional programs using this system for university general biology courses, the actual use of this technology in an instructional setting, and the potential for future development using this space-age technology are given. Student perceptions of the use of an interactive videodisc system for biology instruction in university general biology are also illuminated.

SCIENTIFIC LITERACY AND INFORMAL SCIENCE TEACHING

Johan Strauss
J. Maarschalk

Previous concepts of scientific literacy as exemplified by Pella, Lucas, Rubba and Anderson, Guthrie and others are usually confined to scientific

performances, ability and concept mastery. Tamir's work on cognitive preference is used to broaden the concept of scientific literacy to encompass also whether a person "does" or "wants" to "do" science. Informal science teaching (as distinguished from the interchangeable way in which many authors blithely use "non-formal" and "informal" teaching) is identified as unplanned and spontaneous science teaching (e.g., discussions on the spur of the moment over coffee) and thus an indicator of scientific literacy. It (informal science teaching) can, however, also occur when the learner is physically absent from the teacher, e.g., when the learner spontaneously reflects on scientific matters.

Research designs are discussed in which formal science teaching (in schools), non-formal science teaching (in museums, clubs, etc. and through media exposure) and informal science teaching are respectively used as dependent and independent variables.

The dismal failure of formal science teaching alone to promote scientific literacy is discussed. It is suggested that the explicit aim for all formal and non-formal science teaching should be to eventually result in informal science teaching and, thus, scientific literacy.

CATEGORIZATION OF GENETIC PROBLEMS BY SUCCESSFUL AND UNSUCCESSFUL PROBLEM SOLVERS

Mike U. Smith

Certain studies in physics and mathematics have suggested that experts often begin a problem by recognizing it as one of a given type. This recognition is hypothesized to "activate a general schema" which includes a set of appropriate approaches for solving this type of problem. This study addresses four basic questions out of the previous research:

- 1) Do subjects who are successful at solving a group of genetics problems tend to sort a second group of genetics problems differently than do subjects who are unsuccessful genetics problem solvers?
- 2) If so, what are these differences and what are the bases or principles upon which these different categorizations are made?
- 3) Do successful subjects tend to focus on the same words in the problem statement as being important in this categorization?

- 4) How does this categorization develop as a problem-solving strategy?

The subjects for this study consisted of 20 biology major undergraduates, four medical students, four medical residents, and ten faculty geneticists. Subjects were classified according to whether they solved a set of three preliminary problems correctly, solved none, or solved less than three. Subjects were also asked to separate 24 typical genetics problems according to how they would solve them and the time required was recorded. The subjects were also instructed to circle the "keyword/s" in each problem which were important in their categorization decisions. Two subjects from each of the four groups were also questioned at length about how their categorization decisions were made. In addition, the subjects were asked to report their perceptions of how frequently in approaching genetics problems they initially recognize a problem as belonging to a general type. The remaining 30 subjects received a packet of problems and instructions which they sorted in private, recording the time taken for the categorization.

The data collection described above is currently in progress. These subject groups will be compared according to the following: 1) the mean number of categories produced, 2) the mean number of problems per category, 3) the mean number of categories required to include a majority of the 24 problem sample, 4) the similarities between category labels or descriptions, 5) the mean number of keywords identified, and 6) the frequency at which the same keywords were identified in the different groups. A cluster analysis will be performed to provide further insight into the underlying distinctions between the types of categories chosen. Special emphasis will be placed on identifying possible developmental patterns which could guide instructional design.

Twenty-two additional subjects will be asked to sort a second group of 24 problems selected to emphasize the identified essential distinction/s between the type of categories selected by successful vs. unsuccessful subjects.

The answers to the questions raised in this study promise to have direct implications for instruction including whether or not categorization should be taught as a problem-solving strategy, and if so, how it might be taught so as to take its normal pattern of development into account.

ANALYSIS OF EXPERTS' AND NOVICES' PERFORMANCE
WHILE SOLVING PROBLEMS ON CHEMICAL EQUILIBRIUM

Moises Camacho
Ron Good

The major purpose of this study is to describe the problem-solving behaviors of experts and novices in solving chemical equilibrium problems. Other basic objectives are: To determine what general and specific problem-solving behavior appear to be unique to chemical equilibrium problem solving. To compare problem-solving behaviors in chemistry with those behaviors exhibited in other domains such as physics and biology. To investigate to what extent problem-solving performance in chemical equilibrium is affected by specific and general knowledge of other concepts involved such as stoichiometry, thermodynamics, kinetics, and mathematical skills needed. Since chemical equilibrium is a pervasive phenomenon in nature, a central topic of the chemistry curriculum, and involves several chemistry concepts i.e., stoichiometry, thermodynamics, kinetics) it provides an important area for the study of problem-solving performance in the chemistry domain. The methodology involves the think-aloud technique, described in detail in Ericsson and Simon's Protocol Analysis: Verbal reports as data. A pilot study was conducted to refine the chemistry problems, methodology, time needed by novices and experts, etc. The main study will involve video-recording and analyzing the problem-solving behaviors of twenty subjects while they solve the same problems by the think-aloud technique.

The subjects involve 14 novices and 6 experts. To have enough variability of problem-solving behaviors, the main sample will include high school students who have taken one or two courses in chemistry, undergraduate non-majors, undergraduate majors in chemistry, graduate students, and professors of chemistry. The high school students are drawn from the Development Research School (DRS) of Florida State University (FSU). The undergraduate majors, graduate students, and professors are from the chemistry department of Florida State University. The scheme for analysis of data will follow the suggestions outlined in Ericsson and Simon's book and M. Smith's 1983 dissertation.

IDENTIFYING STUDENTS' DIFFICULTIES IN UNDERSTANDING
CONCEPTS PERTAINING TO CELL WATER RELATIONS

Yael Friedler
Pinchas Tamir

Three different instruments to identify students' difficulties in understanding concepts pertaining to cell water relations were used: (1) student self report, (2) two forms of true-false tests, and (3) students' definition of two concepts: diffusion and osmosis. Five hundred and seven students in grades nine to 12 were administered the three instruments. An analysis of the student self report showed that 8 of 15 concepts had been studied by at least 70% of the students. All 15 concepts received relatively high understanding rating (mean score of 3.8 out of 5). The results of the two forms true-false tests were 57% and 54%. For the definitions, the mean score was 59 out of 100. Further indepth analysis of each instrument, and their contribution to existing misconceptions regarding diffusion and osmosis at the various grade levels is discussed.

SCIENCE CURRICULUM DEVELOPMENT WHICH SUPPORTS
SCHOOL BASED CURRICULUM DEVELOPMENT

Jeff Northfield

This session will discuss the way in which curriculum development ideas have been greatly modified to provide a model which places the teacher at the center of curriculum development. The session will include displays of the materials which have influenced schools to accept a greater responsibility for curriculum development. The materials developed to support schools in this role will be displayed and examined to emphasize the differences from conventional curriculum materials.

The assumptions underlying School Based Curriculum Development will be developed so that implications for supporting the curriculum process can be discussed. Examples of the way in which science teachers are being supported will be presented to illustrate the curriculum development policy that is going to be followed in a major review of science education in one state of Australia.

THE ACCURACY OF MALE AND FEMALE JUNIOR HIGH SCHOOL STUDENTS'
PERCEPTIONS OF PARENTAL FIGURES' SCIENCE ATTITUDES AND THEIR
RELATIONSHIP TO STUDENTS' ACHIEVEMENT IN SCIENCE

Melody J. Leithold
H. Seymour Fowler

Previous research suggested that the attitudes a student perceives from adult significant others toward himself or herself affect classroom achievement. The student incorporates the perceived attitudes, positive or negative, into his or her self-image and acts accordingly. This study investigated the direction and accuracy with which students perceive science-related attitudes from adult significant others. The adult significant others were defined as the parental figures and adult role models in a student's everyday experiences. They were identified as the father, the mother, and the science teacher. The science-related attitudes considered were those that the adult held toward the student as a science learner and those that the adults held toward science. Analysis of variance and t-test procedures were used to determine if significant differences existed between the mean science grades of eighth-grade students depending on the accuracy and direction of the attitudes they perceived. Student gender and identity of the adult significant other were parceled out as confounding factors in the comparisons.

The data indicated that the majority of students held inaccurate perceptions of the adults' attitudes toward the student as a science learner and toward science. However, the accuracy of the students' perceptions did not seem to affect the students' achievement. The students' achievement was influenced by the direction of the perceived attitudes. The students who perceived positive attitudes from the adults tended to have a significantly higher mean science grade than their counterparts who had perceived negative attitudes from the adults. A large percentage of the students perceived the attitude direction of their adult significant others not as positive or negative, but as undecided, even though the largest percentage of the adults held positive attitudes. When the confounding factors were considered, data indicated that a gender difference appeared when the mean science grades of boys and girls who perceived negative attitudes from the adults were compared. In addition, perceived attitudes from the mothers and science teachers seemed to be more influential than the perceived attitudes from the father.

THE USE OF MNEMONICS IN TEACHING MIDDLE SCHOOL SCIENCE

George Banks
Michael Piburn

Of the many separate skills that contribute to learning in science, one that is well known but often overlooked in research is the ability to retain information and retrieve it. This study reports the result of an attempt to teach mnemonic techniques to middle school science students in conjunction with their regular course of study.

Two classes, of 31 and 32 students each, were chosen as control and experimental groups. Both classes received the same instruction, and from the same teacher, during units on "weather" and "minerals." The experimental group received additional instruction from another person on two memory techniques; the Link System and the Cartooning System. Pre and posttests of both vocabulary and comprehension were given for both units.

Before the experiment, the control and experimental groups achieved similar and rather low scores on all pretests. There were no significant differences between the groups. After instruction, scores of both groups had improved remarkably. However, the posttest scores of the experimental group were significantly higher than those of the control group. The instruction in memory techniques apparently led to significantly higher performance both in vocabulary and in comprehension in both units.

The proper use of mnemonic techniques, by the teacher, can be an instrument to help students retain information. More teachers need to be given help in incorporating such strategies into their unit and lesson plans. Properly used, these techniques would improve retention and reduce the need for remedial teaching.

EFFECTS OF ETHNICITY ON ATTRIBUTIONS, SELF-CONCEPTS AND
ACHIEVEMENT OF MALE AND FEMALE WESTINGHOUSE AWARD WINNERS

James R. Campbell
Charlene Connolly
Jean Pizzo

The objective of this study was to examine the self-concepts and attributions made by Asian-American and Caucasian Westinghouse Award winners. The study centered upon comparisons of the males and females of each ethnic group.

The sample consisted of a random sample of the 1984 national Westinghouse Award winners and the full cohort of 1985 national winners. The study showed that females (especially Caucasian females) had significantly lower self-concepts than both groups of males. More importantly, we found that this "ethnicity connection" must be included in the theoretical frameworks that are currently being developed to explain gender differences in attributions, self-concepts and achievement. In our study, ethnicity was shown to affect both self-concept development and achievement.

THE IMPACT OF MICROCOMPUTER-BASED SCIENCE
LABS ON CHILDREN'S GRAPHING SKILLS

Janice R. Mokros
Robert Tinker

Microcomputer-based Labs (MBL)--the use of microcomputers for student-directed data acquisition and analysis--represent a promising new development in science laboratory instruction. Students use probes that are connected to the computer to gather data on physical phenomena such as motion or temperature. These measurements are instantly graphed in real time on the computer screen. Because the tools link the concrete data-gathering experience with an instantaneous symbolic representation of that experience, they are a potentially powerful learning device for science laboratories.

The purpose of this descriptive study was to determine the impact of microcomputer-based labs on middle school students' understanding of graphs of distance and velocity. The study was based on the premise that understanding the use and interpretation of symbol systems such as graphs is a central developmental task for all children.

Sixth grade students received five MBL lessons on distance and velocity, where they were challenged to construct different kinds of graphs via their own movements and the movements of a toy cart. They used a sonic detector "probe" linked with the microcomputer to produce and observe the graphs of these motions in real time. Classroom observations, consisting of narrative records of the behavior of lab groups, were conducted on all five days, using an event sampling process. A post-intervention quiz, which required students to match graphs with written descriptions of these graphs, was administered.

Results indicated that after experience with MBL, students could accurately match complex graphs of physical phenomena with written descriptions of these graphs. Children attained a mean accuracy level of 85% on the matching task which involved graphs of position and velocity (including negative velocity). Observations corroborated these findings, and showed that students' understanding of graphs was resistant to countersuggestion.

The power of the intervention stems partly from the fact that it reinforced many learning modalities. The kinesthetic experience of using one's own movements as "data" was linked with the visual experience of seeing graphs of these movements on the screen. By linking the concrete and the abstract, MBL may be providing a bridge that facilitates the development of formal operational thinking.

USE OF MICROCOMPUTER SIMULATIONS OF SCIENCE ACTIVITIES
TO STUDY THE RELATIONSHIP BETWEEN SEQUENCING AND
NATURE OF LEARNING ACTIVITIES AND CONCEPT DEVELOPMENT

Arthur L. White
Robert McNemar

Educational research favors the use of mixed sequences over sequences of all positive instances in a conjunctive feature identification task, while psychological research favors sequences of all positive instances over sequences of mixed positive and negative instances.

Middle school science students were given instruction on using negative instances in a conjunctive letter string task. They were given sequences of instances and asked to identify the critical features of the microcomputer simulation of science activities. Students were able to use negative instances and to identify the two critical features of the microcomputer simulation of science activities.

The two sequence conditions (+ and \pm) were crossed with the frequency conditions (1:1 and 9:1) to form four treatment groups. The sequences consisted of either all positive instances (+) or alternating positive and negative instances (\pm). The features in the irrelevant dimensions were either balanced so that each occurred about 50% of the time (1:1) or they were weighted so that one feature occurred about 90% of the time (9:1). There was significant interaction between the sequence conditions and the frequency conditions. This interaction suggests feature frequency is a potential variable in explaining the differing results between the psychological research supporting the use of mixed positive and negative instances.

THE EFFECTIVENESS OF SUPPLEMENTING THE TEACHING
OF THE VOLUME DISPLACEMENT CONCEPT WITH USE OF
AN INTERACTIVE COMPUTER SIMULATION

Bonita DeClercq
Eugene Gennaro

The concept of displaced volume has been identified as difficult to teach, yet essential to the understanding of other science concepts such as density and buoyancy. This study examines the effectiveness of supplementing the

teaching of the volume displacement concept using an interactive computer simulation.

Students in 9th grade Introductory Physical Science classes were pretested on their understanding of the volume displacement concept, divided into "high" and "low" pretest groups, and then, for each period of the day, students in the "high" pretest group were randomly assigned to either the experimental or control group. The same was done for the "low" pretest group for each period of the day. After completion of the regular text material, demonstrations, and experiments on volume displacement, the experimental group received an additional 10-20 minutes of instruction on these concepts using an interactive computer simulation. A posttest was administered 55 days later.

The posttest revealed that the experimental group scored significantly higher than the control group who received no exposure to the computer simulation. This study suggests that computer simulated experiments may be effective adjuncts to the science curriculum in the learning of some topics by using a small expenditure of time.

Once a school has made the initial investment in computer hardware and software, the cost of performing supplemental experiments using interactive computer simulations is essentially zero. In the future, it may be more economical both in terms of time and money to do the more basic and less expensive experiments as hands-on experiences and supplement these with effective simulations that if done in hands-on fashion would be either too expensive or too time consuming.

EVALUATING CONSTRUCT VALIDITY OF A BASIC PROCESS SKILLS
TEST USING QUALITATIVE RESEARCH METHODS

Linda Cronin
Meghan Twiest
Michael Padilla

Paper and pencil tests of science content and skills are often used because they are easy to administer and score, especially to large groups of students. Before a test can be used by classroom teachers and researchers, its validity must be demonstrated. One of the best ways to evaluate science process skills test items for construct validity involves comparing actual student responses to demonstrations of process skills-related activities with performance on a paper and pencil process skills test. The objective of this study was to develop and qualitatively evaluate a set of basic process skills activities in order to establish the construct validity of a basic process skills test.

The BAPS test is a pencil and paper test designed to measure the following six basic process skills: observing, communicating, classifying, measuring, predicting, and inferring. The test contains six items of varying difficulty for each identified process skill in a multiple choice, four-answer option format. Although the test is designed to measure basic process skill ability in science, no science content knowledge is required to successfully respond to the items. BAPS reliability (KR-20 = .82) and content validity were reported in a previous study.

For this study, five activities requiring observable demonstration of the six basic process skills were developed. The questions asked during the activities were designed to parallel the test items in both complexity and style. The complete activity sequence contained three questions of varying difficulty for each of the six basic process skills.

The BAPS test was administered in a large, urban school district in Georgia to 133 students in grades 4, 6, and 8. For this study, a subset of the sixth graders completing the test was chosen to participate. Two participants were chosen from each of the following three total score ranges: POOR (16-21), SATISFACTORY (22-27), and EXCELLENT (28-33).

Student responses were evaluated and rated on a prepared coding sheet immediately after the participants answered each question. The entire session was tape recorded so the numerical response ratings could be evaluated at a later time.

The data gathered from these activities were analyzed in two levels. The first analysis consisted of an evaluation of the quality of the numerical rating system. After listening to the taped transcripts of responses, only one

response rating out of a total pool of 108 responses was changed. This indicates that when the rating system is used by an observer familiar with basic process skill responses, the system is both an efficient and an accurate tool for performance evaluation.

The second analysis dealt with the relationship between BAPS and the activities and questions developed. Analysis indicated that there was a greater chance of variation in scores of the two measures on participants in the lower end of the continuum of BAPS test scores. Generally, it appears that lower level students perform better on demonstrations of the process skills than they do on the written test. A Pearson product moment correlation between the two sets of scores was also calculated. This correlation of .67 (corrected for attenuation of BAPS) indicates a high degree of agreement between the skills tested in BAPS and the demonstrations of these skills.

THE DEVELOPMENT, VALIDATION AND ADMINISTRATION OF A TEST OF SCIENCE PROCESS SKILLS TO COSTA RICAN SECONDARY SCHOOL STUDENTS

Juan M. Esquivel

The purpose of this paper is twofold. First, to describe the development and validation procedure of a science process skill test in Spanish. Second, to report the data obtained from the administration of the test to a sample of seventh grade Costa Rican students.

Several instruments are available to measure basic and integrated skills, among them, tests developed by Wallace, Isaccs, Fadilla, Dillashaw and Okey, all in the English language. A Spanish test on science process skills is not available. There is a need of such a test in order to assess the impact on secondary Costa Rican students of the impetus given to the teaching of process skills in general science and in chemistry.

The following criteria were outlined for test:

1. It should measure the following science process skills: observing, classifying, measuring, communicating, graphic reading, predicting, inferring, controlling and manipulating variables, interpreting data, formulating hypotheses, defining operationally and planning investigations with emphasis on the last five process skills (integrated).
2. Its content should not be slanted towards any particular subject.

3. It should be capable of being administered to a class-sized group.
4. An average test readability below the seventh grade level.
5. A multiple choice, four option, format.
6. The test should not last for more than 35 minutes.

Objectives were written for each process skill. Items were developed to match these objectives. More emphasis was given to integrated process skills (20 items) than to basic process skills (7 items). A panel of 10 science educators judged the congruence between each item and the objective it was supposed to measure, the objectivity of the key score, and the overall clarity of the test items and the test instructions.

The test was administered as a field test to a sample of 70 tenth graders. The KR-20 test reliability was 0.60. The revised version was field-tested a second time with a sample of 200 secondary students of 7th and 10th grade. Item difficulty and discrimination indices were obtained and the test reliability calculated with this data was 0.73 (KR-20). The final version of the test was administered to samples of 503 seventh, 400 tenth and 528 eleventh graders. Means by region, type of secondary school and sex were compared by means of analysis of variance.

A content valid and fairly reliable instrument in Spanish is now available. The results of the administration to a sample of Costa Rican students reflect a very poor achievement in science process skills.

THE DEVELOPMENT OF A TEST OF SCIENCE PROCESS SKILLS FOR ELEMENTARY STUDENTS

Sylvia Leith

The purpose of this study was to develop valid, reliable and usable assessment instruments so that researchers and teachers may diagnose and monitor the science process skill acquisition of children of elementary school age.

Science teachers are very cognizant of public pressure to state and justify their position relative to the value of science teaching and its role in education. They must teach the essence of the scientific endeavour (product and process) as well as prepare children for the ever changing world

situation. Many national and international studies point to the need for improved science instruction in which there is an increased emphasis on the teaching and assessment of the science process skills at all levels. There is a dearth of these measures, especially at the elementary school level. This Test of Science Process Skills was developed specifically for this program.

This test has a multi-format approach and tests a selected number of the science processes. Because programs of elementary science stress the active involvement of the children, this test reflects this premise. The formats used are paper and pencil items, station-type performance items and individual performance items. Operational objectives for the science process skills were written and suitable items were selected and/or written for each objective. The science process skills which were selected were a meld of those from Science - A Process Approach and from the British Assessment of Performance in Science Study. They are basically observation, communication, interpretation of data, and planning and doing investigations. Items from other assessments were scrutinized and modified for the study; new items were written when necessary. Two written tests were designed - grade 3 and grades 5/6. The tests were submitted to a team of three science consultants to establish the content validity of the items, the objectivity of the scoring keys, and the clarity and suitability of the items for the populations to be tested.

Because Manitoba has a diverse cultural and linguistic base, it was deemed necessary to use several groups in the field trials - Native, Français, French Immersion, and Urban/Suburban. The test was translated into French for the Français and French Immersion groups. An interpreter was available for the Native children. For the written test children from 15 intact classrooms (with several from each group) were tested at the grade 3 and at the grade 5/6 level, selected by the science consultants. For the performance items (station type), groups of 8 children were tested at the time (96 grade 3 children, 80 grade 5/6 children). The individual performance portion of the test was done on a more limited basis (48 children at grade 3, 38 at grade 5/6), each doing one of four items which took from ten to thirty minutes to complete. Children were randomly selected from each classroom by the teachers to give a representative sample.

The results indicated that the multiple format was appropriate for all the populations. Separate means were not reported as the study was not a comparative one. Discrimination indices and difficulty levels were established for all the items. Two thirds of the written items will be retained in the revised tests, whereas in the performance station type one item from the nine will be dropped, and one item from the four will be eliminated.

PRELIMINARY INVESTIGATION OF STUDENTS' STRATEGIES WITH ELECTRIC CURRENT

David P. Maloney

This paper reports on a preliminary study of students' strategies with electric current. The study used paper and pencil tasks to determine the strategies students used to decide which current-carrying wires had the larger net charge and which series circuits had the greater current at specified points. The tasks, which are based on the Rule-Assessment technique, are called "ranking tasks" since that is what students are required to do. Each task has six situations which the students are to rank on a specified basis. Values for the variables in the situations are chosen so that different strategies for ranking the situations will produce different sequences. In addition to ranking the situations, the students are also required to explain their reasoning. There were two tasks dealing with the net charge on a wire segment when a current was flowing in the wire. One of these had the current and the length of the segment as the variables. The other one had the current and the voltage across the segment as the variables. Two other tasks dealt with the current in a simple series circuit. One of these had two resistors in each circuit with the battery voltage and the resistances as the variables. The other task had circuits containing three resistors in series. For that task the resistance values varied, as did the location within the circuit where the current was to be estimated. These tasks were administered as both pretest items and as posttest items. The results showed that most of the students used definite, identifiable strategies, and that a small number of strategies accounted for the majority of strategies identified. For the tasks on current-carrying wires the commonly used strategies, both preinstruction and postinstruction, were derived from a conception that the wires had a net charge. One of the two series circuit tasks had about thirty percent of the students using the correct strategy on the posttest, but the other proved more problematic for the students. Strategies related to the "current is used up" alternate conception were common. Implications of these results for conclusions about student learning and for instructional strategies will be presented.

A COMPARATIVE STUDY OF STUDENT CHARACTERISTICS
IN TWC SCIENCE METHODS PROGRAMS: FIELD-BASED
METHODS AND TRADITIONAL METHODS

Diana M. Hunn

A detailed descriptive investigation was undertaken to examine characteristics of students enrolled in two different science methods programs for elementary education majors. The field-experiences track was developed in response to beliefs and evidence supporting early and continuous practice with science methods in elementary classrooms. Preservice students completed a sequence of one-hour methods classes with a science field-experience component for three semesters along with science content courses. Although this plan was the required program for elementary education majors, a "traditional" three-hour methods course taken on completion of science course requirements was maintained for transfer students and individuals changing majors. A comparative study of the two groups over a two-year period yielded information not previously identified by teacher educators involved with the program.

In addition to collection of demographic data (total hours completed, GPA, total hours of science, GPA in science), four other measures were gathered for each subject. A standardized achievement test in science was administered, a locus of control measure was completed, and a general self-concept score was gained through a self-reporting instrument. Interest in the construct of self-concept in science teaching led to the development of a scale from a parent self-concept in science measure previously reported in the science education literature. Relationships between self-concept in science teaching scores and other variables became a focus for this comparative study.

Significant Pearson correlations were found between several variables including locus of control and general self-concept, locus of control and GPA, and general self-concept and GPA. Total hours completed at the university contributed most to the group differences with the number of science hours, locus of control, and self-concept in science teaching also being significant in the traditional group's higher scores. Subjects enrolled in the two tracks are not equivalent, and these differences impact on several of the variable measurements.

High correlations with the self-concept in science teaching scores and total GPA, science GPA, general self-concept, locus of control, achievement, and science methods indicate that the construct warrants further investigation. A stepwise regression analysis revealed the ordered contributors of science GPA, general self-concept, science methods, and science achievement.

Although results were not consistent with the expected superiority of field-experiences science methods, the data gathered reinforced some relationships among the variables investigated and showed that additional research with preservice teachers should be designed and completed.

UNDERGRADUATES STUDYING SCIENCE: VIEWS ON STS OF FUTURE SCIENTISTS AND NON-SCIENTISTS

Reg Fleming

Very little is known about the independent training experiences of the professional scientists and the educated layperson. Yet this is a crucial period, for it is here both future professionals and future laypersons gain a supposed grounding in the basics of a discipline. The assumption is made that such a grounding will be put to two very different uses. Specifically, one will use it as the first step towards becoming a professional scientist, whereas the other will use it to help in functioning in a technological society. As well, science education programs often draw prospective teachers from the ranks of the educated layperson. The layperson's scientific and technical education ceases at the undergraduate level; the future professional has merely taken the first step. The effects of such a bifurcation in training can often be seen most vividly when laypersons and scientists meet and deal with each other over socio-scientific issues. Quite simply, it is in dealing with the interactions of science, technology, and society either in the arena of an actual issue or in the design of science-technology-society (STS) curricula that both groups' understandings of science and technology and assumptions about society come into play.

This research examined several features of those understandings and assumptions. Specifically, over a one year period in a chemistry department at one Canadian University, those training experiences which both directly and indirectly prepare students to deal with socio-scientific issues were examined.

There were three objectives for the project:

- A. To assess the understanding(s) of science-technology-society (STS) topics held by students in various stages of professional science training and students in various stages of educated layperson training.

- B. Following the assessment in (A), to select students from each of these stages for semi-structured clinical interviews concerning specific socio-scientific issues.
- C. Concurrent with (A) & (B), to perform a field study of the students' environment to determine which factors in it affect the results in (A) & (B).

Briefly summarized, the findings were:

- A. There is no significant difference in the understandings of STS topics between preprofessional scientists and laypersons. This holds across age, gender, and year of study.
- B. Interview data suggest a remarkably superficial understanding of the nature of science in all groups. As well, there was a strong faith that the scientists designing their training knew what they were doing, and that "all would be revealed" in due course. Chemistry students offered strong opinions that there were not facts in chemistry, only theories. The function of the laboratory was to prove these theories and to prepare students for "later" by ensuring that a repertoire of techniques had been mastered.

Strong economic arguments were advanced for the necessity of science. Understanding the physical world was perceived as a rationale for doing science. Progress was the real reason.

An attempt to examine specific socio-scientific issues resulted in most students' naiveté prompting them to reveal that science as they studied it offered little to discussions of these issues.

- C. The ongoing field study of the students' environment reveals that their perceptions of the role of the laboratory are very accurate. Labs are training exercises, offering the chance to verify lecture statements while honing technique. The idea of discovery was never espoused; rather, the lab was a problem solving station.

ADMINISTRATION OF SCIENCE PROGRAMS: A POLICY PERSPECTIVE

William Callison

The panel will look at a variety of policies (some policies by default) to better understand the role of administration at the national, state, and local level as it relates to the quality of science programs delivered in the schools. During the period of great expenditures for science between 1955-75, very slight attention was given to preparing administrators at all levels for the new programs. It is not surprising, therefore, to discover that many programs lacked critical administrative understanding and support which may account for the poor rate of adoption of otherwise excellent curricula by school districts.

Peterson's analysis of National Science Foundation expenditures to improve K-12 science instruction between 1955-75 indicate that a 1 to 3 funding ratio between curriculum (33%) and staff development (66%) occurred. We know now that administrators should have been required to participate in some of the elements of the teacher training. We base this on Berman and McLaughlin's study of the effectiveness of federal funding in K-12 schools in which they found the principal to be the "gatekeeper of change."

It is an irony that a series of projects designed to heavily involve faculty from colleges and universities succeeded in faculty involvement but neglected to include the admission officers and test writing experts at Educational Testing Service. Consequently, fine new curricula were designed and taught but the same old questions were maintained on the College Entrance Examinations. Hence, principals quickly figured out that it hurt their students' chances to go to a selective college if they were taking the new "biology" or "physics." They were not learning the material on the tests, and soon the schools began to withdraw from the new curricula

At the present we find a renewed interest in the teaching of science and an increase in federal and state support for this purpose. In addition, there is a dramatic increase in the use of technology seen generally in our culture and world wide that may lead us to another bountiful period for the improvement of science instruction. We look forward to the possibility of appropriate involvement of administrators at all levels this time around. Our panel will offer a variety of perspectives on the administration of science programs as follows:

- What is the Record? (historical background)- Roger Olstad
- Policy Implications? (national, state and local levels) - Roger Bybee
- How Can It (administrative support) Be Improved?
 - On the Instructional Side? - Carl Berger
 - On the Administrative Side? - William Callison

THE ATTITUDE CONCEPT: CAN IT BE DEFINED?

Robert L. Shrigley
Thomas R. Koballa, Jr.
Ronald D. Simpson

A concept central to the study of the influence that humans have on each other, attitude is essential in the research of the behavior of teachers and students in the science classroom. Yet science educators seem unsure of its definition. Attitude is used interchangeably with other psychological concepts. Without a clear definition, the design of attitude scales and treatment procedures is considerably hampered.

Thus, the purpose of this symposium is to investigate the definition development of the attitude concept within the social psychological literature and its implications for attitude research in science education. The symposium will be organized into four phases. First, subcomponents within the concept will be analyzed and described. Second, attitude will be compared with related psychological concepts, including belief, opinion, and value. Third, principles of measurement central to the definition of attitude will be cited. Fourth, models identifying the conditions under which the relationship between attitude and behavior is most strong will be described.

A STUDY OF UNCERTAINTIES IN THE META-ANALYSIS OF
RESEARCH ON THE EFFECTIVENESS OF "NEW" SCIENCE CURRICULA

James A. Shymansky
Larry V. Hedges
George Woodworth
Craig Berg

This study was designed to verify the results of the meta-analysis of the research on the effectiveness of post-Sputnik science curricula using procedures proposed by Hedges. The reanalysis took into account the standard error inherent in the sample-based effect size estimates obtained using the procedures outlined by Glass. Mean effect sizes determined in the Shymansky, et al. synthesis were recalculated using weighted values of effect sizes.

The results of the mean effect sizes obtained using the Glass and Hedges procedures are compared and discussed. The increased precision obtained using the weighting serves to clarify questions about the effectiveness of the post-Sputnik science curriculum projects and simultaneously clarify some of the controversy surrounding the recently developed meta-analysis technique.

Data from the original meta-analysis of new science curricula studies and the results obtained using the Hedges weighting procedures will be presented and discussed. Where effect sizes are shown to be nonhomogeneous across study groups, explanations for the variations in effect sizes will be offered. By explaining the systematic variation in effect sizes, i.e., treatment-by-study interactions, a more meaningful mean effect size for the study groups is achieved.

CHANGES IN LOGICAL REASONING IN THE MIDDLE SCHOOL YEARS

Michael J. Wavering

This study investigated the development of logical reasoning during the middle school years (grades six through eight) as measured by five tasks: first, simultaneous seriation using two criteria (concrete operational reasoning); second, the cone task (concrete projective spatial reasoning); third, measurement in two-and three-dimensions (concrete operational reasoning); fourth, the shadows task (formal operational proportional reasoning); and fifth, bending rods task (formal operational reasoning measuring separation and control of variables). These tasks were chosen because they measure the types of logical reasoning necessary for understanding many common science tasks. In addition, these tasks were chosen because they are interrelated developmentally. A longitudinal study was undertaken because few longitudinal studies have been done in the field of developmental logical reasoning and most developmental sequences are inferred from the measurement of a large sample at only one point in time.

Twenty-six students were given the same five tasks once each year while in grades six through eight. These students were chosen at random from the sixth grade of a university laboratory school during the first year of the study. Students remembered performing the tasks during subsequent years of the study but gave no indication that they remembered how they responded in previous years or that they were attempting to respond the same way during the present interview.

There was an overwhelming increase in reasoning levels during the three year period as measured on all the tasks. Also, significant percentages of students showed no change or negative change on the measurement task, the shadows task (proportional reasoning) and the rods task (separation and control of variables). On these tasks fifteen to twenty percent stayed at the same reasoning level. These three tasks required higher levels of reasoning that can only be reached after the development of other prerequisite concrete operational structures.

Since many science classroom tasks require at least concrete operational reasoning abilities for complete understanding, this study showed that a large number of middle school students, even at the time they become high school students, still have not fully developed certain concrete operational structures.

CHILDREN'S FORMATION AND RETENTION OF MENTAL IMAGES

Ann C. Howe
Ellen Vasu

Two studies were conducted to determine the effect of verbalization of the formation and retention of mental images in children in kindergarten through fifth grade. In the first study 71 children were presented a series of tasks designed to determine their ability to represent mental images of cross sections of familiar fruits and to test the hypothesis that self-generated verbalization would aid in image formation. The hypothesis was not confirmed. No significant differences were found to be associated with gender or ability level. Individuals varied widely in the images produced.

In the second study, 32 subjects from first grade and fifth grade took part. Two treatment groups were formed. One group listened to a verbal description of an unfamiliar fruit, drew a cross section and gave a description. The other group observed the fruit, drew it after it had been removed, and then described it. Both groups were brought back two weeks later and instructed to draw and describe the fruit. It was hypothesized that the image constructed by processing verbal information would be retained longer than the image constructed after observing the object. This hypothesis was not confirmed. Visual perception is a stronger stimulus and leads to longer retention. Those who observed the kiwi fruit and did not hear a description scored as high on immediate and delayed descriptions as those who had listened to a verbal description.

AN EXPERIMENTAL STUDY INTO THE EFFECT OF OUTDOOR SCIENCE, TEACHING ON THE FOURTH GRADE CHILD'S CONCEPT OF PIAGETIAN PHYSICAL CAUSALITY

Louise L. Gann
H. Seymour Fowler

The purpose of the present study was to investigate the effect of outdoor science experiences on students' concepts of physical causality. Fourth grade children served as subjects.

The specific Piagetian causal concept tested was dynamism. The investigation sought to determine if a gender difference occurred in an outdoor teaching experience.

The independent variable of Piagetian stage of development was assessed through the use of the Concept Assessment Kit - Conservation (Form A).

Prior to the testing of the subjects, students had been randomly assigned to four home-room teachers. Groups two and three were selected for the study since these two classes permitted enough time to get to the teaching site without interfering with their other regularly scheduled classes.

Students in both classes were given 450 minutes of instruction, with the first 200 minutes devoted to teaching the cause of floating while the remaining 250 minutes were devoted to actual experimenting with various types of objects being placed in the water.

Upon completion of the treatment phase, post testing was conducted. The Concept Assessment Kit - Conservation (Form A) was readministered for the purpose of identifying those subjects who had changed from one developmental stage to another. A change in developmental stage was considered an independent variable during the analysis of the data.

The Clinical Interview II - The Concept of Floating was readministered to reassess students' concept of the cause of floating.

Analysis of data revealed significant findings according to the 't' test. Significant differences for gender and developmental stage were evidenced. Girls had significantly higher scores than boys. The mean for the girls was 5.76, for the boys, 5.20; 't' was -4.64 and significant beyond .001.

The boys and girls who were at the concrete operational stage of development had significantly higher scores than did boys and girls in the transitional stage of development level. The mean for children at the concrete stage was 5.77, for the transitional stage 5.14; 't' was -5.55 and was significant beyond .001.

From the results of this study it was concluded that when girls are provided with proper incentives and equal instructional practices that are of interest, they can and do perform well in science.

Those children who are classified as concrete operational had acquired the necessary cognitive structure to conserve, do reversible thinking, and make multiple comparisons.

STUDENT CONCEPTIONS OF CHEMICAL CHANGE

Joseph J. Hesse, III
Charles W. Anderson

Shortly after completing an instructional unit on chemical changes, the writing of formulas and equation balancing, about 100 first year high school chemistry students were asked for written explanations of three chemical changes: the rusting of an iron nail, the heating of copper in air, and the burning of a wood splint.

From the larger population, 11 representative students were selected for clinical interviews during which they were asked to expand upon and clarify their written responses. In depth analysis of three of the eleven form the major portion of this study with some comparisons being drawn between the three and the remaining eight students.

Analysis of student responses focused upon three different aspects of chemical understanding: 1) Chemical knowledge which includes knowledge of symbols, formulas, reactants and products, the role of energy, and the rules which govern their use in chemical change. 2) Conservation reasoning, which is related to the student's ability to conserve mass and substance in physical as well as in chemical transformations. 3) Explanatory ideals or the standards by which the acceptability of scientific explanations are judged. Modern notions of chemical change, for example, assume that all chemical reactions can and should be explained in terms of atomic-molecular theory.

Only one of the eleven students stood out as possessing the chemist's understandings in all three areas. This student understood conservation of mass and of chemical elements well enough to quickly correct minor errors in his explanations of rusting and the oxidation of copper. He was confident in the power of the atomic-molecular theory to explain the changes before him.

Of the remaining ten students, five held enough chemical knowledge to say many of the right words but were inconsistent in their conserved mass and substance. Their explanations included both those based upon atomic-molecular theory and non-chemical homespun analogies. These students exhibited a lack of confidence in their ability to produce acceptable explanations. Three of the five were "A" students. They indicated that while they believed their atomic-molecular explanations were essentially correct, they did not find them intellectually satisfying.

The remaining five students possessed little chemical knowledge, very seldom conserved mass or substance and seemed oblivious to the notion that

atoms, molecules and their interactions formed the basis of an acceptable explanation of chemical change. These students preferred home spun analogies (e.g., describing rusting as "like" mold growing on bread) as their only form of chemical explanation. Three of the five believed that their explanations were wrong but stated that their explanations made sense to them regardless of what the chemist might think.

In conclusion, the ability to give chemically acceptable explanations requires more than the learning of chemical facts. This study suggests that the ability to conserve mass and substance presents problems even for students who have achieved above-average grades in chemistry. Students often fluctuate in their explanations between chemical representations and naive analogical explanations which focused upon the observable characteristics of the change.

CHARACTERIZING QUALITATIVE MENTAL MODELS OF LEARNERS ABOUT ENERGY METABOLISM

Marcy J. Leeds

With information processing, cognitive science, and artificial intelligence as influences, much of the research in education has begun to focus on how students represent information. A specific area of educational research looks at how students form mental models of particular concepts. Understanding these mental models which students form is of utmost importance in the learning process. A study was undertaken to characterize and categorize qualitative mental models of learners. The vehicle for this research was the energy metabolism system.

Students who had completed a basic nutrition course were interviewed about their understandings of the energy metabolism system. These interviews were tape-recorded, and the tapes were transcribed. The transcribed verbal protocols were utilized to prepare models of the students' mental representations about the energy metabolism system in relation to the protocol of questioning used for the interview.

A scientifically acceptable structural-functional model of the energy metabolism system was divided into five nodes of major concepts and three links or connecting ideas. Each subject's model of the mental model was broken down into the same nodes and links, if present in the model, and a tally was made of how many of each node and link were found for all of the subjects.

According to the number of nodes and links present, the models were categorized into one of four levels of knowledge within an investigator-prepared hierarchy. The levels of knowledge were organized in terms of how students access information from long term memory (LTM).

The research findings show that the majority of learners fell into one level of knowledge, partial systemic, consisting of individuals who access concepts through patterns of organized relevant categories. The results suggest that educators should consider methods of teaching which would not only encourage students to store knowledge in terms of patterns, but would also encourage them to link together the relationships between the organized concepts. The instructional methods used would enable students to integrate the concepts they learn into schemata.

STUDENT KNOWLEDGE OF A NATURAL RESOURCE ISSUE IN THE GULF OF MAINE

Michael J. Brody
Helmut Koch

This research identifies and analyzes student science knowledge of a current marine natural resource issue. The World Court U.S./Canadian Boundary Decision has received a great deal of news coverage, affected the lives of many people and reflects the dilemma of determining natural resource policy based on our understanding of marine systems. This study generated base line data on student science knowledge of 4th, 8th and 11th grades on this specific issue. A representative sample of public school students (n=226) from Maine were interviewed on marine science, natural resource and decision-making concepts. Student knowledge was assessed and classified according to correct concepts, missing conceptions and misconceptions. Similarities and differences between grade levels were analyzed. This research project identifies student knowledge of marine science and natural resource concepts which affect learning and helps define the relationships among scientific knowledge, student understanding and current natural resource issues. The results will lead to the design of a curriculum for teaching natural resource decision-making based on science concepts and people's understanding and beliefs.

TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENCE:
DO THEY REALLY INFLUENCE TEACHING BEHAVIOR?

Norman G. Lederman
Dana Lewis Zeidler

Improving the scientific literacy of the public is the most compelling challenge facing science educators. Furthermore, an adequate conception of the nature of science is considered to be a distinguishing attribute of the scientifically literate individual. Researchers have long been dismayed by the apparent misconceptions held by secondary school students and science teachers. Consequently, much time and effort have been invested in programs specifically designed to improve science teachers' conceptions of science with the anticipation that improved student conceptions would necessarily follow. These efforts were based on the prevalent assumption that teachers' concepts of the nature of science influence their classroom teaching behavior. Unfortunately, the validity of this persistent and influential assumption has remained virtually untested. The purpose of this research was to directly test the assumption that a teacher's conceptions of science influence his/her teaching behavior.

Eighteen high school biology teachers were compared with respect to their conceptions of six aspects (i.e., amoral, creative, tentative, testable, parsimonious, and unified) of the nature of science as measured by the Nature of Scientific Knowledge Scale (NSKS). In addition, qualitative classroom observations were made of each teacher throughout the fall semester.

Quantitative comparisons were made between the "high" group of teachers (i.e., those exhibiting the highest NSKS scores) and the "low" group teachers (i.e., those exhibiting the lowest NSKS scores) with respect to 44 classroom variables. "Down Time" was the only classroom variable which significantly ($p < .05$) differentiated between the "high" and "low" group of teachers. Consequently, the data did not support the prevalent assumption that a teacher's conception of the nature of science influences his/her classroom behavior. Interestingly, most of the classroom variables used for teacher comparisons have previously been shown to be related to improved student conceptions of the nature of science.

Finally, the results indicate that a more balanced treatment of history/philosophy of science and specifically targeted teaching behaviors/skills is needed in preservice and inservice science teacher education if we are to successfully promote more adequate conceptions of the nature of science among our science students.

SCIENCE EDUCATION RESEARCH INTERESTS OF ELEMENTARY TEACHERS

Dorothy L. Gabel
K. V. Samuel
Stanley Helgeson
Joseph Novak
Saundra McGuire
John Butzow

Science education researchers have always sought to improve the quality of our nation's schools. One way of doing this is to make research findings on the teaching of science available to teachers. Perhaps an even more effective way is to plan research studies with teachers' interests in mind. The purpose of this study was to determine the science education research interests of elementary teachers and to examine the data according to certain demographic variables. The sample consisted of 553 elementary teachers in 98 schools from across the nation. The survey instrument contained 28 items, 26 of which were included on a survey instrument prepared by White et al. The data collected using the Likert-type questionnaire were dichotomized as "1" important and "0" not important and were analyzed using the Cochran Test and the McNemar Test for post hoc comparisons. Results of the study indicate that the top five research interests of teachers in the order of preference are: hands-on experiences, science content of the curriculum, cognitive development and learning styles, problem solving, and teaching strategies. The area of lowest interest was research on sex differences.

Results of the survey have several important implications for science education. First, they can be used to help science educators plan research that may be of interest to elementary teachers. Second, they can be used by groups such as NSTA who publish research reviews, and by colleges and universities that prepare elementary teachers, as a guide to not only what is of interest to elementary teachers, but to identify those areas of research for which dissemination has been lacking.

TEACHER MISCONCEPTIONS-IMPLICATIONS FOR SCIENCE INSTRUCTION

Marianne Betkouski
Sandra McDonald
Paul Eggen

This study was designed to assess the thinking of preservice elementary teachers with respect to the concept of density. The study was founded in the research on "alternative frameworks" that has received considerable recent attention.

The subjects were 35 education majors taking an elementary science methods class. They were directed to use their observations to arrive at a series of conclusions about the concept of density, and were further directed to identify the best choice of reasons for the conclusions.

The results indicated that the subjects had significant misconceptions about the concept. Not only did prior experience and intuition dominate their thinking as opposed to the observations they were supposed to make, but they also revealed substantive uncertainty about the concepts of mass and volume, which provide the foundation for the concept being investigated.

The results have serious implications for the teaching of science. If teachers have major misconceptions, it is highly unlikely that they will be in a position to prevent or eliminate these misconceptions in their own students.

AN INVESTIGATION OF THE MEANING EXEMPLARY SCIENCE TEACHERS ASSIGN TO STS INSTRUCTION CONCEPTS

Peter A. Rubba

The meaning assigned to concepts associated with science-technology-society (STS) instruction, the percentage of science course time allotted to STS instruction, the categories of STS issues infused into sciences courses, and the instructional procedures used to do so were examined among a sample of 65 exemplary secondary level science teachers. The teachers were volunteers from the 87 science teachers locally

nominated for the Presidential Awards Program during 1982 and 1983 from a mid-western state. Data were collected using the Science Teaching Issue Opinionnaire (STIO) and a questionnaire, both developed by the researcher and content validated. The STIO used a semantic differential format; it was composed of 23 STS instruction concepts (e.g., science, technology; students' need to understand the interrelationships among science, technology, and society; my ability to teach. . .), each followed by 13 seven-point bipolar adjective scales (alpha reliability = 0.97). The instruments were distributed and returned by mail. The exemplary science teachers held moderately positive opinions of 1) science, 2) technology, 3) their understanding of science, and 4) their ability to teach science. The teachers expressed slightly positive opinions of 1) students' understanding of STS, 2) students' need to understand STS, 3) their own understanding of STS interrelationships, and 4) their ability to teach STS. The teachers suggested that 15% of science course instruction time should be dedicated to STS. "Pollution" headed the categories of issues infused into science courses. However, expository instructional procedures were dominant.

HOW TO LINK SCIENCE AND WRITING: WHAT WRITING RESEARCH
CAN OFFER SCIENCE TEACHERS

Barbara Fassler Walvoord

The research findings of Linda Flower, John Hayes, Elaine Maimon, Donald Murray, Sondra Pearl, Lee Ode11 and Nancy Sommers are reviewed and linked to specific opportunities to implement writing in the science classroom. Holistic grading and primary trait scoring, evaluative methods used in marking various national writing tests are defined by discourse and example. Common writing techniques that may be easily adopted by the science teacher are reviewed. These include: free writing, webbing, transparent reader conferencing, and distinguishing performance-based and knowledge-based errors. The methodology in protocol studies is described and defined in the context of ethnographic research.

THE EFFECT OF WRITING ASSIGNMENTS ON ACHIEVEMENT
IN COLLEGE GENERAL CHEMISTRY

Phillip Horton

This study was designed to determine if student learning in college general chemistry could be increased through the addition of required writing assignments. Sixty-four students enrolled in the same section of a General Chemistry II course were randomly assigned to two groups. Treatment group members were required to turn in written summaries of eight class lectures. These summaries were graded and returned with mistakes in chemistry and writing noted. Feedback concerning errors in chemical content was shared with the entire class prior to the posttest. Analysis of covariance of the posttest results showed that the treatment group members scored significantly higher than the students who did not write the summaries ($F = 6.78, p < .05$). No interaction was observed between group membership and pretest scores. These results indicate that student achievement in chemistry may be enhanced through required writing assignments. The study results are inconclusive as to whether the gains in achievement were due to the processes involved in organizing and writing the summaries, or due to the additional study time required to write the summaries.

SCIENCE AND WRITING - LINKING RESEARCH WITH CLASSROOM MODELS

Virginia Johnson Gazzam
Barbara Fassler Walvoord
Phillip Horton

The writing and thinking processes of upper level biology and chemistry majors enrolled in a required technical writing course were examined. The eleven students kept logs, saved notes, kept all drafts and rough copies, and talked into a tape recorder as they conducted and reported original science research. Each student compared two commercially available products on the basis of cost and quality. Peer conferences, teacher-student conferences, and other ethnographic data were recorded.

The analysis of this data revealed five major points of consideration for teachers of science and writing. These are:

1. Although all students had completed a minimum of three laboratory science courses, only two of the eleven conducted a pilot.
2. Time on task in recording data or thinking about writing was not a significant factor. Timelines of the writing process suggest that writing up the experiment as if it had been designed was the only factor that resulted in improved design.
3. Ten of the eleven students expressed, on tape, confusion and concern about where information should be placed in the scientific report format. Stressing format writing interfered with the composing process.
4. Operational definitions were the most difficult process task for the students.
5. Eight of the eleven recorded only two or fewer possible topics. Taped records tend to indicate this was not due to misunderstanding of taping directions, but of the student's desire to "close" on an idea as the assignment was structured.

The writing protocol study has provided a close look at the writing process and an opportunity for teachers of writing in science to design better supporting assignments. These include: ten possible topics worksheet, pilot reports and conferences with the instructor, earlier pre-writing assignments, manipulative activities with scientific format information, and better lecture and practice coverage of operational definitions.

WHAT RESEARCH SAYS ABOUT USING SCIENCE TEXTBOOKS

William G. Holliday
David J. Lockard
Michael J. Padilla
Rosemary K. Padilla
Denise Muth
Fred Finley
James Shymansky
Dianne Schallert
Larry Yore
Carol M. Santa

Students have trouble comprehending information from their science textbooks for a variety of reasons - an undisputed fact, according to science and reading educators. Yet, researchers in these two areas never have gotten together in a public forum to debate how research and theory can help in a precise way practicing science teachers. The proposed symposium will focus on research and application problems of mutual concern to the participating reading and science researchers, followed by an exchange of views with the audience.

The first group of presenters will link reading research and theory to the problems: (1) authors have in writing reader-considerate science textbooks, (2) science teachers have in orienting and testing students, and (3) students have in choosing studying techniques such as underlining, notetaking, outlining, mapping, summarizing, questioning, clarifying and predicting.

The second group of presenters will show how science process skills acquired in the laboratory are related to the metacognitive skills useful in students' monitoring and fostering of their comprehension of science textbooks, that is, by using self-regulatory techniques such as organizing information, predicting, testing outcomes, making hypotheses and drawing conclusions.

The third group of presenters will link research dealing with misconceptions and prior knowledge in science to writing textbooks, correcting and remediating students' conceptualizations and preparing students for science instruction in subsequent formal and informal learning experiences.

The fourth group of presenters will report a spirited debate between previous editors of science and reading research journals while linking research from both domains to highly specific questions asked by today's science teacher.

IDENTIFYING GAPS IN THE RESEARCH ON PRECOLLEGE SCIENCE
EDUCATION FOR FEMALES: OPINIONS OF
A SAMPLE OF EQUITY RESEARCHERS

Marsha Lakes Matyas

Over a decade ago, large disparities between the precollege mathematics backgrounds of male and female freshmen were widely reported. Since then, a sizeable body of research has developed, examining factors related to the persistent gender differences in precollege science and mathematics achievement, interest, enrollments, and career choices. Several reviews and studies have synthesized parts of these findings, but no overall conclusions concerning research in all four areas have been drawn. The purpose of this study was to survey a sample of science education researchers whose work has been primarily concerned with equity issues to determine their opinions on the status of research in the areas described above.

In conjunction with a project to link community-based organizations to science-based organizations and researchers, the Office of Opportunities of the American Association for the Advancement of Science initiated a series of regional meetings with math/science educational equity researchers and program implementors to: discuss the status of mathematics and science education for women and minorities; explore avenues of available funding for further research; and promote networking among equity researchers. Participants in these meetings (n=50) were asked to complete a survey which listed 31 different factors which research indicates may influence science/mathematics achievement, interest/enrollment, and/or career choice. Researchers were asked to express their opinions on how extensively each factor had been researched; what conclusions, if any, could be drawn; and which two factors should have top research priority. In addition, the survey was mailed to 60 additional researchers who did not attend regional meetings, but whose work has been primarily in the described areas. From these data, an overall synthesis of the "gaps" in the research on science education for women was constructed.

Preliminary results indicated that: 1) research on factors related to mathematics achievement and interest is more extensive than is research on factors related to science achievement and interest; 2) for both mathematics and science, research on parental factors was felt to be more conclusive than was research on either attitudinal/perceptual or school-based factors; and; 3) little research has been conducted to determine the influence of these factors on female students in specific minority groups. In addition, specific results for each of the 31 factors will be presented.

Young women, compared to young men, still take fewer courses in high school science and mathematics, earn lower science and mathematics scores on SAT and national achievement examinations, and are less likely to pursue science-related majors at undergraduate institutions. The factors leading to these gender differences are complex and resistant to change. The study described here is a qualitative and exploratory attempt to gauge our knowledge about factors affecting educational equity in science by tapping the opinions of those who work in the field.

GENDER DIFFERENCES IN SCIENCE ACHIEVEMENT: A MATTER OF KNOWLEDGE OR OF CONFIDENCE?

Hanna J. Arzi

This paper is concerned with gender differences in feelings of confidence in cognitive performance, as a possible source that impinges on females' inferior achievement in science. Gender differences in physical science achievement in secondary schools in Israel were longitudinally investigated from grade 8 to 10 (ages 13-15). Both girls and boys studied the same science courses. The study was replicated twice, and the pooled data were longitudinally matched for analysis to avoid selection effects due to attrition. No gender differences in achievement were detected in any of the three grade 8 tests. However, girls scored significantly lower than boys on a retention test in grade 10, and used more frequently the "I don't know" alternative which was offered in each item. In a second retention test, where examinees were asked to accompany each answer by a declaration on level of confidence, yet could use the "I don't know" alternative, the gap in achievement was no longer significant. Moreover, the "I don't know" gap was largely reduced, and instead, girls admitted to lack of confidence in their responses significantly more than did boys. It is possible that these results are a manifestation of sex-role behaviours: Girls tend to have less confidence in their cognitive knowledge, tend more to obey test instructions, and consequently hasten to say "I don't know" whenever they feel uncertain, rather than to take risks and make informed guesses. Yet, it is possible that girls' feelings of uncertainty are also indicators of knowledge which is not sufficiently consolidated. That is to say, while no gender differences are found in immediate knowledge acquisition, girls may retain less over the long-term. The present findings on girls' feelings of uncertainty in science suggest that discrepancies between actual knowledge, measured knowledge and levels of confidence need to receive more attention.

FEMALE SCIENCE MAJORS: DO THEY DIFFER FROM
THE MALE SCIENCE MAJOR?

Veronica Reardon Mondrinos
George Pallrand

This four year longitudinal study focused on science majors as they progressed through the college science program. The study looked at the difference presented between male science majors and female science majors. It followed a group of 384 students throughout their college experience. Their initial choice of major and the factors involved in this choice are examined as well as the factors which effect the eventual completion of a major within the sciences. Variables examined included the aptitudes, attitudes, and achievement variables developed during high school along the college achievement and attitudinal variables.

Student performances during the four years of the study were examined at specific chronological points to see what factors influence their choices and successes. Grades received in science core courses such as chemistry, biology, physics and mathematics were analyzed as were the scores received on the SAT math and verbal measures, College Placement Test in biology, Advanced Placement Test in biology, attitude measures and other background information. There were eleven entry variables and eight college variables. The data were analyzed primarily by discriminant analysis.

The study examined the differences exhibited by male science graduates and female science graduates. The results of the study show that the sexes differ primarily on their entry characteristics. These continue to discriminate between the sexes throughout college. Chemistry proved to be the most important of the college variables, not physics or math. The importance of the freshman year consistently presented itself in the study. Success as a science major is linked to the freshman GPA and the ability to deal with the transitions and adjustments necessary for the successful completion of the freshman year. The females in this study do not leave the sciences in greater numbers than do the males. They represent forty two percent of the science graduates. The area of concern is the total drop in the number of science majors.

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EVALUATING THE TEACHING EFFECTIVENESS OF PRESERVICE SCIENCE TEACHERS USING PUPILS' FEEDBACK

Richard Duschl
Hersholt Waxman
Robert Morecock

The objective of the present study was to examine the use of students' perceptions of their classroom environment to improve the teaching effectiveness of preservice science teachers. More specifically, this study addressed the following research questions:

1. Are students' perceptions of preservice science teachers' effectiveness a reliable and valid method for monitoring preservice teachers effectiveness?
2. What relationships exist among students', student teachers', cooperating teachers', and university supervisors' perceptions of the classroom environment established by the student teacher?

Approximately 900 secondary level students from 34 science classrooms completed the Our Class and Its Work (OCIW) questionnaire which assessed each student teacher. In addition, each cooperating teacher, university supervisor, and student teacher completed a modified version for the OCIW which assessed each of their perceptions of the classroom environment. The data from these four sources or coders (students, cooperating teachers, university supervisors, and student teachers) were aggregated to the classroom level of analysis (N=34).

The OCIW gathers data on eight scales related to classroom environment: 1) didactic instruction, 2) enthusiasm, 3) feedback, 4) instructional time, 5) opportunity to learn, 6) pacing, 7) structuring comments, and 8) task orientation. In the present study only scales 3-8 were employed. Each of the scales used in the study provides information on variables addressed in the methods courses and field experiences which are a part of the preservice teacher education program. Each scale contains six Likert-type items. The total test reliability using Cronbach's Alpha is .85 while the range of reliabilities for the six scales is .84-.92. The OCIW also has been found to have predictive validity with students' academic achievement.

The ANOVA results revealed significant differences between or amongst coders on five of the six scales. On the "instructional time" scale student teachers had significantly higher means than both students and cooperating teachers. For the "pacing" scale students' perceptions were

significantly higher than the other coders. The only significant differences found to exist on the "task orientation" scale was that students had significantly lower scores than student teachers. On the "feedback" scale, university supervisors' perceptions were significantly higher than all other coders. On the "structuring comments" scale, university supervisors' perceptions were also significantly higher than both student teachers and cooperating teachers, and, student teachers perceptions were significantly lower than those of the students.

The results of the present study found that students' perceptions were significantly lower than student teachers perceptions on four of the six OICW scales. This finding is especially pertinent since in none of the same scales are students' perceptions significantly different from university supervisors. The results of the present study suggest that students' perceptions can be used in providing preservice science teachers with formative evaluations of their teaching effectiveness.

THE INTEGRATION OF SCIENCE MICROTEACHING AND FIELD EXPERIENCE WITH TWO FEEDBACK LEVELS ON PRESERVICE ELEMENTARY TEACHERS

Mark R. Malone
Patricia Hauslein
Carolyn Sommersell

The purpose of this study was to determine the effectiveness of integrating the practices of microteaching and field experience in preservice teacher training for elementary science methods courses. Students receiving the integrated approach were compared to students participating in practice teaching in field experience alone. The amount and type of feedback on practice teaching was also considered as a factor in the effectiveness of the two practices. Four treatment groups were utilized: combined microteaching/field experience with systematic feedback (MICRO/FEX-1), combined microteaching/field experience with limited informal feedback (MICRO/FEX-2), field experience with systematic feedback (FEX ONLY-1), and field experience with limited informal feedback (FEX ONLY-2). Subjects for the investigation were enrolled in four sections of an elementary science methods course. Subjects were randomly assigned to one of the four treatment groups listed above.

At the end of the treatment, which lasted a full semester, students were evaluated on five outcome measures selected because of common use in previous investigations in these fields. These included teaching behaviors rated from video tapes made of all students teaching a lesson at

the end of the semester. Lessons were rated on the Inquiry Teaching Behaviors Instrument (ITBI). Other instruments included measures of science process skills, attitudes toward science and science teaching, and student concerns about teaching science. An instrument to measure attitudes toward practice teaching was also developed and administered.

Analysis of variance procedures were used to identify significant differences among groups for all outcome measures. Significant differences among groups were identified for both the treatment and levels of feedback. Post hoc analysis of means indicated that the MICRO/FEX groups generally scored significantly better on measures of inquiry teaching behaviors, science process skills, and attitudes toward type of practice teaching. There were no significant differences among groups on measures of attitudes toward science and science teaching, or on concerns about teaching science. Groups receiving systematic feedback on their practice teaching also showed significantly higher scores on related outcome measures than groups receiving only limited informal feedback.

It appears that integrating science microteaching with field experience in undergraduate methods courses is superior in developing inquiry teaching skills and science process skills than is field experience alone, particularly if systematic feedback on practice teaching is given. Traditional field experiences, however, can be significantly improved by systematic feedback. The lack of significant differences between groups on the measures of attitudes toward science and science teaching, and science teacher concerns indicates that these attitudes and concerns are at least not negatively affected when field experience is somewhat decreased in order to implement a microteaching program.

The study suggests a need for further study into the integration of microteaching and field experience. A model for that integration is proposed based on the results of this and related studies.

THE INFLUENCES OF SEQUENCED INSTRUCTIONAL STRATEGY AND LOCUS
OF CONTROL ON PRESERVICE ELEMENTARY TEACHERS'
UNDERSTANDING OF THE NATURE OF SCIENCE

Lawrence C. Scharmann

Science educators have claimed that well-conceived instructional strategies foster an understanding of the nature of science; further, such an understanding was more predicatable for preservice elementary teachers possessing an internal locus of control, substantial science content

knowledge, and a high level of logical thinking ability. The intent was to determine the influence of three instructional strategies, differing in their respective emphases on science content, teaching methods, and process science, to predict an understanding of the nature of science. Data were collected from 135 elementary preservice teachers enrolled in science teaching methods courses at the endpoint of three sequences: (a) introductory process instruction with three subsequent semesters of integrated science content and teaching methods; (b) process instruction with separate subsequent content and teaching methods; and (c) only science content with subsequent teaching methods. Another 29 preservice teachers, assessed prior to entry into instructional sequences, provided a cross-section for examining developmental changes in locus of control, logical thinking, nature of science, and science content knowledge. Statistical procedures included ANOVA, regression, correlation, discriminant analysis, Kruskal-Wallis ANOVA, and Wilcoxon tests. Results revealed that the nature of science was most predictable for internals and a separate process/content/teaching methods strategy. Major conclusions were: (1) process instruction was influential in promoting the development of science content knowledge and the nature of science; (2) logical thinking ability was the most influential predictor of the nature of science; and (3) separate rather than integrated experiences in content and teaching methods as well as an internal rather than an external locus of control were superior in developing an understanding of the nature of science.

EFFECTS OF GROUP SIZE AND ADVANCE ORGANIZERS ON
ACHIEVEMENT, RETENTION, AND RATE OF LEARNING
WHEN USING MICROCOMPUTER TUTORIALS IN KINEMATICS

Ernest Carnes
Joy S. Lindbeck
C. Frank Griffin

The purpose of this study was to investigate how the use of CAI tutorial programs, incorporating advance organizers and involving various sizes of groups of subjects would affect students' achievement scores, retention scores, and rates of learning. Used as subjects were 100 suburban high school physics students running interactive tutorial physics programs focusing on strobe simulation and displacement- and velocity-time graphs. For fifty students (experimental group) an advance organizer program preceded each tutorial. The remaining fifty students (control group) had an advance non-organizer program preceding each tutorial. Five days were allocated for the students to run the four tutorials at the 90% competency level. Achievement and retention were measured by individually administered paper-pencil teacher-made tests sampling the content of all four tutorials. Rate of learning was determined for groups by the number of times the first three tutorial programs were executed in order to attain 90% competency.

The hypotheses focused on the effects of advance organizers and the effects of group size as measured by achievement, retention, and rate of learning. Although the results of the two-way analysis of variance were in the hypothesized directions for the use of advance organizers, the only hypothesis which yielded a significant difference at the .05 level pertained to group size. Students working in different sized groups at the computer had significantly different rates of learning. Results of the Tukey test revealed that students working in groups of three and four on CAI tutorials had significantly better rates of learning than students working alone. Thus it can be concluded that students working on CAI tutorials in groups of three or four students attain competency faster than students working alone, while no significant differences in achievement or retention were observed.

The implications for using CAI tutorials in physics point to grouping students in fours as a time saving and economic method of presenting material without significant loss of achievement or retention.

CHANGES IN PRESERVICE ELEMENTARY TEACHERS' HYPOTHESIZING SKILLS
AND SELECTED ATTITUDES FOLLOWING GROUP AND INDIVIDUAL
STUDY WITH COMPUTER-PRESENTED TEXT OR COMPUTER SIMULATION

William E. Baird
Thomas R. Koballa, Jr.

The purpose of this study was to assess the effect of group size and mode of presentation on the acquisition of the science process skill of forming and testing hypotheses and selected attitudes. All participants received two one-hour sessions presented by microcomputer, one week apart. The sample consisted of 87 preservice elementary teachers in five intact classes. These subjects were assigned to one of four cells in a two-factor, quasi-experimental design. The two factors were group size and mode of computer presentation. One half of the subjects were assigned to three-member cooperative learning groups, while the rest worked alone at the computer. Matched problem situations which required the forming, testing, and revision of hypotheses were presented as color simulations to one-half of the subjects and as textual exercises to the rest.

The effect of group size and mode of presentation was found to depend on subjects' initial hypothesizing skills and formal reasoning ability. Subjects with low formal reasoning skills benefitted more from small group interaction with computers than from working alone. Learners in this study with higher formal reasoning ability also performed better after receiving textual exercises than similar subjects who interacted with color computer simulation. In addition, cooperative group learning and color computer simulation were found to be more effective than individual learning and computer text in elevating the learner's perceived success in use of the computer and attitude toward the program being used. The most noteworthy implication from this study is that, without pre-assessment of learner aptitudes, it may not be possible to prescribe one mode of computer presentation or group size over another.

THE EFFECTS OF SIMULATION MODE ON DECISION-MAKING

John C. Park

This research was designed to investigate suggested reasons why fourth-grade children generate more alternatives in a decision-making task when

manipulating concrete materials than do children performing the same task using a computer simulation. The decision task was to distribute nine prizes between two winners in a fair way.

Factors investigated included the level of verbal interaction, the ease in accomplishing the task, and the presence of real objects. The children participating in the study were rural, predominately white, and middle class.

Thirty one children were randomly assigned to one of two computer simulations of the decision task. The computer simulations differed in the level of verbal interaction between the researcher and the child. The level of verbal interaction did not influence the number of alternatives the children generated ($p < 0.05$).

Two hundred forty children were randomly assigned to four simulation modes stratified by gender. The four simulation modes included: 1) computer simulation with light pen input; 2) computer simulation with keyboard input; 3) computer simulation with keyboard input and real prizes for reference; and 4) a simulation with real prizes for distribution. Each simulation presented the same decision task. The children who manipulated real prizes generated more alternatives than the children who interacted with any of the computer simulations (Scheffe, $p < 0.001$). There were no significant differences in the number of alternatives generated among the children interacting with the computer simulations. Neither the presence of real objects nor the ease in accomplishing the task influenced the number of alternatives generated in the computer simulations.

Time variables were the best predictors of simulation mode. Children distributing real prizes required the least amount of time to display an alternative. There are indications that more time is required in making the first move during the second alternative than any other alternative across all simulation modes.

The data and observations suggest that the environment in which the decision task is encountered influences the pathways taken through the decision-making process.

EFFECTS OF NOVELTY-REDUCING PREPARATION ON EXPLORATORY BEHAVIOR
AND COGNITIVE LEARNING IN SCIENCE MUSEUM SETTINGS

Carole Kubota
Roger Olstad

The literature shows contradictory results as to whether, what, and how much students learn on the thousands of field trips to novel settings taken every year. The purpose of this study was to manipulate novelty, a possible link between exploratory behavior and cognitive learning, to answer the following questions: What is the relationship between (a) novelty and on-task exploratory behavior? (b) novelty and cognitive learning? (c) on-task exploratory behavior and cognitive learning?

Subjects were 64 sixth grade public school students who visited the Pacific Science Center, the novel setting for the experiment. Campbell and Stanley's posttest-only control group design was utilized. The experimental treatments were: (1) a vicarious exposure treatment reducing the novelty of the field trip setting, (2) a placebo treatment, informative but not novelty-reducing, and (3) an actual exposure treatment, the field trip itself. Statistical analyses were conducted on both dependent variables (cognitive learning and exploratory behavior) using MANOVA, ANCOVA, and multiple regression analysis with socioeconomic status and academic achievement as covariates, novelty-reducing preparation as the independent variable, and gender as the moderator variable.

Multiple regression analysis showed treatment group membership combined with group by gender interaction to be a better predictor variable than academic achievement in terms of exploratory behavior. On-task exploratory behavior was positively correlated with cognitive learning. Significant differences ($p < .05$) were detected for exploratory behavior, with the vicarious treatment group outscoring the placebo treatment group. For both dependent variables, gender by treatment group interaction was significant ($p < .05$) with novelty-reducing preparation shown to be effective on boys but not on girls.

Novelty-reducing preparation results in more on-task exploratory behavior and greater cognitive learning in a science museum setting. The gender by treatment group interaction requires further explication. Teachers, other educators, and those involved in the formulation of programs at informal learning institutions should be able to capitalize on the novelty phenomenon described in this study to make the thousands of field trips taken every year more educationally productive.

A STUDY OF VISITOR LOCUS OF ATTENTION: PREDICTING MUSEUM VISITOR BEHAVIOR

John H. Falk

A study was conducted at the National Museum of Natural History, Washington, DC to assess visitor behavior as a function of time in the museum. A total of 100 adults, selected from family groups, was tracked from the moment of entrance to the moment of exit, and every five seconds the dominant locus of their attention was recorded. Five loci, plus a "Can't Tell" category, were possible. They were: attention to exhibit; attention to setting; attention to self, attention to own social group; and, attention to other visitors.

Results showed that during the first 45 minutes of a visit, locus of attention remained essentially constant with attention directed about half the time to exhibits, 20% to setting, 15% to own social group, and the remainder to the other two categories. During the remaining 30 to 60 minutes of the visit, attention to exhibits fell dramatically, while social/physical attention rose.

These results support earlier research conducted at the Florida State Museum of Natural History and strongly suggest that the generalized behavior of museum visitors is predictable. Family visitors to museum initially look very intently at exhibits, normally the first exhibits they encounter upon entering the museum, until boredom or fatigue over take them. Then they change to a "cruising" mode, "seeing" as much of the museum as possible before exiting. These results are important for investigators interested in learning in the formal setting.

AN INSTRUCTIONAL PROGRAM AT A SCIENCE MUSEUM AND ITS EFFECT ON SIXTH GRADE STUDENTS

Barbara Atwater Parks
Mildred W. Graham

Recent reports have highlighted the important role that informal education, including museum programs, should play in science education. Museum education programs are attended by millions of youngsters and cost taxpayers millions of dollars annually, but very little evaluation has been done on these programs. This study evaluated specific and general effects of an instructional program on dinosaurs as demonstrated by the cognitive achievement and scientific

attitudes of sixth grade students. Measurements were made to determine if these programs changed attitudes toward learning about science, the museum and the science of paleontology.

Students from five schools in the Birmingham, Alabama, area participated; 157 sixth grade students were randomly assigned to experimental and control groups. All subjects were pretested two weeks prior to the museum lesson; a posttest was given the day after the program; and another posttest was given two weeks later. All pretests and posttests consisted of these validated instruments: Dinosaurs, the Science Attitude Inventory, and the Inventory of Attitudes. Analysis of variance procedures were performed to test hypotheses which dealt with differences in performance between experimental and control groups. Hypotheses which dealt with relationships between measures were tested using Pearson correlation procedures.

Results showed no significant differences between experimental and control group means on any of the measures. Additional analysis using a t test revealed that the experimental group showed a significant gain on the Dinosaurs instrument. Analysis of relationships showed significant correlations between cognitive achievement and scientific attitudes. Significant correlations also resulted between attitude toward learning about science and scientific attitudes and between attitude toward the museum and scientific attitudes.

While some changes occurred in cognitive achievement, lack of changes in attitudes measured shows that the effectiveness of these kinds of museum programs needs to be questioned. If the instructional program is to be of greater worth in terms of effectiveness and the wisest use of instructional time, then changes must be made in the program. Recommendations for changes concerning previsit activities, restructuring the program at the museum and recasting the museum's role in informal education in the community are made.

EXEMPLARY PRACTICE IN SCIENCE CLASSROOMS

Kenneth Tobin
David T. Treagust
Barry J. Fraser
John C. Happs

The purpose of the Exemplary Practice in Science and Mathematics Education (EPSME) study was to identify high quality science and mathematics teaching, to document exemplary practice through case studies, and to investigate key characteristics common to exemplary teaching in different sites.

Effective science and mathematics programs in elementary and secondary schools are fundamentally important in the increasingly technological society that characterizes today's world. Traditional educational research techniques rely on random samples of students and schools to examine practice as it exists in a complete system. Such procedures were not appropriate for this study. What was needed was a carefully selected sample of teachers who were recognized by good judges as being effective science and mathematics teachers. These teachers were then observed and their classrooms examined in a systematic way to enable the elements that contribute to their success to be identified and described. These descriptions are valuable as they will allow other teachers to gain ideas for practice in their own classes, and also to recognize that good practice may take many forms.

The EPSME study was an extension of a set of studies conducted in the USA from 1982 until the present time. The major purpose of the USA studies, known as the Search for Excellence, was to identify excellent science teaching practices in an endeavor to improve science achievement in American schools. Replication and extension of the Search for Excellence provided opportunities to identify exemplary practices incorporated into science and mathematics teaching in Australian schools.

The study endeavored to identify a number of models that accounted for differing views on exemplary practice and teaching and recognized the importance of contextual variables in determining the effectiveness of teaching and learning strategies. In each case study the contextual variables likely to influence learning were investigated intensively and were fully described.

A research team consisting of 13 of Western Australia's leading science and mathematics educators conducted a series of intensive case studies to identify factors that contributed to successful practice. The investigation encompassed the intended, implemented, perceived and achieved curriculum in science and mathematics classes at selected elementary and secondary year levels. Through careful observation of successful science and mathematics teachers it was anticipated that teaching practices could be described, analyzed and presented in a form that was useful for teachers and teacher educators wishing to improve science and mathematics teaching.

HOW IMPORTANT ARE DIFFERENT TYPES OF SCIENTIFIC KNOWLEDGE?:
CURRICULUM IMPLICATIONS

Leo West
Peter Fensham
Heidi Kass
Sunee Klainin
Pinchas Tamir

This symposium provides a point of convergence of 1) an important theoretical position (which evolved as part of a chemistry curriculum development project in North America) about differential values given to different types of knowledge, and 2) a quite independent evaluation of a chemistry curriculum in Thailand, the results of which are well explained by the theoretical position mentioned above. A science educator with a long interest in curriculum development and evaluation will, as discussant, explore the implications for both of those endeavors.

Curricula are not neutral with respect to type of knowledge valued. The science curricula of the 1960s gave particular value to empirical and methodological knowledge; many current science curricula place high value on applicational knowledge. Messages about these value perspectives are usually communicated implicitly rather than explicitly to the students. Often, competing and inconsistent messages are communicated from other sources.

The first paper of the symposium will describe these normative perspectives notions. It will identify a set of knowledge types, discuss the differential values that might be given to each, and will articulate their influences on what students and teachers think the subject is, and on what kinds of learning student undertake.

The second paper describes the results of an evaluation of a chemistry curriculum in Thailand. The curriculum spans years 10, 11 and 12 and is undertaken by students intending to proceed to university science courses. The curriculum was modelled on inquiry/discovery oriented Western world science curricula of the 1960s. Student performance in measures of empirical and applicational knowledge initially increase (during years 10 and 11), but decline or remain unchanged during years 11 and 12. The reverse is observed with measures of theoretical knowledge. This is explained in terms of competing normative perspectives from the curriculum and from university entrance examinations at the end of year 12. Initially the curriculum "works," in that students improve in manipulative skills, laboratory problem solving, scientific attitudes, and preference for laboratory evidence. Eventually the messages being provided by the entrance examinations take over, and there is a decline in these variables and a corresponding increase in variables related to theoretical knowledge.

The discussant will consider the implications of the issues raised both for curriculum development and curriculum evaluation in science.

EVALUATION OF AN INNOVATIVE SCIENCE TEACHER EDUCATION PROGRAM

Joseph S. Krajcik
John E. Penick
Robert E. Yager

This study describes the evaluation of a model science teacher education program developed with support from the National Science Foundation from 1970 to 1980. The results help to answer the question: Do graduates of this model science teacher education program influence the attitudes and perception their science students have of science, science teaching and science teachers? In answering this, the attitudes of science students of graduates from this program were compared with the attitudes of science students of science teachers in general.

The students of graduates of this program completed a modified version of the 1983 National Assessment of Education Progress (NAEP) attitudinal questionnaire. Data were collected during the last week of the 1985 school year to insure that the most recent science teacher would be highly influential. These data were compared to the results of the NAEP study.

Data indicate significant differences exist. The results of this study provide information for analyzing aspects of this model teacher education program, establishing strengths and weaknesses, and developing insights into the argument over the need and effectiveness of science teacher education programs.

CHARACTERISTICS OF SCIENCE TEACHERS FROM AN INNOVATIVE
SCIENCE TEACHER EDUCATION PROGRAM

John E. Penick
Joseph S. Krajcik
Robert E. Yager

This study describes one component of the evaluation of a model science teacher education program developed with support from the National Science Foundation from 1970 to 1970. The results help determine if a model science teacher education program influences the teaching activities and methodologies of the graduates from the program.

Forty graduates from this program completed the National Survey of Science, Mathematics and Social Science Education developed by Iris Weiss in 1977. The data from these teachers were compared with the results from the national sample.

AN EVALUATION OF A PERFORMANCE-BASED SECONDARY SCIENCE EDUCATION PROGRAM

Ronald J. Bonnstetter
Donald W. McCurdy

This study describes the most recent evaluation of a nationally recognized secondary science teacher education program. Over the last ten years six major studies have assessed various program aspects. This present evaluation effort has two major components. The first assesses the attitudes and perceptions toward science of the science students presently being taught by our graduates. The findings were compared to the attitudes and perceptions toward science of secondary students in general. The second component of this study compares the characteristics of graduates from a model teacher education program to teachers in general.

The students of our graduates completed a modified version of the 1983 National Assessment of Education Progress (NAEP) attitudinal questionnaire. Data were collected during the last week of the 1985 school year to insure that the most recent science teacher would be the major influence.

During the fall of 1985, teachers from this program completed the National Survey of Science Teachers questionnaire, developed by Iris Weiss. These findings were compared to these national norms, as well as comparisons with characteristics of teachers in exemplary science programs.

The results of this study provide valuable information to better assess the effectiveness of science teacher education programs. The comparison of findings with stated program objectives have implications for the need of more wide spread implementation of model teacher education programs and provide insight into strengths and weaknesses of these programs.

THE EFFECTS OF TESTING ON SCIENCE PROCESS SKILL ACHIEVEMENT

Barbara M. Strawitz

The purpose of this study was to examine the effects of testing on the achievement of students using self-instructional materials to learn science process skills.

The subjects were 54 students who were randomly assigned to two sections of an undergraduate science methods course taught by the writer. All students taking the courses were juniors and seniors concurrently enrolled in mathematics and social studies methods classes. The science methods course was developed on the assumptions that teachers will teach as they are taught and that teachers will be more likely to teach science if they enjoy teaching it, feel confident about teaching it, and believe it to be of practical importance to children. Class activities included lectures, discussions, peer teaching, and participation in science activities.

In the field experience component of the course, students interviewed elementary school children about their knowledge of science concepts, administered Piagetian tasks, assessed process skill achievement, and taught science lessons to small groups of children. The same self-instructional process skills textbook, Learning Science Process Skills by Funk, Okey, Fiel, Jaus, & Sprague, was used in both sections; however, the method of using the programmed materials differed. In one section, students were paced through the textbook and were given short quizzes in class as each of the skills was assigned while in the other section, students were held responsible for completing the self-instructional lessons on process skills by the end of the semester. Students taking the quizzes throughout the semester were expected to attain a higher level of process skill proficiency because previous studies have shown that taking a test immediately after learning leads to better retention of the material.

A two-group posttest-only design was used. At the end of the semester students were administered a science process skill measure and a questionnaire to collect demographic data. Results of the one-way ANOVA indicated that there was no significant difference between the performance of students in the two groups. It appears that periodic testing of students using self-instructional materials to learn science process skills does not enhance their acquisition of those skills. Class time used for brief quizzes could be better spent on other activities.

THE RELATIONSHIPS BETWEEN PERFORMANCE ON SCIENCE THINKING SKILLS AND READING COMPREHENSION SKILLS OF ELEMENTARY STUDENTS

Betty Crocker
David P. Butts

This study examines the relationships between performance on science thinking skills and reading comprehension skills in elementary school students. The subjects of the study were 1,240 third and fifth grade students enrolled in eight public elementary schools in a suburban system near Atlanta, Georgia. The reading program of these students was the Harcourt Brace Jovanovich Bookmark series. All of the students participated in Science - A Process Approach modules appropriate to their grade levels.

Student performance on reading and science tests were recorded at the individual item level. Information about performance at the objective level was computed by combining student scores at the test item level. The student scores of the performance levels on the objectives were factor analyzed by grade levels and examined for correlations to determine if reading comprehension skills and science thinking skills were discrete factors. Statistically significant correlations occurred between reading comprehension skills and science thinking skills were discrete factors. Statistically significant correlations occurred between reading comprehension skills and science thinking skills were discrete factors. Statistically significant correlations occurred between reading comprehension skills and science thinking skills, and these skills merged into six common factors. These factors included organizing information, synthesizing information, analyzing information, interpreting information and application of information. Thus, activities designed to practice science thinking skills appear to have a potential for providing practice for skills present in both reading and science. If science activities are designed in such a way as to enable students to practice these skills and if reading activities are designed in such a way as to enable students to practice these skills and if reading activities are designed to enable students to practice these same skills, then both reading and science classes can play an increased role toward enhancing student thinking skills-- more than either of the classes alone.

THE EFFECTS OF DIAGNOSTIC TESTING USING DIFFERENT
ITEM FORMATS AND COGNITIVE LEVELS ON SCIENCE ACHIEVEMENT

Janet Irby
Russell H. Yeany

Much research has been done on the effectiveness of diagnostic testing to improve science learning. But, little thought has been given to the effects of item type and cognitive level. No research has been reported on studies looking at variation in diagnostic testing format and level on science learning. The purpose of this paper is to report on an experiment designed to assess the effects of: (1) diagnostic item format; (2) diagnostic item cognitive level; (3) pupil ability; and (4) gender on the science achievement of 10th grade biology students. In addition the statistical interactions of the above variables were also examined.

The study employed a sample of 205 students and looked at immediate achievement in two different units of instruction as well as retained achievement on the same topics. Ten classes were randomly assigned to one of three kinds of treatment: (1) choice type diagnostic items; (2) short answer items; or, (3) essay format items. Within these treatment levels, students were randomly assigned to one of three item cognitive level treatments. They were: (1) knowledge level; (2) comprehension level; or, (3) application. No untreated control group was used because the purpose was not to assess the effect of diagnosis compared to no diagnosis. That question has been answered satisfactorily in the science education literature.

Achievement tests were designed to assess the objectives of the two units of instruction presented during a six week period. Achievement was measured immediately after a unit of instruction was completed and again three weeks later. In order to assess the specific effects of the treatment types, the items on the achievement tests were categorized as to format and cognitive level. All achievement tests contained a balance of the three types and levels.

The data were analyzed using ANCOVA procedures with a prior achievement score being used to adjust for group bias and increase statistical power. The host of specific results across all types and cognitive levels of diagnostic testing treatments and all types and cognitive levels of achievement testing plus interactions with ability and gender are numerous. Generally, the results indicated that the nature and level of the diagnostic item does influence learning and that influence shows up in achievement measures in ways most akin to the diagnostic experience.

A STUDY OF FACTORS AFFECTING STUDENT PERFORMANCE
IN JUNIOR COLLEGE GENERAL CHEMISTRY COURSES

Karen Sanchez
Marianne Betkouski

The high attrition rates in junior college chemistry courses are cause for concern. The colleges are often open-door institutions where little placement information is available on entering students. There is a need to identify variables correlated with student achievement in junior college chemistry courses as a means to identify and remediate student learning problems.

This study examines a number of variables affecting student performance, including intellectual development (as measured by the TOLT), attainment of science process skills (as measured by the TIPS), background in chemistry, algebra, physics and lab science, cognitive style and attitude towards science. One hundred seventeen students enrolled in introductory chemistry courses at a northeast Florida junior college were pre and post tested in the Fall of 1985. Results were correlated with midterm and final grades. Regression analysis was used to ascertain predictors of chemistry success. The variables differentiating high achieving students from low achieving students are reported. Implications for design of appropriate interventions are discussed.

ANXIETY LEVELS OF COLLEGE STUDENTS TAKING REQUIRED SCIENCE COURSES

Mary Westerback
Clemencia Gonzalez

All students taking required science courses in the department of Biology, Chemistry, Geology-Geography, Physics, and Psychology at C.W. Post College were given the State-Trait Anxiety Inventory to determine their initial anxiety levels about taking required science courses. The results indicate that students are not anxious about taking these courses. There were no significant differences between the scores of males and females taking the same course, except for psychology where the females' scores were significantly higher than the males' scores. It appears that the state anxiety scores of females taking chemistry, physics and earth science/geology are lower than those of females taking biology and psychology.

When asked about their previous background in science students reported previous influences in science in a ratio of 3:1 positive to negative.

INFLUENCE OF PRIOR FAMILIARITY AND TEXT STRUCTURE ON COLLEGE STUDENTS' RECALLS OF EARTH SCIENCE PASSAGES

Sarah L. Ulerick

Researchers in reading comprehension and cognitive science have shown that text structure and degree of prior knowledge or familiarity influence the quantity and quality of information subjects recall after reading prose passages about a given topic. Little of this research has been conducted in actual classrooms using "natural" textbook passages. The study reported here investigated these two factors of comprehension in an ongoing college course. The experimental "read-recall" paradigm was applied using four passages from the students' textbook. Two geology passages represented "unfamiliar" or entirely new information. Within each subject area, a descriptive- and a process-type text structure were selected. Students' recalls were scored for literal recall, replacements, deletions, mistakes, and additions. Relational mapping was used to create an initial "template" for scoring each passage. Proportion scores were calculated for total idea units, literal recall, replaced recall, and additions. The scores were compared for the four passages using several paired analyses. Students recalled more information from the "unfamiliar" astronomy passages, and elaborated more (replaced and added ideas) in their recalls of the "more familiar" geology passages. Effect of type of text structure was not significant, though there was a trend for more recall of the descriptive passages. A third research variable emerged during the analysis of recalls. Although equivalent in length and overall readability, the four passages differed in degree of comprehensibility. A numeric ranking of text-difficulty was based on the relational maps. The ranked order of difficulty correlated strongly with amount and type of recall. Students recalled less information for the more difficult passages and added or replaced more information in their recalls of these passages. Because text-difficulty confounded the effects of the initial research variables, firm conclusions about the research questions cannot be drawn. Instead, the study serves as a strong reminder to science teachers and researchers that readability and comprehensibility are very different. Students' comprehension of textbook passages is influenced by a complex interaction of text-based factors and student-based factors.

A PREACADEMIC PREPARATORY CRASH COURSE IN SCIENCE AS A FACTOR
IN ENHANCING EQUAL OPPORTUNITIES AND EXCELLENCE IN
ACADEMIC HIGHER SCIENCE EDUCATION

Uri Zoller
D. Ben Chaim
M. Danot

In addition to high school graduates formally qualified for acceptance into universities for undergraduate studies and science teaching certificate, there exists motivated adult population (defined as "attentive" to science) interested in such university-level courses of study, but which lacks the required learning basis as well as the formal certificates.

In view of the new needs and increasing demand for competent science and mathematics teachers and educators on the one hand and the striving towards good quality and excellence on the other, it is imperative to find unique ways to invest much effort in appropriate pre-academic preparation for such candidates in order to provide them with equal opportunity while responding to their special problems.

In this study we compare data collected during 6 years (1978-1984) concerning the achievements of two different target student populations. The first (group A) consisted of the science "attentive," unprepared adult students for which a specially preacademic preparatory crash course (including chemistry, physics and mathematics) was specially designed. The second (group B) was that of ordinary ("average" and above average) high school graduates - bearers of the science-oriented matriculation certificates. A total number of 170 students, most of whom were prospective biology science teachers participated in the study.

Our findings suggest that specially designed science preparatory crash courses - limited in time, duration, content, and scope - can advance unprepared highly-motivated adult students to later perform as well as, or better than, the formally prepared students who are qualified for direct acceptance to the university.

Specifically, we found that in spite of the (expected) lower psychometric scores of the unprepared students (group A) compared with those of the academically prepared ones (group B), the achievements of the former group - at the end of the first academic year - in chemistry, physics, and mathematics are the same and even slightly better.

Moreover, the data concerning the weighted average "total" scores of the students in all the compulsory science courses during their 4-year, academic study program clearly demonstrate that the unprepared students (group A) did equally well and even (slightly) better than the ordinary academically-bound students (group B) as far as academic science studies are concerned.

Our findings suggest that the unpreparedness of students in a scientific discipline may be completely remedied by an appropriate crash program, and thus equal opportunity for higher education can be given to different target populations devoid of the formal pre-requisites, provided both students and faculty are highly motivated. Existing formal secondary science education - being important as it may be - is not necessarily an essential precondition for successful academic (undergraduate) studies. Contingent on the particular target population, other alternatives do exist and should be explored.

VARIABLES THAT AFFECT STUDENTS' ENROLLMENT IN SCIENCE COURSES: IT IS NOT ONLY ACHIEVEMENT

Avi Hofstein
Ruth Ben-Zvi
Nava Milner

In recent years we are concerned with the problem of low enrollment in physical science courses. Thus, it is of utmost importance to investigate the reasons that influence students' decisions concerning enrollment in these courses. Two methods were used for this investigation. In the first, students' mean ranking of their properties of a list of given reasons for enrollment was used. In the second, regression analysis was used. In this analysis, the number of physical science credit points served as the dependent variables and a list of affective scales and socioeconomic variables served as independent variables. It was found in both the first and the second method that the most predominant factor that influenced students' decision concerning students' enrollment in physical science courses is the one that deals with students' interest in science studies (these explained 24% of the total variance). Using the ranking method it was found that extrinsic factors, i.e., media, parents and peers are perceived to be less effective concerning students' enrollment.

It is suggested that the next generation of curriculum material should aim at meeting the needs and interests of a wide range of students. It is suggested that more research should be conducted in the future in order to explore areas and topics in science that will increase students' interest in science and eventually will increase enrollment in these courses.

ACADEMIC WORK IN HIGH SCHOOL SCIENCE CLASSES

Kenneth Tobin
James J. Gallagher

An investigation was conducted in 15 high school science classes in order to investigate the nature of the academic work and to identify variables that influenced academic work. The results indicated that the assessment system was the main motivating force that focused the way that science lessons were planned and implemented and the way that students engaged in learning tasks.

Teacher and student expectancies also appeared to influence the implemented science curriculum. Within classes the more able students were involved in interactions to a disproportionate extent. Between class differences were also observed. Higher ability classes received a more enriched curriculum than lower ability classes. For example, discussions which related science to the world outside of the classroom and laboratory investigations were more evident in the higher ability classes than in the lower ability classes.

There was some evidence that the content area knowledge of the teacher influenced the manner in which the curriculum was implemented. When teachers taught out of field, they tended to be less expansive and less interactive than when they taught in field. Consequently, out of field lessons tended to be lecture oriented and interactions in whole class settings involved a small number of more able students.

Although science is perceived to be a cognitively demanding subject, the cognitive demands of the activities observed in this study were not high. The tasks required of students usually involved learning and recall of facts and use of procedures to obtain correct answers. The results of the study suggest that the cognitive demands of the academic work interact with classroom management. The incidence of off task behavior was often high when the cognitive demand of the academic work was high. However, in the same classes a low incidence of off task behavior accompanied low cognitive demand activities.

A SYMPOSIUM ON SCIENCE EDUCATION RESEARCH IN
LATIN AMERICA AND THE CARIBBEAN

Arthur L. White
Donna F. Berlin
Pamela Fraser-Abder
Deyanira Barnett
Juan Esquivel
Rita Peterson
David Butts

The purpose of this symposium is twofold.

- A. To report the proceedings of the first regional consultation on science education research in Latin America and the Caribbean held in Trinidad and Tobago, February 12-15, 1986.
- B. To discuss the application of science and technology to education problems in developing countries and discuss policy for future cooperative research activities by science education researchers in the Caribbean and the Americas.

The symposium will include representatives from The University of The West Indies, Trinidad and Tobago; The University of Panama, Panama; The University of Costa Rica, Costa Rica; The National Pedagogical University of Mexico, Mexico; The Ohio State University, USA; University of California, USA and The University of Georgia, USA.

Each of the participants will discuss their perceptions of:

- A. The relationship of technology to the needs of developing countries.
- B. The relationship of their particular research efforts to the needs of developing countries.
- C. The collaborative activities which would benefit both the developing countries and the other countries.

SYSTEMATIC REPRESENTATION OF BIOLOGY KNOWLEDGE

J. Faletti

A major goal of science education is to turn novices (students) into experts (scientists or science literates) with a minimum amount of pain, effort, and time. However, the transfer of biology knowledge, instructor to student, usually results in a loss of the rich interconnections that an expert has. The papers in this set describe efforts to restore and exercise these interconnections in the knowledge of the student.

This paper first provides a rationale for and overview of the general approach taken which is to (A) design a formal and systematic representation of biology knowledge in the form of a semantic network of concepts and the relationships between them; (B) build a set of computer-based tools to support the design and construction of semantic networks for particular areas of biology; (C) build a set of computer-based games to present semantic networks to students along with tasks which will require the students to exercise the interconnections among concepts.

Previous studies of methods of improving integration of new information are briefly reviewed. Previous work in knowledge representation is then discussed. Since the representation method chosen is somewhat simpler than the current trend in knowledge representation, the reasons are discussed, all stemming from practical constraints arising either from the goal of use in instruction or from the capabilities of current computer systems.

SYSTEMATIC REPRESENTATION OF MOLECULAR BIOLOGY KNOWLEDGE

Kathleen M. Fisher

The first paper in this set outlines the rationale for developing systematic means of representation of biological knowledge using techniques from artificial intelligence and cognitive science. This paper describes the analysis of one subdomain, molecular biology, in the context of an introductory biology courses.

A small set of relationships has been identified which appears to be sufficient for describing all molecular and cellular reactions and structures discussed in an introductory biology courses. A precise definition has been

developed for each relationship. These twenty relationships are of four types: analytical (e.g., a "set" and its "members"), spatial (e.g., "contains" and "contained within"), temporal (e.g., "precedes" and "follows"), and process (e.g., "input," "agent").

Three different computer-based semantic network representations of molecular biology knowledge were developed. Two list-structure nets were useful in identifying problems in net design. The most successful of the three prototypes involved spatial representations (concept maps) for each concept, with the maps being linked together to form a network (details are described in the third paper of the set).

Various styles of knowledge representation were tested with students enrolled in introductory biology. The students were most enthusiastic about exercises in which partially completed concept maps were given to them and they had to fill in the missing pieces (concepts or relationships).

The systematic analysis of relationships between concepts reveals relationships not explicitly perceived before, even by experts. We believe that these representational techniques will be useful in facilitating student learning.

COMPUTER-BASED SEMANTIC NETWORK IN MOLECULAR BIOLOGY: A DEMONSTRATION

J. Callman
K. Fisher
J. Faletti

This paper analyzes the hardware and software features desirable in a computer-based semantic network system for representing biology knowledge. It then describes in detail a prototype network of molecular biology knowledge that has been developed using Filevision software and a Macintosh computer. The prototype contains about one-hundred linked concept maps.

Design principles are delineated. For example, the decision was made not to include direct links between members of a set such as "RNA" and "DNA." To move from one to the other in the network it is necessary to move up the hierarchy to "nucleic acids" and back down. This requirement is pedagogically attractive and reduces clutter. Many other such principles are required to assure consistency in map generation.

Working with information in the computer-based semantic network provides an experience heretofore unavailable. Project members find it is fun, and somewhat challenging even for creators of the data base, to find paths from point X to point Y in the database. Moving through the net requires an integration of concepts that seems qualitatively different from that encountered in most other interactions with academic subject matter.

SYSTEMATIC REPRESENTATION OF KNOWLEDGE OF ECOLOGY: CONCEPTS AND RELATIONSHIPS

Y. Garb
J. Faletti
K. Fisher

This study describes efforts to apply principles of systematic knowledge representation, specifically the concept mapping and computer-based semantic networking techniques outlined in earlier papers, to the domain of ecology. Ecology is problematic for several reasons. First, ecology involves interrelationships between concepts of widely disparate degrees of concreteness and abstractness (ranging from "snowshoe hares" to "carrying capacity"). Second, a large proportion of concepts in ecology are highly abstract, and there is relatively little literature in linguistics or artificial intelligence to guide us in representing such concepts. Third, there is a striking lack of consensus among experts in the field regarding the definition of basic concepts.

On the other hand, linear (text) descriptions of ecology often fail to capture or convey the complex web of interrelations that exist between concepts. Semantic network representations may provide a particularly useful alternative form of description for this domain.

A set of twenty-four relationships and modifiers is presented that seems sufficient for describing all ecological relationships discussed in introductory courses. Many of these relationships are identical to those used in describing molecular biology. The relationships can be divided into classes: analytical, spatial, temporal, process, connector, and modifier.

Methods used in developing and testing these relationships are described, including use of materials in an undergraduate Plant Ecology course. A prototype version of a semantic network of ecology knowledge is also described. A student can move through the network from concept to related concept via a relational pathway as described previously. In addition, at any time a user can "move up" to a definition frame for a concept or "move down" to an example frame for that concept. These additional features seem essential for adequately summarizing ecology knowledge. Their utility is not, however, limited to ecology (they could be added on to previously developed networks such as molecular biology as well).

CHANGING PRESERVICE TEACHERS' ATTITUDES: THE EFFECT
OF ANECDOTAL AND DATA-SUMMARY PERSUASIVE COMMUNICATIONS

Thomas R. Koballa, Jr.

Two anecdotal and two data-summary persuasive communications were developed and validated. The communications were organized around a series of four arguments gleaned from "How Effective Were the Hands-On Science Programs of Yesterday." The effect of the communications to change preservice teachers' attitudes toward supplementing traditional, textbook-based science programs with either SAPA or SCIS was tested. Communication type (anecdotal vs. data-summary) and program type (SAPA vs. SCIS) served as the independent variables; attitudes toward supplementing textbook-based science programs with either SAPA or SCIS served as the dependent variable. Attitude was operationalized as scores reported on a semantic differential scale. The counterbalance design was used. Subjects in one section of an elementary science methods course (N=19) read the SAPA anecdotal and SCIS data-summary communications. Subjects in another section (N=19) read the SAPA data-summary and SCIS anecdotal communications. Data analysis revealed that: Communications developed from research based upon persuasion theory affected the subjects' attitudes in a positive manner. Regardless of program type, anecdotal communications were superior to data-summary communications in changing the subjects' attitudes immediately following treatment and three weeks later.

CLASSROOM CLIMATE AND SCIENCE-RELATED ATTITUDES
OF JUNIOR HIGH SCHOOL STUDENTS IN TAIWAN

Frank E. Crawley
Bao-Shan Lin

Differences in classroom climate and science related attitudes were investigated among junior high school science classes and students' in Taiwan. The sample consisted of 1,269 students enrolled in 40 science classes distributed equally among 10 junior high schools, 5 metropolitan and 5 rural. Classes were further classified according to sex (21 boys' and 19 girls' classes) and ability (19 High and 21 low ability classes). Using the Learning Environment Inventory to measure climate, science classes in metropolitan schools, more than rural, were found to be characterized by Speed, Friction,

Favoritism, Difficulty, Cliqueness, and Competitiveness. No differences were found in the classroom climates of classes in which students were grouped according to sex or ability. Using the Test of Science-Related Attitudes, students in science classes in metropolitan schools, in contrast to rural, expressed more positive attitudes toward the Social Implications of Science, Adoption of Scientific Attitudes, and Attitude to Scientific Inquiry. Boys more than girls recorded high scores on Leisure Interest in Science and Career Interest in Science. High ability students were found to have higher scores on Attitude to Scientific Inquiry than did low ability students. When examining the relationship between the 15 subscale scores of the LEI and the 7 subscale scores of the TOSRR for the 40 classes, only 9 out of 105 correlations proved to be significant. Most differences in climate, attitude, and their interactions were attributed to school location rather than to student characteristics.

THE EFFECT OF PERSUASIVE COMMUNICATION ON FEMALE PRESERVICE ELEMENTARY SCHOOL TEACHERS' ATTITUDES TOWARD VIEWING SCIENCE AS AN ENTERPRISE FOR BOTH SEXES

Martha Nabors
H. Seymour Fowler

The purpose of this study was to determine the effects of persuasive communication on changing attitudes of female preservice elementary teachers toward viewing science as an enterprise for both sexes.

The dependent variables were: (1) the females' attitude changes, in viewing science as an enterprise for both sexes, as measured by the Attitude Toward Science as an Enterprise for Both Sexes (ATSEBS) Scale, and (2) the persistency in attitude change, as measured by the ATSEBS Scale. The independent variable was the persuasive communication.

The procedure involved 88 female preservice elementary school teachers randomly assigned within four regular class sections of a science education methods course (Teaching Elementary School Science) to one of two treatment groups (experimental or control). The two groups were administered the ATSEBS Scale to determine their initial attitudes. Three weeks later, the subjects were administered either the persuasive communication (Viewing Science as an Enterprise for Both Sexes) or the control communication (Sleep and dreams). Immediately following treatment, all subjects were administered an appropriate eight-item recognition test and the ATSEBS Scale as a posttest. After another three weeks the subjects were administered the ATSEBS Scale as a delayed posttest.

The results indicated the subjects from both groups obtained high attitude scores toward viewing science as an enterprise for both sexes. There was no significant difference in mean scores on the posttest between the experimental and control group after receiving a persuasive communication or a control communication. There was no significant difference in mean scores on the delayed posttest between the experimental group and the control group. There was also no significant difference between experimental group's posttest and delayed-posttest mean scores.

The study concluded that, contrary to findings reported in the literature, females do feel science is an enterprise for both sexes, where men and women can achieve on an equal basis.

A STUDY OF THE IMPLEMENTATION OF THE COMPONENTS OF INTERMEDIATE SCIENCE CURRICULUM STUDY

Robert K. James
Stephen E. Holaday

The Intermediate Science Curriculum Study (ISCS) was reported by Weiss to be one of the most widely adopted of the NSF supported curriculum development programs to come out of the 1960's curriculum reform movement. The ISCS made several departures from previous NSF projects in the unique components that were a part of the curriculum. By its nature it had numerous management and evaluation problems which teachers had to master. The purpose of this study was to examine the nature and extent of implementation of the components of ISCS within individual classrooms.

Hall and Loucks developed a strategy for assessing the ways teachers configure the various parts of an innovation. Known as Innovation Configuration (IC), this procedure seeks to identify the major parts (called components) of the innovation and the various ways (called variations of use) each may be used. Variations were listed in order, beginning with "ideal" use which conforms to the developer's perspective. The remainder of the variations can be divided into "acceptable" and "not acceptable" categories. The ISCS Innovation Configuration was developed by the authors using the procedure suggested by Heck and others. The population of the study consisted of all Kansas teachers who could be identified as using ISCS.

The results from 80% of those sampled showed that these teachers averaged 7 years experience teaching ISCS, while most had 20 or more years of teaching experience. More than one-third of the teachers had no training to teach ISCS, while an equal number had had more than 40 clock hours of training. In general, the configuration results showed that ideal variations were most frequently reported for use of the record book, self evaluations, and perceived teacher and student roles. A significant portion (24%) of the teachers were not using any self-pacing and very few teachers (6%) reported using only self-pacing. The least ideal or acceptable use of ISCS components were tests, excursions, and self-pacing. Most teachers (80%) used teacher-made tests, or some combination with ISCS tests. In no classrooms were students allowed to choose their own excursions.

Most teachers were using ISCS in a way the researchers believe to be "acceptable." They do report modifications apparently designed to better meet local needs of the teacher, school, and/or students. The IC can be a valuable tool to gage the extent of use of the overall program and its various components. A supervisor who gathered these data in his/her district might want to examine them on a component-by-component or teacher-by-teacher basis. The general implications of this study are that IC's can be developed as a strategy for monitoring the implementation of new science programs.

CURRICULUM EMPHASIS BY CALIFORNIA'S EIGHTH-GRADE SCIENCE TEACHERS

David R. Stronck

The National Science Foundation in 1980 reported that science teachers throughout the U.S.A. tended to neglect problem-solving, the relationship between science and technology, and a coherent articulated twelve-year educational program in science. The Department of Education of the State of California attempted to correct such problems through publishing the Science Framework for California Public Schools: Kindergarten and Grades One Through Twelve in 1978 and the Science Framework Addendum in 1984. To measure the implementation of recommendations in these publications, the California Assessment Program will provide a science test for all students in grade 8 annually, beginning in May of 1986.

The purpose of this study is to describe the curriculum emphasis recognized by California's eighth-grade science teachers in 1985. Comparing their analysis of teaching practices with the recommendations of California's Science Framework Addendum may provide important details on neglected areas of the science curriculum. The data may help to define specific problems that suggest inservice programs.

In May of 1985 approximately 10,000 students took the eighth-grade science test of the California Assessment Program. Throughout the state 1669 items were field-tested through the use of matrix sampling. Approximately 1,800 teachers reviewed and commented on the field test forms. These teachers responded to a question about the amount of curriculum emphasis on each item, i.e., whether the topic received "much," "some," or "none" in the science curriculum presented to the students before they took the eighth-grade science test.

The achievement of the students has a high positive correlation with the curriculum emphasis described by the teachers. Some of the generalizations from the teachers' responses are the following.

1. Content topics were more emphasized than science process skills.
2. Among the five content areas, "manipulative skills and safety" received the greatest emphasis.
3. The second most emphasized content area was "biological science." Among the eight topics of biological science, "cells," "human beings," and "plants" (in that order) had the greatest emphasis while "evolution" was the most neglected.

4. The third most emphasized content area was "physical science." "Matter" and "mechanics" were preferred over "energy." The least emphasized reported category (among all 33 topics and subtopics) was sound (a subtopic under the topic of energy).
5. The fourth most emphasized content area was "earth science." More emphasis was on topics of astronomy and geology than on meteorology and oceanography.
6. The least emphasis on a content area was for "science, technology, individuals and society." The topic "knowledge of careers related to science and technology" was especially neglected.
7. Among the science process skills, the categories of "experimenting" (a topic of the area "relating") and "observing" were the most emphasized.
8. The least emphasized process skill was "applying," i.e., using knowledge to solve problems

These results suggest that large numbers of junior-high-school and middle-school science teachers in California need inservice help to implement better the recommendations of the California Science Framework Addendum.

CONCERNS OF TEXAS SCIENCE TEACHERS ABOUT THE 40% LAB TIME RULE

Robert K. James
Don Hein

The Texas Education Agency (TEA) began in Fall, 1985 enforcing an existing rule that 40% of science teaching time in grades 7-12 would be given over to laboratory instruction. Knowledge of the concerns of science teachers about this rule might be helpful in facilitating its implementation. The purpose of this study was to examine the concerns of Texas science teachers about the 40% lab time rule and to determine the perceived barriers they face in implementing this rule.

Hall and others at the R&D Center for Teacher Education at the University of Texas - Austin reported the development of the Seven Stages of Concern About the Innovation and have used it to gain an understanding the concerns of teachers as they move into and through the implementation of new programs in their classrooms. Hall, Wallace, and Rutliff report the development of a 35 item instrument (Stages of Concern Questionnaire (SOCQ)) for assessing concerns. This instrument was used in this study along with a demographic

section in which respondents were asked to rate their greatest needs in surmounting eight hypothesized barriers to their achievement of the 40% rule. This instrument was sent to 450 randomly selected Texas science teachers. Two-hundred and twenty-seven returned them (a return of 51%).

The results showed that teachers perceived that their greatest barrier was "more preparation time," while "improved facilities," "additional supplies" and "additional equipment" all tied for second ahead of "existing equipment repaired or upgraded," "improved instructional materials," "increased administrative/supervisory support," and "enhanced lab teaching methods."

The findings for the SOCQ showed that the pattern of concerns was nearly identical for all subgroups with a profile that is typical of non-users of an innovation, in that it shows intense informational and personal concerns and low consequence and collaboration concerns. The most intense peak on all profiles is personal. Consequence concerns are lowest for all groups, and refocusing concerns are unexpectedly high for all subgroups except chemistry. In general it can be said that the high personal concerns, low consequence and collaboration concerns, along with unexpectedly high refocusing concerns indicate an uneasiness with the 40% lab time rule. Teachers were concerned about the consequences of this rule for them. They have ideas about how to do things differently. In considering the generalizability of these results, the reader will recognize the limitations imposed by the percent return.

These data confirm what observers of the Texas scene might already have concluded. A large portion of the population of science teachers were negative about the 40% lab time rule. Hall suggests interventions for teachers with intense personal concerns and points out the "need to be very careful in working with persons with personal concerns." A program such as Hall describes is difficult to imagine on a state-wide basis, and neither is it consistent with the "top down" mentality that spawned the enforcement of this rule in the first place. The research on change does not support the apparent conclusion that change happens because it is mandated.

Those who do believe that the concerns of teachers about the 40% lab time rule will make a difference in whether or not it is ever implemented can use these data as a basis for the selection of interventions from the work of Hall. Subsequent use of the SOCQ could provide supervisors with a strategy to monitor the resolution of teacher concerns through time. Local supervisors will find the examination of individual teacher profiles to be helpful in working with individual teachers.

AN ANALYSIS OF FIFTH AND SIXTH GRADE STUDENTS'
ACQUISITION OF THE INVENTING PROCESS

Christine Kuehn
Gerald H. Krockover

Invention, one of the strongest forces in human affairs, is the very foundation of civilization. Inventions cause change, development, and evolution in world affairs. Inventive thought should be encouraged for the purpose of solving problems for humanity since the key to many new products and inventions which will transform the environment and supply many of the needs of society may well be the knowledge of how to invent.

Despite the importance of inventing, few schools incorporate the process of inventing into the curriculum. A search of the literature finds articles and books which make suggestions for teaching inventing to elementary students; however, no references of formal studies concerning teaching an inventive process to elementary children were located.

The purpose of this study was to determine whether an instructional unit on inventing affected the inventive abilities of fifth and sixth graders and to investigate the possible effects of the instructional unit on students' creativity scores and attitudes towards science. Concomitantly, this study attempted to determine whether relationships existed between students' inventive abilities and the following: achievement, intelligence, creativity, and creative interests.

One hundred seven fifth and sixth graders in three elementary schools were randomly assigned by school to experimental and control groups. The experimental group received instruction in the process of inventing followed by participation in a Rube Goldberg lesson and invention fair. The control group participated only in the Rube Goldberg lesson and invention fair. A posttest only control group design was used. Multivariate analysis of covariance was used to adjust posttest scores using pretest scores, achievement and intelligence test scores.

Analysis of the data revealed a number of significant interactions. For the measure of inventing, instruction by sex and school by grade were significant interactions. Achievement as a covariate was found to be significant. The interaction, school by grade by sex, was significant for creativity. There were no significant correlations between inventing, creativity, and attitude towards science, as measured by this study. The results of this study suggest that instruction does increase inventiveness for some students.

THE EFFECT OF IMAGINING BEHAVIORAL SCENARIOS ON STUDENTS' INTENTIONS TO ENGAGE IN SCIENCE-RELATED ACTIVITIES

Elisabeth H. Charron

The purpose of this study was to investigate the cognitive effects of thinking about behavioral scenarios on tenth grade students' intentions to perform science-related activities. Some researchers have suggested that beliefs about oneself depend on the availability of appropriate scenarios. Students' beliefs about their own behavior in science-related situations may then depend in part on the relative ease or difficulty of imagining themselves performing in those settings. Students may have intentions to write scientific articles, teach others about science or design experiments to the extent that it is easy or difficult for them to imagine scenarios in which they are the main characters who actually engage in those activities.

Two hundred-and-nine tenth grade biology students participated in the investigation. Participants were asked to imagine a series of behavioral scenarios, and to draw them in cartoon form. The cartoon activity was chosen because students get involved in it, often producing elaborate sequences rich in imagined details. For each student, three of the scenarios concluded with the main character deciding to do the target behavior (positive outcome), and three ended with the main character deciding not to do the target behavior (negative outcome). Within the positive and negative sets, one scenario was presented (and sketched) three times, one was presented twice, and one only once. Before and after the drawing activity, students' intentions regarding each of the target behaviors and analogue behaviors were measured on ten point scales. The analogue behaviors were included to test whether a shift in intention with respect to a given target behavior would result in a corresponding shift with respect to its analogue.

Students were randomly assigned to four groups of roughly equal size. The first group was instructed that the main character in each scenario should be themselves, members of the second group were to use a close friend, and those in the third group a disliked acquaintance. The fourth group comprised a no-treatment control group. The second and third conditions were included to test whether self-as-main character in the imagined scripts was a precondition for intention change.

The primary prediction was that for students drawing cartoons with themselves as the main character, intention to perform a behavior would change in a direction paralleling the outcome of the scenario, and would show greater change if the scenario was presented more often. It was also expected that there would be no significant change in intentions among students whose cartoons involved a close friend or disliked acquaintance as the main character.

For negative outcome scenarios, the students' intentions to engage in the target behaviors were significantly lower on the posttests than pretests, and the greatest shift occurred for scenarios drawn two or more times. When intention changes across negative conditions was examined for each main character condition, the intention changes were significant only for the self or disliked acquaintance conditions. As expected there was no significant change in the control students' pretest and posttest scores. An unanticipated result was the lack of significant change in students' intentions for the positive outcome scenarios. One contributing factor was that students tended to "top out" on the pretest for certain target behaviors. There were also no systematic changes in the analogue scores on the pre and post measures.

COGNITIVE DEVELOPMENT, SCIENCE-RELATED ATTITUDES, AND
SCIENCE ACHIEVEMENT OF PRE-SECONDARY STUDENTS IN PORTUGAL

Gerald L. Abegg
Amalia Barrios
Robert E. Kilburn

Encouraging the transition from the concrete to the formal state is essential for teachers who teach students at the pre-secondary level. A large number of research studies indicate that about 50% of American adolescents and some adults do not function consistently beyond the concrete level. No similar data on adolescents exists in the literature for Portugal.

In addition to intellectual development there are other variables that influence learning. One of these variables is students' attitude. Thus, the present study relates science achievement and cognitive development of students with their attitudes towards science and science teaching.

The Raven Test of Logical Operations was translated into Portuguese and was administered to establish the cognitive level at which the students were functioning. A criterion-referenced science achievement test was constructed and validated to assess students' achievement in science. In addition a science-related attitude questionnaire was developed and validated to assess students' attitude toward science and science teaching.

The study data revealed that the majority of the students were functioning at the concrete level (32% early concrete and 53% late concrete). The remainder (14%) of the students were categorized as early formal thinkers. Significant relationships were found between student's cognitive development and achievement. As the cognitive level increased, an increase occurred on achievement of both concrete and abstract science concepts. The data also revealed that, regardless of cognitive development, the majority of the students manifested favorable attitudes toward science and science teaching. Significant interaction was found between cognitive development level and attitudes on achievement in science.

RELATIONSHIPS BETWEEN TEACHER COMPETENCIES AND STUDENT COGNITIVE GAIN
IN ACHIEVEMENT ON CRITERION-REFERENCED MATHEMATICS TESTS:
IMPLICATIONS FOR SCIENCE TEACHING

Janet G. Warren
Mildred W. Graham
Sidney P. Smith

The study examined the relationships between the classroom teaching competencies of veteran elementary school mathematics teachers and cognitive achievement in mathematics for third, fourth, and fifth grade elementary school students across high and low socio economic status (SES) settings. The study also investigated the predictive validity of the Teacher Performance Observation Record (TPOR), a systematic observation evaluation instrument used to evaluate all veteran teachers in a large county school system in Georgia.

Classrooms were randomly selected within a stratified design from 78 schools. The TPOR was administered to 25 veteran elementary mathematics teachers by trained data collectors on two occasions during mathematics instruction. School system criterion-referenced mathematics tests were used as pretests and posttests for 590 students during the seven-week period of research. Specific methods of analysis included: Pearson Product-Moment Coefficients of Correlation, Multiple Regression, Analysis of Variance, and Hotelling's T^2 .

The results supported the validity of the TPOR with one significant indicator behavior for all teachers, "Manages disruptive behavior" and three for low SES teachers: "Uses time efficiently," "Demonstrates patience, empathy, and understanding," and "Manages disruptive behavior." Three indicators involving use of materials, structuring, and warmth had significant inverse relationships to student percentage gain scores for both SES groups. Significant correlations ranged from .67 to -.74. Of the 27 TPOR indicator process-product comparisons, 63% showed reversals across the two different SES settings. The relationship between the number of instructional groups per classroom and student gain was slightly positive but not significant.

The predictive validity for several TPOR indicators was established as a result of the study. The instrument appears to differentiate between teaching behaviors which are effective for high and low SES groups, as a contextual effect was indicated. Further research is warranted in order to identify patterns of effective instructional behavior for heterogeneous groups of teachers and students.

DIFFERENTIAL TREATMENT OF WHOLE CLASSES AND INDIVIDUAL STUDENTS
BY MIDDLE SCHOOL SCIENCE TEACHERS

Okhee Lee
James J. Gallagher

The questions to be addressed in this study are:

- (1) how do middle school science teachers differentially treat whole classes and individual students within classes, and
- (2) what are the causes and consequences of differential treatment?

The nature of the questions implied an ethnographic method in which middle school classes were observed over a long duration supplemented by interviews and informal conversations with teachers and students. To understand differential treatment of whole classes, six classes (two each) taught by three experienced middle school teachers were observed over a duration of four months. One of each teacher's classes observed was labeled as are "enriched" class by the district because high achieving students were enrolled. The other class of each teacher observed was labeled as a "regular" class and contained no students identified as higher achievers. To understand differential treatment within classes, four other teachers were added to the sample and observations were made of regular classes.

Observations of "enriched" and "regular" classes of all these teachers showed significant differences in treatment of whole classes in terms of (a) content taught, (b) teaching strategies, and (c) attitudes toward students. With high achieving classes, the teachers concentrated on academic content, presented information in ways that interested and motivated students, and interacted with students in a personal, cordial way. With "regular classes," on the contrary, the teacher's attempts to sustain group focus on academic lessons frequently were disrupted by students. More time was lost in transition between activities, and teachers' behavior toward students appeared detached. Teachers were always watchful for misbehavior.

Within the same class, individual students received quite different treatment. A select group, target students, received more questions of a higher cognitive level. They were encouraged to speak more and were given more freedom and responsibility within the class. Disruptive students, on the other hand, were constantly warned of the consequences of misbehavior and were often dealt with impatiently by the teacher.

Factors contributing to the situation observed include (a) teacher's role definitions, (b) teachers' defense mechanisms and their need for positive feedback, and (c) their need for control. The consequences of differential treatment of students by middle school teachers are differences in students' content learning, attitudes, self esteem, expectations, and behavior.

QUALITATIVE ETHNOGRAPHIC AND STRUCTURED DATA COLLECTION -
GROUNDED THEORY VERSUS A PRIORI DESIGN:
A DATA BASED COMPARISON

Russell H. Yeany
D. Daryl Adams
Elisabeth H. Charron
Michael E. Hale
Kenneth G. Tobin
Wayne Welch

The general purpose of this symposium is to focus on issues regarding the selection of qualitative and quantitative research designs to describe science classroom interactions. Much has been said recently about the advantages of one method or the other. The two approaches have been discussed and compared largely through descriptions of the methodologies and the nature of the information generated. Little has been done to make a systematic comparison by examining the sets of results and conclusions drawn after applying the two methods in the same context. The specific purpose of this symposium is to air such a comparison.

Two teams of science education researchers spent four weeks collecting data relevant to the task of describing the interactions in five science classes. Both teams focused on the same classes within identical time frames. Each was kept blind to the specific methods and findings of the other. The known and agreed upon condition was that one team would use ethnographic/interpretive methods; while, the other used structured quantitative data collection procedures. The teams were constituted so that the appropriate data collection and analysis skills resided on each team.

After the data collection period, each team analyzed its own data, formulated/tested hypotheses, and constructed conclusions about the nature of interactions in and across the five classes.

In order to seek an unbiased comparison of the two positions, a well qualified science education researcher from another major institution agreed to receive the two reports and generate a comparison and integrated position. These three reports will serve as the focus of the symposium.

The intention of the parties involved in this symposium is to show that there are strength and weakness in different approaches to data collection in science classroom. We should move beyond the point of debating whether to use this approach or that. Hopefully, the integration and serious discussion of the two sets of results can convince researchers that a combined data collection strategy will be useful and feasible in most studies.

A CONCEPTUAL FRAMEWORK FOR IMPLEMENTING AN EXEMPLARY
ELEMENTARY SCIENCE CURRICULUM

Thomas Gadsden, Jr.
Sylvia McCloskey
Betty Ann Fults
William C. Kyle, Jr.

This paper set describes the implementation and evaluation efforts associated with an elementary science program recognized as a state exemplar in Texas. This paper discusses the network of activities that constitutes the Science Through Discovery curriculum, the nature of the administrative support, and the inservice education associated with the program. Subsequent papers in this paper set will focus on the results of evaluation studies designed to assess the effectiveness of the Science Through Discovery implementation.

A LONGITUDINAL ASSESSMENT OF STUDENTS' AND TEACHERS' ATTITUDES TOWARD
SCIENCE IN PROCESS-APPROACH VS. TRADITIONAL SCIENCE CLASSES

Ronald J. Bonnstetter
William C. Kyle, Jr.

This two-year longitudinal study was designed to assess and analyze the attitudes toward science of students and teachers in first- and second-year SCIIS classes compared to students and teachers in non-SCIIS classes. This study also identifies specific needs that teachers have regarding the teaching of inquiry-oriented process-approach science.

The results of this study substantiate the fact that students have a preference for process-approach science. Significant attitudinal differences were observed between SCIIS and non-SCIIS students for both the existing academic year data and for the longitudinal data, while no observable differences were found as students progressed from the first year of a process-approach science curriculum to the second year.

The teacher survey reveals that the entering behaviors and perceptions of SCIIS and non-SCIIS teachers are very similar. While over 50% of first year SCIIS students chose science as either their first or second favorite subject in school, only 12% of all teachers indicated similar preference for science. In effect then, the academic subject which students find most interesting and exciting is among the least favored by their teachers.

The data reported in this study appear to suggest that the nature of process-approach science allows SCIIS teachers to portray a much more positive and exciting image of science and scientists. Implications of these results for inservice and preservice teacher education will be provided.

ANALYSIS OF STUDENT AND TEACHER BEHAVIORS IN PROCESS-APPROACH VS. TRADITIONAL ELEMENTARY SCIENCE CLASSES

William C. Kyle, Jr.
James A. Shymansky

This study was designed to assess and analyze specific student and teacher behaviors in first- and second-year SCIIS classes compared to students and teachers in non-SCIIS classes. This study, in conjunction with the previous paper in this paper set, identifies specific needs that teachers have regarding the teaching of inquiry-oriented, process-approach science.

Thirty-four teachers were randomly selected to participate in this study. Each teacher was observed teaching two complete science classes. The classroom observations were not pre-arranged in order to ensure that the classroom climate and environment was not disrupted. During the classroom observations, 199 students were selected randomly and their behaviors were coded for approximately 10 minutes per observation.

Three dimensions of the classroom interactions were coded: 1) the teaching/learning mode, 2) the activity context within the teaching/learning mode, and 3) the specific behavior exhibited by the teacher or student. Intercoder reliability using the Scott coefficient was .87 for teacher observations and .91 for the student observations.

The results of this study substantiate the fact that students in SCIIS classes are more actively engaged with the scientific process than are students in non-SCIIS classes. SCIIS students spend 75% of their allocated science time engaged with manipulatives. This compares with non-SCIIS students who spend less than one-third of their time engaged with manipulatives and over half of their time engaged in large group settings without manipulatives. From the teacher's perspective, it is interesting to note that non-SCIIS teachers spend far less instructional time engaged with manipulatives and that a greater percentage of their time is devoted to administrative and/or procedural tasks.

Thus, it is clear that the nature of process-approach science classes positively affects the interactive structure of science classes. However, when the specific teacher and student behaviors are analyzed, there are few observable differences between teachers and students in SCIIS classes compared to non-SCIIS classes. The latter results would apparently confirm the self-reported needs of teachers (reported in the previous paper in this paper set) regarding assistance related to implementing effective instructional strategies for process-approach science. Implications of these results for inservice and preservice education will be provided.

A COMPARISON OF PIAGETIAN DEVELOPMENTAL LEVELS
TO VIDEO CONCEPT LEARNING

John W. Butzow
Jay Calkins

This study was designed to test the effectiveness of a video tape program with junior high school, senior high school, and collegiate audiences. The study included the production of a 30-minute video program designed to teach facts and conservation issues about commercial fisheries in the Gulf of Maine. To be included, concepts needed to be central to the understanding of the fishing industry, such as the idea that fresh fish are marketable for 14 days from catch to table under optimum conditions of temperature. Concepts were used as a basis for the selection of material for video taping and were validated with separate expert samples of science educators as being in the program.

The study was designed to investigate program effectiveness with learners of differing developmental levels. Also studied were the characteristics of the conceptual segments of the program.

The study population consisted of three groups of students (grades 7-college), all representing intact classes. The total 257 included 126 males and 131 females. Investigators used a minimum of two class sessions spaced at least a week apart. In the first session, the Lawson test, demographic items, and the pretest were presented. During the second session, the video treatment and the posttest were taken by students. Results were analyzed using SPSS-X subprograms for t-test, ANOVA, ANCOVA, and factor analysis. The ten pre- and posttest items were written for the purpose by the authors using the ten major concepts validated by items of science educators. The ten item posttest showed a split-halves reliability of .59 and Spearman-Brown reliability of .60.

T-test was used to determine overall difference between total pre- and posttest scores ($t=25.01$ $p<.0001$). ANOVA on posttest scores with developmental level as the independent variable yielded an F-ratio of 45.46 ($p<.001$). Tukey-HSD comparison of means found significant differences ($p<.05$) between concrete and transitional, transitional and formal, and concrete and formal developmental levels. Similar differences were found for the pretest scores. No significant differences were found when either pre- or posttest scores were compared by gender. ANCOVA on posttest scores using pretest scores as covariate with both developmental level and gender as independent variables showed a significant main effect difference ($F=37.92$, $p<.001$) for developmental level but not for gender and no significant interactions. Factor analysis of pretest item scores produced factors recognizable to some degree by the similarity of conceptual content of items. Factor analysis of the posttest item scores produced results more related to the position of the material in the program or to the abstractness of the concept than to the concept itself.

CAN YOU BREATHE FORMALLY?
(STUDENTS' COGNITIVE DEVELOPMENT AND THEIR BIOLOGY LEARNING OUTCOMES)

Michal Shemesh
Sophia Penso
Reuven Lazarowitz

This study describes and analyzes the detailed learning outcomes of 10th grade concrete and formal students, following the instruction of the biology topic, the respiratory system. The purpose of this study was to compare students' developmental base level to the quality of their learning on this particular topic, using the SOLO taxonomy as the basis for students' responses evaluation. The sample included 34 students (75% of them girls) who study the topic of human respiratory system as part of their biology curriculum which included learning units on the anatomy and physiology aspects of the human body. The research was performed during six weeks of instruction by an experienced biology teacher in a middle-class urban school. The teaching strategies encompassed classroom and laboratory instruction, and lessons were taught in expository settings. Two tests were administered: (1) a video-taped group test for assessing students' reasoning skills; (2) an achievement test in biology, composed of 25 items, categorized as low (recall and memorization), a medium (understanding and implication), and high level (interpretation of data and variables manipulation) items. Data collected were treated by parametric and non-parametric statistics. This study emphasizes the relationships which exist between students' reasoning skills and their actual learning outcomes in a specific learning topic. Implications for science education in all school levels are set forth in light of the relevance of these findings to the general issue of science learning.

AN ANALYSIS OF THE DEVELOPMENTAL PATTERN OF BRAIN WEIGHT
GROWTH AMONG SIX TO EIGHTEEN YEAR OLDS AND FACTORS
RELATED TO WEIGHT VARIABILITY:
IMPLICATIONS FOR THE PHRENOBLYSIS HYPOTHESIS

Raymond W. Walton
Phillip B. Horton

Advocates of the phrenoblysis hypothesis have proposed a major restructuring of the middle school curriculum. The phrenoblysis hypothesis proposes that special periods of mind and brain growth occur during childhood and adolescence. Proponents indicate that childrens' brains develop in

two-year incremental patterns of growth spurts and lags, and that spurts in achievement and intelligence follow this same pattern. According to phrenoblysis advocates, the middle school curriculum should be altered to avoid novelty, and should emphasize experience and practical skills. It has been further recommended that middle school students be removed from school for most of the week and be put to work in public service projects, nature reclamation projects, day-care centers, etc.

It is also claimed that the phrenoblysis hypothesis provides a biological explanation for Piaget's theory of cognitive development, since transitions to higher levels of Piaget's cognitive developmental stages occur at the same ages as brain growth spurts are said to occur, while little development occurs during brain growth plateaus. The existence of a brain growth lag or plateau of ages 12-14 is cited as necessitating the radical changes in middle school education mentioned above.

Because of the sweeping claims made on behalf of the phrenoblysis hypothesis, the current study was undertaken to check the underlying premise that brain growth in human progresses in an incremental pattern of spurts and lags. A major problem in testing the phrenoblysis hypothesis lies in the fact that no raw data were used by the original author of the hypothesis. Since the only brain weight information available in the literature was in the form of grouped data compiled from autopsy reports, it was necessary to collect new raw data that would allow the determination of the variability in brain weights at various ages. The data for the current study were collected from autopsy records in Dade Broward, and Brevard County, Florida. The sample consisted of 326 cases whose deaths occurred from 6 to 18 years of age. The data collected included sex (140 females, 186 males), body weight, height, and brain weight.

The results of the data analyses failed to support the claims for the existence of brain growth spurts and lags. Rather, the variability in brain weights within the same age range was found to be as large as the variability within the entire range of ages (6-18). Furthermore, there was no statistically significant correlation between age and brain weight for the entire sample. The same was true when the samples were divided by sex. When the variables of body weight, height, and age were regressed intrasexually against brain weight, only height was found to be statistically significant for females, while no variable was statistically significant for males. Furthermore, only 7-12% of the variability in brain weights was accounted for by the three variables.

Since these data do not confirm the phrenoblysis hypothesis, curriculum changes that have been implemented based on this hypothesis should be reexamined.

THE EFFECT OF TEACHER INVOLVEMENT ON STUDENT PERFORMANCE
IN A COMPUTER-BASED SCIENCE SIMULATION

Michael L. Waugh
Kevin C. Wise

The purpose of this study was to establish the influence of the teacher in facilitating student use of a computer-based science simulation. The simulation selected for study, Volcanoes by Earthware Computer Services, possesses three important characteristics: (1) it fits well within the eighth grade science curriculum; (2) it is supported by a relatively large quantity of ancillary instructional support materials; and, (3) it is highly rated as a vehicle for teaching several science process skills.

The study population consisted of 20 average and below average eighth grade students from a rural, south Georgia public school system. These students were randomly assigned to one of two computer simulation laboratories where teams of two students each worked for a total of three hours over a period of four days to become proficient in predicting volcanic eruptions.

Teacher behavior was systematically varied between the two laboratory groups. In one laboratory, the teacher was a content "expert" and employed a Socratic questioning strategy to assist the students in "discovering" facets of the simulation. In the remaining laboratory, the teacher played the role of one unfamiliar with the content of the simulation and therefore was able to offer only minimal, technical assistance.

Student attitudes and achievement were measured using locally developed test instruments. Student attitudes toward science, scientists and microcomputers were generally positive. Based on the posttest measure neither laboratory group learned significantly more than the other about the content of the volcano's simulation. However, the total population mean on the posttest was only 55%, indicating that these students learned little from the simulation experience despite the differences in teacher involvement.

LEARNING FROM SCIENCE COMPUTER SIMULATIONS

Fred N. Finley

Computer simulations of complex problems have been produced in a number of science disciplines. In each case there have been accompanying claims that the students learn a great deal from the problem solving experience offered by the simulation. Unfortunately, there has been little empirical research to support that claim. One result of this dearth of research is that the educational value of simulations remains unknown. Another result is that an opportunity to understand how students' knowledge changes as a result of rich problem solving experiences is lost. The study reported here is a determination of the changes in students' knowledge that result from their attempts to solve a simulated geologic problem. The rationale is based on recent research in schema theory, problem solving, and knowledge representation. That research indicates that describing what and how students learn is a matter of determining changes in conceptual and procedural knowledge that result from the interaction of background knowledge with the instructional content.

Determination of the specific changes in students' knowledge was done by obtaining talking-aloud protocols from four students. The students, who ranged from novices to experts in the problem domain, provided verbal reports as they used the simulation on three occasions--one before the accompanying written material was studied and two afterwards. The reports were captured on a videotape machine interfaced with the microcomputer and later represented in terms of the sequence of the students' goals, their reasons for setting those goals, their actions and their reasons for taking those actions.

Comparisons among the transcripts and comparisons of the transcripts to a model response served as the basis of the following results: (1) In each case there were ways in which the students' prior knowledge interfered with their ability to effectively conduct the simulation during the initial attempt. (2) Only the student who had completed a course specifically related to petroleum geology was able to use the simulation to learn the essential geologic concepts and then replicate the optimal strategy during the initial use of the simulation. (3) The three least knowledgeable students learned little geologic knowledge during the first attempt. However, they did learn what concepts and propositions were necessary to solve the problem. The improved understanding of what knowledge the task required guided these students' subsequent learning of new geologic concepts and propositions from the text and their reasoning and performance was very similar to the model solution during the next attempt.

These results imply that if students are to learn from simulations alone they need to be knowledgeable in that specific domain before the simulation is encountered. This is not to say that students should not use a simulation prior to learning the necessary background knowledge. In fact, the major

knowledge changes seem related to the students creating a need for specific information during their initial attempt and then learning that information from the accompanying text materials. An instructional strategy that begins with the use of a simulation, provides the necessary background information, and then returns the student to the simulation may be particularly effective. An alternative is to carefully determine the domain-specific knowledge students find necessary to use a simulation and then redesign it so that students' questions and problems can serve as a guide for seeking and learning new information that is provided explicitly within the simulation. Simulations designed in this way may provide a context in which students can learn scientific knowledge.

CHILDREN'S NATURAL INFERENCE RULES DURING COMPUTER-SIMULATED PROBLEM-SOLVING TASK

Larry Flick

The science teacher is regularly faced with delineating exactly how to interpret a very narrow range of demonstrated phenomena and is unable to lead students to draw connections to a more general category of events. This problem arises from the pre-existence of psychological representations of the phenomena used for instruction.

Sixth grade students were interviewed while they interacted with a force and motion problem-solving task simulated with the Logo computer language. The interview transcripts were transformed into "working hypotheses" of the subject in order to observe natural inferences made from the subject's existing concepts.

The subjects were observed to make inferences based upon previous experiences with moving objects and to ignore visual evidence that contradicted those inferences. Hints and suggestions posed by the interviewer were either ignored or remembered in rote fashion separately from the subject's general approach to the problem. Some success with changing the direction of the turtle was achieved by simply varying computer input, but controlling and stopping the turtle would not yield to this game-like strategy. Subjects achieved success when they able to infer a match between the parameters of a previous experience and the turtle environment.

Implications for science education include the imperative for using verbal interactions for generating meaningful associations with classroom activities. Students will not only fail to refute existing concepts when faced with contradictory evidence but will supply additional concepts to maintain the integrity of their current beliefs. Conceptual change seems to arise out of the resolution of existing beliefs that have been made to interact in a problem-solving situation.

THE FOUR-CARD PROBLEM RESOLVED? PROPORTIONAL REASONING
AND REASONING TO A CONTRADICTION

Anton E. Lawson

To test the hypothesis that subjects (Ss) who display proportional responses on the Pouring Water Task have developed the ability to comprehend logical arguments of the form referred to as "reasoning to a contradiction," while Ss who display additive responses on the same task have not, 100 additive and proportional high school Ss (mean age 16.4 years) were administered three versions of a four-card task requiring them to reason to a contradiction before, immediately after, and one month after verbal instruction in use of the reasoning pattern. Results were generally as predicted as most of the additive Ss failed the immediate and delayed posttest problems (62% and 80%, respectively) while most of the proportional Ss succeeded (80% and 71%, respectively). Group differences were significant ($p < .001$) in both cases.

THE RELATIONSHIP OF SUCCESS WITH LOGICAL SYLLOGISMS
TO SUCCESS IN SCIENCE COURSES

Dorothy A. Petrushka

It has been accepted that one role of educators has been to promote skills in reasoning. Since logical thinking has been deemed necessary for success in science, the science classroom seems to be an ideal site for the development or acquisition of logical abilities. Followers of the Piagetian theory of cognitive development have used various logical tasks to ascertain whether students have reached the formal level of thought. Results from many tests have indicated that many college students have not reached this level. Propositional logic tests have been used in these evaluations. The tests have been consistent with the Piagetian "hypothetical-mathematical" model which has limited the content to symbols rather than familiar material, even though it is realized that persons reason pragmatically in everyday situations. Some recent studies have shown that familiar content enhances logical thought. Additionally, practice with familiar-content tasks has led to Ss inventing the rule for solving logical syllogisms, and has enabled them to generalize the rule to symbolic-content syllogisms. These successes were achieved in a survey type course in introductory biology. It was of interest to determine whether students enrolled in courses with a narrower range of topics might be successful with syllogisms in which the content was limited to that particular course material.

Two groups of subjects were chosen. One group was enrolled in a microbiology course, the other in a nutrition course. Each group of subjects completed one conditional syllogism task and one inclusive disjunction syllogism task. The material was, in each case, related to course material. The data indicate that each was equally proficient for the conditional operation, but a significant difference exists between the two groups in proficiency with the inclusive disjunction operation. Neither group were highly successful with the latter.

When final course grades were compared with success with the conditional syllogism, it appears that a high percentage of students receiving an "A" performed logically on this operation. Conversely, a high percentage of students who earned a "C" performed illogically. Although success with the inclusive disjunction syllogism was so low that even "A" and "B" students performed poorly, there was an obvious association between a "C" grade and illogical performance.

There may be some value in recognizing illogical students early in the semester and perhaps designing a course of study which does not (at least at first) require logical thinking expressly for these students. There may be a possibility to ease these students toward a transition to formal thought with a series of exercises of increasing difficulty. This may not be possible, considering the limited amount of time available for student-teacher interaction with a one-semester course. However, a concerted effort between disciplines and/or a longer time may make this achievement possible at the college level.

HOW TO DEVELOP POSITIVE ATTITUDES TOWARDS SCIENCE
AND CHEMISTRY THROUGH A NEW CHEMISTRY CURRICULUM

Zahava Scherz
Ruth Ben-Zvi
Avi Hofstein

The present study is based upon the authors' belief that one of the main goals of science teaching today is to develop positive attitudes towards science in order to improve students' interests in science and to increase their enrollment in science courses.

A research was undertaken to evaluate students' attitudes towards science in relationship to two chemistry curricula: a well established concept oriented and laboratory-based programme, "Chemistry- a Challenge" (CAC), which was designed with the following main features:

- a. The level of the course was cognitively proper for a heterogeneous unselective population, with special consideration of students' difficulties and misconceptions within the chemistry subject matter.
- b. An emphasis on the relevance of chemistry to students' life and surroundings.
- c. A humanistic and historical approach to chemistry.

The sample consisted of 1958 10th grade students from 52 classes in 17 academic high schools in Israel, 578 of which studied CAC program. Students' attitudes were investigated through questionnaires aimed to identify students' appreciation of science, scientists, chemistry and chemists, their opinions about the interest, easiness and importance of chemistry as a school subject, and their consideration of science as a possible future career. Multi-variate analyses of covariance technique, for each of the dependent variables, was undertaken. Students' scores in initial tests in science served as covariates.

The main findings indicated that:

1. CAC students' tendency to choose science as a future career was significantly higher than that of CFH students.
2. CAC students' appreciation of scientists in general and chemists in particular was significantly higher than that of CFH students.
3. Chemistry and science were considered by CAC students to be significantly more important and attractive than by CFH students.

4. CAC students regarded chemistry as a school subject to be more interesting, more important, and less difficult than CFH students.

It was concluded that a curriculum geared to the needs and interests of students can help in developing positive attitudes towards science.

AN ACTIVE HIERARCHICAL ORGANIZATION - A VEHICLE FOR PROMOTING RECALL AND PROBLEM-SOLVING IN INTRODUCTORY CHEMISTRY

Bat-Sheva Eylon
Ruth Ben-Zvi
Judith Silberstein

The previous presentation described the program "Chemistry - a Challenge" designed to help students overcome learning difficulties in beginning chemistry. The present report describes a systematic effort to introduce active organizational features into this program and the characteristics of students' knowledge with and without this active organization treatment.

The organization treatment included features suggested by previous research: economic representation of important ideas and their relationships (e.g. visual representations); hierarchical structure and its active use; task adaptation, i.e., emphasis of ideas and relationships instrumental in performing desired tasks; a "global" structure relating more detailed substructures.

The comparative treatment included interesting historical accounts of various topics. All the learning aids were given in written form and the students had to actively engage in their study.

Seven teachers, each teaching two 10th grade classes studying the new program, participated in the study. One class of each teacher received in addition the "organization treatment" (N=168) while the other class received the "comparative treatment" (N=195).

Both groups received the same tests during the year: (1) A multiple choice Chemistry background pretest in the beginning of the year. (2) Three tests after the treatment had taken place: (a) An organization test. (b) A diagnostic test. (c) An achievement test. (3) An additional achievement test towards the end of the year.

The main item in the organization test required students to summarize from memory the important ideas in the program. There was a considerable difference between the groups in amount, content and structure of the summaries. More

than 50% of the control group wrote a list of chapter titles or a list of concept names vs. 25% in the experimental group. ANCOVA analyses performed on parameters signifying features of the summaries showed a statistically significant effect of the treatment (pretest serving as covariate, $35 < F < 45$, $p < 0.0001$). These parameters include the number of concepts, the number of sentences linking at least two concepts, and the average number of concepts per sentence (length). Many more students in the experimental group provided summaries with an underlying hierarchical structure than students in the control group (38.7% vs. 12.4%). Also, as expected, students in the experimental group referred more to models, and wrote more sentences relating phenomenology to models (70% vs. 45%).

The diagnostic test included items where the relationships between phenomenology and models were instrumental. As expected, there was also a difference between the groups, both in the number of correct answers and the number of models used as explanatory devices (40% vs. 15%). Although it was not expected, moderate but statistically significant differences were found also in the achievement tests.

It should be stressed that the organization treatment in this study was given on top of a well structured program emphasizing the same relationships. However, the additional feature leading to an active use of a hierarchical and economical organization adopted to important tasks led to considerable improvement in recall and problem-solving with relatively little additional effort by the student.

RESEARCH ON CONCEPTUAL DIFFICULTIES IN CHEMISTRY AS A BASIS FOR CURRICULUM DEVELOPMENT AND EVALUATION

Ruth Ben-Zvi
Bat-Sheva Eylon
Judith Silberstein

The present paper illustrates one cycle of research, development, implementation, and evaluation as part of an on-going long-term activity of curriculum improvement. The research focused on student difficulties within an existing program and led to the design of a new one.

The Science Teaching Department in the Weizmann Institute of Science started in 1980 a long-term project designed to improve chemistry teaching at the high school level. The first phase was to identify the difficulties students have in the beginning of studying chemistry and revealed students' misconceptions in three areas: (1) the atomic model, (2) aspects of chemical structure, (3) aspects of chemical reactions. These findings served as a basis for a new elementary high school program "Chemistry - a Challenge."

This program attempts to teach students central concepts and basic skills in chemistry and was designed to include the syllabus of an introductory course in chemistry. However, the methods of presentation are geared to prevent students from developing misconceptions. The implementation of the program in schools was accompanied by a study designed to examine the effects of the program in relation to the diagnosed difficulties.

The sample consisted of 1,078 students (average age, 15 years) from 10 high schools all over Israel (35 classes). Half of the sample (538 students, 17 classes, 5 high schools) studied the course "Chemistry for High School" (the control group). The rest (540 students, 18 classes, 5 high schools) studied the new course "Chemistry -a Challenge" (the experimental group).

In the beginning of the academic year all students were given a chemistry background pretest and a concept oriented pretest which examined how they understand concepts of chemical structure. During the year students were given regular achievement tests and a conceptual test which examined misconceptions in the three areas mentioned above.

A set of multiple regression analyses was carried out on the various test scores and showed a statistically significant effect of group affiliation after the pretest was partialled out (with minimum $p < 0.001$). More detailed analyses with respect to dependence on ability (as defined by pretest) showed that in some cases the lowest third of the students in the experimental group benefitted most relative to the corresponding group in the control group. For example in their view of the atom, about a third of this group demonstrated an acceptable understanding in the experimental group vs. none in the control group. Similarly, the low and medium ability students gained most in understanding chemical structure. As the understanding of chemical reactions, all ability groups gained considerably in viewing the dynamic nature of chemical reactions, but in viewing a chemical reactions a process of bond breaking and bond formation, the difference between the groups was less pronounced.

The results of this study formed a basis for a new cycle of development, implementation and evaluation, which stressed farther problematic areas. The evaluation indicated an additional improvement in understanding.

A DESCRIPTIVE RESEARCH STRATEGY ASSESSING COMPUTER
ASSISTED INSTRUCTION IN SCIENCE EDUCATION

Vincent N. Lunetta
Patricia Simmons
Joseph Krajcik

The field of computer assisted instruction is new, and we do not yet have data that can be used to identify a comprehensive array of research problems. The research described in this symposium was designed in response to this need. The symposium will report the design and development of a research strategy to observe students engaged in using instructional software. Preliminary results have shown: 1) most individuals have a definite preference for either graphics or for alphanumeric video displays, 2) while interacting with the software students based explanations for their decisions on their conceptions of scientific terminology, principles, and on their interpretation of what they observed, and 3) students' reasoning behaviors ranged from systematic and organized patterns to random and disorganized patterns. Other findings, such as students' observations, misconceptions, control of variables in an open ended genetics program, and attitudes toward microcomputers and instructional software will be discussed. Strategies such as the one described in this symposium are needed to develop and examine questions relevant to the instructional use of computers in science education. This descriptive research study was generated a number of such research questions. These questions and their implications for future research will be elaborated in the symposium paper set.

OUTSTANDING NARST PAPER
JRST AWARD

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THE INFLUENCE OF SEX ROLE CONFLICT AND ROLE SPECIFIC SELF
CONCEPT ON COURSE TAKING BEHAVIOR AND CAREER
PREFERENCES IN SCIENCE

Dale Baker

This study examined the influence of role-specific self-concept and sex role conflict on course-taking behavior and career preferences in science. As predicted, females who expressed career preferences in science perceived themselves as more masculine than females preferring other careers and had a better self concept of themselves as learners of science. Males who expressed career interests in science also perceived themselves as more masculine and had a better self concept of themselves as learners of science than males preferring non science careers. Males and females preferring a career in science also had higher logical reasoning scores than students preferring other careers. It seems likely that the good role-specific self-concept of these students may be the results of their better ability, even though the items on the self concept test were not directly related to achievement. The more masculine self perception of both males and females preferring science careers than males and females preferring non-science careers substantiates the notion that students think of science as a male domain. A comparison of males and females regardless of career preferences indicated that males planned to take more higher level math courses, had better logical reasoning ability and a better role-specific self-concept of themselves as learners of science. Correlations indicated that logical reasoning was related to perceived ability and course taking behavior in math and science. Role-specific self-concept items clustered into two groups. Group one consisted of correlations among items considered positive behaviors and group two consisted of correlations among items considered negative behaviors.

INCREASING THE PARTICIPATION OF MINORITIES IN SCIENCE:
RESEARCH PERSPECTIVES FOR CHANGE

Julia V. Clark

As few minorities are studying science in this scientific and technological society, a well-focused and concentrated effort needs to be put in place that will illuminate the influencing factors that result in scientific careers by minorities. Research has recently been conducted to identify these factors. More than seventy-five minorities who have successfully pursued careers in

science and are currently employed in several different scientific fields throughout the United States have revealed the factors that influenced them to pursue careers in science. These factors have led to educational strategies, role modeling and mentoring associations for the early fostering of programmatic activities to increase scientific interest, confidence, competence, and opportunities for many who might otherwise avoid fields requiring science.

The tendency for minority students to opt out of science may have profound social, economic, and political consequences in a world where the impact of science and technology is becoming increasingly significant. The absence of minorities from today's science classes will lead to a corresponding absence of minorities from professional science tomorrow.

EIGHTH GRADE SCIENCE TEACHERS AS SEX-ROLE MODELS FOR EIGHTH GRADE GIRLS' SCIENCE AND ENGINEERING CAREER INTERESTS

Edward P. Donovan
Robert H. Fronk
Phillip B. Horton

It has been postulated by a number of researchers that one of the important factors relating to the small number of women employed in science and engineering careers (S/E) is the small number of women teaching science at the secondary school level. Because of the small number of women secondary school science teachers, it is thought that girls do not have the necessary role models needed to influence their S/E career interests.

The purpose of this study was to investigate the potential influence of women science teachers as sex-role models for eighth grade girls S/E career interests. The study involved 30 eighth grade science teachers (14 men, 16 women) and their 1,937 eighth grade students (922 girls; 945 boys).

Using a S/E career interest survey developed by the authors, all students were surveyed at the beginning of their eighth grade year and then close to the end of that school year. A 2 x 2 ANOVA using multiple linear regression analysis as the statistical method was used to test the interaction of teacher and student sex on student S/E career interest. It was found that the interaction did not account for a significant amount of the variance of student S/E career interests ($F = 0.00, p > 0.05$). A statistically significant correlation was found between the CIS pre- and postsurvey scores for the students ($r = 0.78, p < 0.05$). Also, a correlation between student sex and the CIS scores was statistically significant ($r = -0.28, p < 0.05$), indicating that the boys scored higher than the girls on the CIS. It was also determined that the teacher's sex did not account for a statistically significant amount of the variance of the girl's CIS postsurvey scores.

The two major conclusions reached in this study were: (a) as sex-role models, the eighth grade science teachers were not found to enhance the S/E career interests of their students, and (b) eighth grade girls S/E career interests, as measured in this study, were not influenced by the sex of their teacher.

THE DEVELOPMENT OF VIDEODISC BASED ENVIRONMENTS
TO FACILITATE SCIENCE INSTRUCTION

Robert D. Sherwood

Recent advances in technology have created the potential for designing environments, sometimes called microworlds, that can have powerful effects on learning. However, despite the promising potentials of technology, it appears that many applications are less-than-optimal and lack research support. The paper presentation will be an attempt to outline a theoretical framework and some initial studies of idealized instructional environments (termed "Havens"), some of which have a computer/videodisc bases which may be applied to science instruction.

As a first step in developing a theory of Havens, consideration must be given to theories of children's learning. On one hand young children seem to have several handicaps when it comes to learning, such as less acquired knowledge, few sophisticated strategies for learning, and perhaps even less working memory. Even with these handicaps, however, most young children are very effective learners. This effectiveness seems to derive from two major situations. One, children's everyday learning usually takes place in the context of meaningful, ongoing activities which allow the child to make use of contextual clues and two, children are often cued by mediators to appropriate actions. In contrast to these everyday environments, school environments often lack the contextual clues and teachers may not have time for effective mediation.

The use of technology may assist the teacher in developing learning environments that more closely match the environments of young children. The technology needs to provide a contextual basis for learning that is familiar to the student and offer the teacher the opportunity to act as a successful mediator. The studies described in the session outline one possible method that might be used and some initial data indicating that the method has merit in science instruction.

Study one dealt with college students who were randomly assigned to two groups, one of which saw a 25 minute segment of the film Swiss Family Robinson and others did not. The assessment instruments dealt with difficult-to-comprehend sentences, abilities to fill in the blank in texts, to infer the meaning of nonsense words, to generate inferences that provided coherence to a message, and a free recall task. The film viewing group was substantially higher on all items as compared to the non-film group.

Study two involved junior high school students in science classes who were divided into three groups: one that received written science information only, one that received written science information with organizing questions, and third a group that saw video segments related to the science instruction before

reading the science information. Preliminary results shows that for groups that are academically equivalent, the video presentation was superior to either of the reading alone methods.

The results of these studies provide some evidence that Haven-like environments can produce increases in comprehension and learning. These first Haven environments are far from ideal and recent developments of more effective situations will also be described in the session.

AN EVALUATION OF ALTERNATIVE STRATEGIES FOR USING INSTRUCTIONAL SOFTWARE TO TEACH MEASUREMENT SKILLS TO SEVENTH GRADE SCIENCE STUDENTS

Kevin C. Wise

The purpose of this investigation was to determine if differing approaches to using a particular piece of instructional software result in differing student outcomes.

Ninety students were randomly selected from seventh grade science classes at a junior-senior high school located in rural northwestern Pennsylvania. The students selected were randomly assigned to one of the three treatments described below.

In the software centered approach, student worked in pairs at a microcomputer with a piece of software designed to give practice with mass, length, and volume measurement. The software was self-explanatory and gave students as many repetitions of practice (with feedback) on mass, length, or volume measurement as requested. The teacher acted primarily as a manager to insure that each student received adequate interaction with the software. Students spent approximately thirty minutes working with a computer.

In the materials enhanced approach, students worked with the software as above for about twenty five minutes. Upon completion of the computer-based practice, each student was asked to determine a mass, a length, and a volume, given objects of unknown dimension and the appropriate measurement devices. Each student checked his or her answers against a key immediately after finishing the required measurements. Students spent about five minutes making and checking the actual measurements.

In the contrast group, students received no particular measurement practice, either computer or materials-based.

All students, regardless of group, were exposed to a traditional type classroom lecture wherein the use of a triple-beam balance for determining

mass, the use of a ruler for determining length, and the use of a graduated cylinder for determining volume were reviewed and demonstrated.

Upon completion of the treatments two separate procedures were used to assess the level of measurement skill attained by the students. Out of a possible 22 points on the measurement skills achievement test the mean group scores were: 14.75 for the materials enhanced approach (n=28), 13.63 for the software centered approach (n=27), and 11.13 for the contrast group (n=30). Analysis of variance revealed significant difference among these group means (p=.003). Post-hoc analysis indicated that the higher mean of the materials enhanced approach group differed significantly from that of the contrast group.

Groups were compared on the measurement task performance examination according to the percent of students demonstrating mastery of each kind of measurement. The percentage of students showing mastery of length measurement was 63% for the materials enhanced group, 37% for the software centered group, and 30% for the contrast group. The percentage of students showing mastery for mass measurement was 52% for the materials enhanced group, 33% for the software centered group, and 40% for the contrast group. The percentage of students showing volume measurement mastery was 33% for the materials enhanced group, 11% for the software centered group, and 10% for the contrasts group. For each kind of measurement the percentage of students showing mastery was significantly higher for the materials enhanced group.

COMPUTER UTILIZATION IN TEXAS SECONDARY SCIENCE CLASSROOMS

Keith L. Mitchell
Earl J. Montague

This research seeks to establish the nature and extent to past, current and anticipated utilization of computer technology in Texas secondary science classrooms. A survey instrument was developed and administered in two steps to a random sample of secondary (7-12) science teachers in Texas, stratified by subject matter. Survey items on the first part determined if the teacher was a user and perceived inhibitors for use of computers. The second part of the survey was sent only to those teachers who indicated computer use on the first instrument. This second instrument included questions to determine current utilization of computers in the science classroom, available resources, and perceived needs for additional resources. Additionally the study sought to determine any trends in the use of computers as a function of a teacher's computer experience.

Initial analysis of the survey returns indicated approximately 15% of Texas science teachers are currently using computers, and about 25% of the districts have science teachers using computers in some manner.

It should be noted that microcomputer technology is effecting, and will continue to effect, changes in the science curriculum with or without guidance. If the adoption of this instructional tool is to be controlled, it will be important to monitor its implementation and to provide appropriate guidance.

MISCONCEPTIONS OF SOME BIOLOGICAL CONCEPTS BY AFRICAN STUDENTS
AND THE EFFECT OF AN INSTRUCTIONAL INTERVENTION

Peter Akinsola Okebukola

The issue of students' misconceptions has assumed a prominent role in contemporary accounts of factors impeding science learning. This study sought to examine the influence of traditional African belief in superstitions and taboos on such misconceptions of the concepts of heredity and evolution. The impact of an instructional intervention in dislodging such misconceptions was also investigated.

Sixty three class two (eighth grade) students served as subjects for the study. Subjects were randomly assigned to an experimental and a control group. The Traditional Cosmology Test and an achievement test in evolution and heredity were administered as pretests. Clinical interviews were also conducted to find out the misconceptions held by the students of the 20 scientific facts identified for the purpose of the study on the concepts of evolution and heredity.

Treatment of experimental group subjects involved practical work on cooperative group basis with heavy emphasis on time-on-task, use of models and charts to complement instruction, visits to the maternity and children's wards of a nearby hospital, and a visit to a nearby agricultural breeding and multiplication station.

After the treatment, the experimental group scored significantly lower than the control on the Traditional Cosmology Test ($t(61)=16.23$; $p<.001$) thus exhibiting less belief in superstitions and taboos. They also had significantly fewer misconceptions ($t(61)=21.20$; $p<.001$) and achieved better ($t(61)=19.88$; $p<.001$) than their control group counterparts.

The results of the study clearly seem to indicate that belief in superstition has an influence on students' view of biological concepts. It was also demonstrated that students' misconceptions are capable of being dislodged by an instructional strategy which provides the students ample opportunities to have first hand practical experience of the physical world.

EVALUATING SECONDARY STUDENTS' MISCONCEPTIONS OF PHOTOSYNTHESIS AND RESPIRATION IN PLANTS USING A TWO-TIER DIAGNOSTIC INSTRUMENT

David F. Treagust
Filocha Haslam

Research which is designed to uncover students' misconceptions in science has been of growing interest during the past decade. This paper describes the development and results of the administration of a two-tier instrument to reliably and validly diagnose secondary students' understanding of photosynthesis and respiration in plants. The first tier of each item is a multiple-choice content question which relates to propositional statements and parts of the concept map. The second tier of each item consists of a multiple choice set of reasons for the answer given in the first tier. The set of reasons, which are based on students' responses to interviews, open ended questions and/or previous research, consist of identified misconceptions and scientifically acceptable answer. The results highlight the consistency of students' misconceptions across secondary grade levels and generally compare well to related research reported elsewhere. The underlying major misconception related to how plants obtained food and the role of the components involved in photo-synthesis, what was meant by respiration, and how plants respire and photosynthesis.

The utility of the methodology for use by classroom science teachers is illustrated together with suggestions for improving the teaching of photosynthesis and respiration within the science curriculum to help overcome these misconceptions.

REMEDICATION OF STUDENT-SPECIFIC MISCONCEPTIONS RELATING TO THREE SCIENCE CONCEPTS

Alan K. Griffiths
Kevin Thomey
Bren Cooke
Glen Normore

For some years science educators have shown substantial interest in investigating appropriate strategies to remediate students who have failed initially to benefit from some aspect(s) of science instruction. One technique has been labelled diagnostic prescriptive instruction. The present paper represents such an approach. It focuses on the identification of each

student's particular misconceptions and offers comparison of treatment through exposure of these in a hierarchical setting, with a hierarchical treatment not focusing on specific individual misconceptions and treatment not based on specific misconceptions nor a hierarchy. Three parallel but separate studies are reported. These relate to the learning of concepts associated with conservation of mechanical energy, food webs, and stoichiometric calculations, respectively. Approximately 200 subjects were involved with each study. Subjects were tested, remediated according to one of the three treatments, and retested. Assignment was stratified according to pretest scores. All testing and remediation was carried out in class with a two-day interval between each session. No significant differences were observed between any of the groups, when an analysis of covariance was performed on posttest scores with pretest scores as covariate.

ANALYSIS OF THE PROJECT SYNTHESIS GOAL CLUSTER ORIENTATION
AND INQUIRY EMPHASIS OF ELEMENTARY SCIENCE TEXTBOOKS

John R. Staver
Mary Bay

The purpose of this descriptive study was to examine selected units of commonly used elementary science texts, using the Project Synthesis goal clusters as a framework for part of the examination. Three questions were answered: 1) To what extent do elementary science textbooks focus on each Project Synthesis goal cluster? 2) In what part of the text is such information found? 3) To what extent are the activities and experiments merely verifications of information already introduced in the text?

Ten science textbook series, which comprise approximately 90 percent of the national market, were selected for analysis. Two units, one primary (K-3) and one intermediate (4-6), were selected for analysis by first identifying units common to most series, then randomly selecting one primary and one intermediate unit for analysis.

Each randomly selected unit was carefully read, using the sentence as the unit of analysis. Each declarative and interrogative sentence in the body of the text was classified as: 1) academic, 2) personal, 3) career, or 4) societal in its focus. Each illustration, excepting those used in evaluation items, was similarly classified. Each activity/experiment and each miscellaneous sentence in end-of-chapter segments labeled "review," "summary," "evaluation," etc. were similarly classified. Finally, each activity/experiment, as a whole, was categorized according to a four-category inquiry scheme (confirmation, structured inquiry, guided inquiry, open inquiry).

In general, results of the analysis are: 1) Most text prose focuses on academic science; 2) Most remaining text prose focuses on the personal goal cluster; 3) The career and societal goal clusters receive only minor attention; 4) Text illustrations exhibit a pattern similar to text prose; 5) Text activities/experiments are academic in orientation, almost to the exclusion of other goal clusters; 6) End-of-chapter sentences are largely academic; and 7) Inquiry is absent or present only in limited forms in text activities/experiments. Detailed findings are given as percentage values. Discussion focuses on the implications of the results and a comparison of NSTA recommendations with the results of this analysis.

TEACHERS' CONCEPTIONS OF THE CONTEMPORARY GOALS OF SCIENCE EDUCATION

William J. MacIntosh
Dana L. Zeidler

Much has been written recently urging science educators to reconsider the goals that come about as a result of the 1960s curricular reform movement. For example, many leaders in the field have agreed that knowledge of the societal implications of science and technology are of paramount importance. Efforts to communicate contemporary goals are ongoing and the effect of these efforts needs to be determined. To this end, this study was initiated to examine what middle and high school science teachers believe should be the goals of science education for the remainder of the 1980s. Participants were given an eight item questionnaire and asked to choose a position on a bipolar scale that had, at one extreme, a statement reflecting a 1960s goal and at the other extreme a statement corresponding to modern science education goals. Additional information such as year of degree, grade level taught and attendance at workshops was compiled. The results of this survey indicated that the majority of respondents believe that science instruction should equally emphasize both the goals of the 1960s and the 1980s. A subsequent analysis demonstrated that when only those responses indicating a preferred goals orientation were considered, teachers expressed predilection towards 1980s goals. Furthermore, those teachers who favor 1980s goals felt stronger in their conviction than teachers expressing a 1960s goals preference. A discriminant analysis was employed to study whether or not differences in definitive 1960s and 1980s views were associated with one or more items on the personal data questionnaire. It was found that a combination of teaching middle schools grades (6-8), attending more inservice workshops and having completed the undergraduate degree on or after 1970 is moderately associated with an Eighties orientation to the goals of science education. The results of the study lead the authors to recommend that a concerted effort be made by professional organizations to convey the importance of contemporary goals to teachers at the high school level. Additionally, an effort should be made to disseminate these goals through local seminars and workshops.

VENEZUELAN NATIONAL ASSESSMENT OF
SCIENCE-RELATED ENVIRONMENTAL ISSUES

Omar Campos Arredondo
Ronald D. Anderson

The purpose of this study was to assess the level of understanding of science-related environmental issues of Venezuelan students and to compare this level with that of students in the United States.

The assessment was based upon items developed by the National Assessment of Educational Progress (NAEP) for assessing United States students. The items pertained to understanding of persistent societal problems, applied science and technology, selected science and personal values, perceived socio-scientific responsibility, and some aspects of personal background. By administering these items, translated into Spanish, to a national sample of Venezuelan students, it was possible to assess the status of Venezuelan students and make cross-cultural comparisons by comparing the results to United States data acquired by NAEP. The main dependent variable, the level of understanding of science-related environmental issues of Venezuelan students, is operationally defined by the 110 items.

The items were administered to a sample of the population of students of both sexes enrolled in the ninth grade of basic education in the public schools in Venezuela in 1984. The sample chosen was five percent of the total number of sections of students, stratified for the eight educational regions. All class sections in the country were listed, and random sample of 276 classes was selected.

Detailed results are available which include several significant differences by educational region and sex. The comparison between Venezuelan and United States students showed that United States students performed better in the following three areas: science-related personal values and perceptions; science, technology and society interface; and inquiry. Venezuelan students performed better in the fourth area, science-related environmental attitudes.

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