DOCUMENT RESUME

ED 391 640 SE 056 655

AUTHOR	Ellis, James D.; Backe, Kathrine A.
TITLE	Using Video To Evoke Reflection on Science Teaching. Interim Report of NSF-Supported Project: Teacher Development Modules for Elementary School Science.
INSTITUTION	Biological Sciences Curriculum Study, Colorado Springs.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	1 Apr 95
CONTRACT	ESI-9253321
NOTE	34p.
AVAILABLE FROM	Biological Sciences Curriculum Study, 5415 Mark Dabling Blvd., Colorado Springs, CO 80918-3842.
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Constructivism (Learning); Cooperative Learning; Educational Change; Educational Technology; Elementary Education; *Elementary School Science; Higher Education; Reflective Teaching; Science and Society; Science Curriculum; *Science Instruction; Science Teachers; Scientific Concepts; *Teacher Education; *Videotape Recordings
IDENTIFIERS	Reform Efforts

ABSTRACT

This document presents an overview of the Biological Sciences Curriculum Study (BSCS) Teacher Development Modules for Elementary School Science. It documents the collaboration of BSCS with science educators, science supervisors, and outstanding science teachers in developing, evaluating, refining, and disseminating four teacher development modules to support the improvement of science teaching in the elementary school. The modules are based on the major themes of the contemporary reform in science education: innovative instruction (constructivism, cooperative learning, and learning styles), curriculum emphases (thematic, less-is-more, and science-technology-society), equitable teaching, and alternative assessment. Subtopics include the nature of science and technology, major science concepts, classroom management, and educational technology. The population that conducted the content review process for the modules included project staff, members of the advisory board, university faculty, teachers, and science supervisors. It is reported that overall, reviewers and teachers responded very positively to the modules and voiced the need for such materials for both inservice and preservice teachers. Contains 60 references. (JRH)

Using Video to Evoke Reflection on Science Teaching

By

James D. Ellis, Principal Investigator
Kathrine A. Backe, Project Director

Interim Report of NSF-Supported project:
Teacher Development Modules for Elementary School Science

A Project Of

BSCS
Pike's Peak Research Park
5415 Mark Dabling Blvd.
Colorado Springs, CO 80918-3842

1 April 1995

This material is based upon work supported by the National Science Foundation under Grant no. ESI-9253321. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessrily reflect the views of the granting agencies.

SESSION ABSTRACT
Using Video to Evoke Reflection on Science Teaching

The session is a demonstration of the BSCS Teacher Development Modules for Elementary School Science. The video cases studies and accompanying instructor's guides are tools for the professional development of practicing elementary school teachers. The authors will distribute interim findings from the formative evaluation of the experimental materials.

With support from the National Science Foundation, BSCS is collaborating with science educators, science supervisors, and outstanding science teachers to develop, evaluate, refine, and disseminate four teacher development modules to support the improvement of science teaching in the elementary school. The modules are based on major themes of the contemporary reform in science education — *innovative instruction* (constructivism, cooperative learning, and learning styles), *curriculum emphases* (thematic, less-is-more, S/T/S), *equitable teaching*, and *alternative assessment*. Subtopics include the nature of science and technology, major science concepts, classroom management, and educational technology. Each module consists of a printed instructor's guide supported by three videodiscs of case studies of innovative instructional strategies and of interviews with outstanding teachers and their students. The materials are to be used by teacher educators and school-based science educators in inservice courses with experienced elementary teachers. Preservice teachers enrolled in methods courses also are a potential audience for the materials.

The teacher development modules have the following goals:

- Improve elementary school teachers' belief that they can teach science effectively and that all students can learn science.
- Assist elementary school teachers in developing their personal philosophy and approach to science teaching to accommodate current educational research and personal action research.
- Increase elementary school teachers' understanding and implementation of innovative approaches to curriculum and instruction in science.
- Enhance elementary school teachers' understanding of the history and nature of science and major conceptual themes of science and technology.
- Develop elementary school teachers' skills at monitoring, evaluating, and improving their own teaching.

Using Video to Evoke Reflection on Science Teaching

The decade of the 1980s was an era of recommendations for educational reform. We have national mandates for changes in education at all levels and for all disciplines, including elementary school science (Bybee, et al., 1989; Loucks-Horsley, et al. 1990; BSCS, 1989; Mullis & Jenkins, 1988; Weiss, 1987; NRC, 1994; AAAS, 1989, 1993; U.S. DoEd, 1991). To realize the reccmmendations and mandates, the 1990s must be characterized as an era of educational reform through action.

There is a cyclic history of reform of science education. In the 1960s, much attention was given to large-scale curriculum development projects as the solution to a nation threatened by the cold war. According to Jackson (1983, p. 152) a common criticism of that curriculum reform effort, however is that "the materials were given directly to practicing teachers, rather than to 'teachers of teachers,' thus effectively skirting the teacher education establishment whose so-called methods courses were commonly lampooned and sometimes pointed to as the source of much of the difficulty." During the past decade in response to the new cycle of educational reform, curriculum developers have renewed the effort to redesign science curricula. Teacher education, however, still lags behind. Consequently to avoid the mistakes of past reform efforts, recent national reports have focused on the need for improved teacher education (Viadro, 1989; Carnegie, 1986; Goodlad, 1991; NRC, 1994; AAAS, 1994).

BSCS, with support from the National Science Foundation, is responding to the call for improvements in science teacher education. BSCS is collaborating with science educators, science supervisors, and outstanding science teachers to develop, evaluate, refine, and disseminate four teacher development modules to support the improvement of science teaching in the elementary school. The modules are based on major themes of the contemporary reform in science education. Figure 1 explains the focus of each module. The materials are to be used by teacher educators and school-based science educators in inservice courses with experienced elementary teachers. Preservice teachers enrolled in methods courses also are a potential audience for the materials.

The modules address the major innovations of teaching for understanding, social construction of knowledge, student centered instruction, student assessment, educational equity, curriculum organization, and program planning as embodied in the emerging national recommendations for science education of the National Science Education Standards (NRC, 1994) and Project 2061 (AAAS, 1994; AAAS, 1993; AAAS 1989). Subtopics include the nature of science and technology, major science concepts, classroom management, and educational technology. Each module consists of a printed instructor's guide supported by an interactive videodisc of cases of innovative instructional strategies and of interviews with teachers and students.

Module 1: Teaching
Focuses on the nature of the learner and of learning, the learning environment, and teaching for understanding. Incorporates science content, educational technology, and management of time, resources, and space. Classroom scenes on the videodisc model innovative teaching strategies. Print materials provide opportunities to explore personal beliefs and practices, to study research on effective teaching practices, and to develop a vision of effective science teaching. Teachers apply understandings by adapting, implementing, and evaluating teaching strategies in their classrooms.

Module 2: Curriculum
Focuses on thematic, problem-centered, issue-oriented, and conceptual learning approaches to curriculum organization. Classroom scenes on the videodisc illustrate curriculum structure. Print materials provide opportunities to explore innovative instructional strategies, science content, educational technology, and approaches to classroom management. Teachers participate in, review, and evaluate units from innovative curriculum projects and apply their understandings by adapting, implementing, and evaluating a unit in their classrooms.

Module 3: Equity
Focuses on strategies to promote an equitable environment in the science classroom and to make science accessible to those groups that are under- represented in science, technology, and mathematics (females, minorities, and the physically disabled). Classroom scenes on the videodisc model strategies to create such an environment and to make science accessible to all students. Print materials provide opportunities to explore personal beliefs and practices, to study research on effective practices, and to develop a vision of equity in the science classroom. Teachers participate in, review, and evaluate units from innovative curriculum projects and apply their understandings by adapting, implementing, and evaluating strategies to improve equity in their classrooms.

Module 4: Assessment
Focuses on innovative approaches to assessing student learning. Classroom scenes on the videodisc model alternative approaches to student assessment. Print materials provide opportunities to explore personal beliefs and practices, to study research on effective assessment practices, and to develop a vision of assessment in elementary school science programs. Teachers participate in, review, and evaluate assessment strategies from innovative curriculum projects and apply their understandings by adapting, implementing, and evaluating assessment procedures in their classrooms.

Figure 1: Description of modules

Assessment of Need

In planning this project, BSCS conducted a needs assessment to identify the topics to emphasize in teacher development programs for elementary school science. BSCS staff first identified topics that were cited in reports on the reform of science education. Next, we reduced our list to nine themes identified as potentially critical to science teaching (see figure 2). To determine which themes should be emphasized in the teacher development modules, BSCS surveyed members of the Council of State Science Supervisors (CSSS), the National Science Education Leadership Association (NSELA), and the Association for the Education of Teachers in Science (AETS). In the survey, respondents rated the desirability of each teaching practice and estimated the extent to which science teachers in their state actually implement the practices. The difference between the desirability and degree of implementation was used as the criteria for determining the priority among the themes. In addition, the respondents listed the themes in order of priority as topics to address in teacher development programs.

Assessment and Evaluation
Classroom Management
Constructivism
Cooperative Learning Skills
Educational Technology
Equity Issues
Learning Styles
Science/Technology/Society Issues
Thematic Approach to Curriculum

Figure 2: Critical themes in the reform of science education

We received 57 responses (a 51 percent return on our surface mail survey of members of NSSA) and 28 responses to our electronic mail survey of members of CSSS and AETS. Data indicate that all respondents considered the nine themes desirable teaching practices and that most individuals reported difficulty setting priorities. By selecting those themes that were rated most desirable and rated least implemented, we identified the following as priorities for the modules: assessment/evaluation, equity issues, and the use of a constructivist approach to instruction. Instructional strategies, such as learning styles and the use of cooperative learning techniques, were identified as being desirable but they rated high on the scale for implementation. The use of a thematic approach and an science/technology/society (S/T/S) approach to curriculum emphasis were rated as being desirable, but not as important as the other issues. Never the less, the respondents overwhelmingly indicated that all of the themes needed greater attention in teacher education.

To further document the need for teacher education modules, BSCS conducted a telephone survey of principal investigators of NSF-funded materials development projects. We asked the principal investigators to indicate the extent to which they incorporated in their programs the teaching practices that we listed in the survey instrument, the degree to which they thought the proposed teacher development modules would enable teachers to implement the new science programs, and whether they would consider granting BSCS permission to use examples of their materials in the teacher development modules. The data from our telephone interviews suggest that each of these innovative science programs includes one or more of the proposed topics and that there is unanimous support for the development of these modules. Many of the principal investigators agreed with the science supervisors' recommendations that these themes should be addressed in concert. After an analysis of the needs assessment data, we determined that the most productive design of the modules would be to emphasize several themes in a given module, with four themes guiding the development process.

Topics of the Modules

The modules focus on the four major themes that best meet the criteria of greatest need as identified by science supervisors and science educators and of greatest representation in current curriculum development projects. These four modules address: 1) teaching, 2) curriculum, 3) equity, and 4) assessment. Major science concepts, the nature of science, classroom management, and educational technology are incorporated across the modules. In addition, strategies for encouraging and supporting teachers in implementing these innovative approaches to curriculum and instruction are part of the learning activities in each module. Teachers complete the learning activities in each module by working individually or in cooperative groups.

Module 1: Teaching

This module focuses on the nature of the learner and of learning and on the instructional strategies related to establishing a positive classroom environment for developing science conceptual understanding. The module engages the participating teachers by having the teachers discuss the instruction depicted in a video of a science lesson. The teachers explore the innovative instructional strategies by participating in model lessons (from primary and intermediate levels) from NSF curriculum development projects. The course facilitator uses the videodisc to model and explain various innovative instructional strategies. The participating teachers read articles and summaries of educational research and elaborate and evaluate their understandings by implementing and evaluating a change in personal practice through conducting classroom-based research.

Teaching for understanding. The learning cycle, an instructional model originally created for the Science Curriculum Improvement Study (SCIS) by Robert Karplus, researched extensively by John Renner, Anton Lawson, and others, and recently extended and refined by Rodger Bybee and co-workers at BSCS, is designed to help students build their own understanding of central science concepts (Lawson, et al. 1989; Gabel, J., 1989; Hegelson, 1989: Resnick, 1983 and 1987). The major assumption of this instructional model is that early, first-hand experience by students with natural phenomena provides opportunities for them to construct meaning and understandings as they interact with material, other students, and the teacher.

Constructivist-based learning theory suggests students learn best when they are allowed to construct their understanding of concepts. The phrase *constructing their understanding* is based on the following:

- *Prior knowledge.* Students begin with the knowledge, skills, and understanding they bring to the classroom. By the time children enter school, they already have what are to them reasonable explanations for how the world works. However, those explanations are usually based on limited experiences.
- *Common experiences.* The purpose of the science curriculum is to provide students with a common set of experiences that invites them to examine their current understanding. The new experiences either support their understanding or give them a reason to question their thinking.
- *Specific information.* Next, students are given more specific information about the concept or phenomenon under investigation. Students are introduced to terms and find out how those terms apply to their previous experiences.
- *Additional experience.* Students participate in more experiences that challenge or elaborate upon their ideas and the information they just received. They use those experiences and the new information to confirm, refute, or expand what they have been thinking.
- *Constructing and understanding.* Throughout this entire process, students question, ponder, discuss, argue, and come to some conclusions about how this aspect of their world works. In this way, they construct a new or refined understanding of the concept or phenomenon under investigation.

Learner-centered instruction.

The change toward approaches to instruction reflecting constructivist views about learning is closely linked with the reform of curriculum standards. Up to now, the design of schooling typically reflected a metaphor of an industrial assembly line. The administrators were managers, the teachers were the workers, and the students were the product. You might imagine students rolling down an assembly line with teachers opening up the heads and pouring in the content and skills. In contrast, constructivist views of learning p33lace the emphasis on the student as worker and teacher as manager/ facilitator (like a manager in the information industry). The student is the one who does the learning. Constructivists find it unproductive to think of students as *black boxes* for which instructional inputs lead to predictable outcomes (performance on achievement tests). Constructivists are interested in what goes on in the student's mind. The emphasis is placed on helping the student construct meaning from educational experiences.

- Learning is a natural process that is active, volitional, and internally mediated.
- The learner seeks to create internally consistent, meaningful, and sensible representations of knowledge.
- The learner organizes information in ways that associate and link new information with existing knowledge in memory in uniquely meaningful ways.
- Higher order strategies for "thinking about thinking" facilitate creative and critical thinking and the development of expertise.
- The depth and breadth of information processed, and what and how much is learned and remembered, is influenced by (a) self-awareness and beliefs about one's learning ability (personal control, competence, and ability); (b) clarity and saliency of personal goals; © personal expectations for success or failure; (d) affect, emotion, and general states of mind; and (e) the resulting motivation to learn.
- Individuals are naturally curious and enjoy learning in the absence of intense negative cognition and emotions.
- Curiosity, creativity, and higher order thinking processes are stimulated by learning tasks of optimal difficulty, relevance, authenticity, challenge, and novelty for each student.
- Learning is facilitated by social interactions and communication with others in a variety of flexible, diverse and adaptive instructional settings.
- Learning and self-esteem are heightened when individuals are in respectful and caring relationships with others.
- Beliefs and thoughts, resulting from prior learning and based on unique interpretations of external experiences and messages, become each individual's basis for constructing reality of interpreting life experiences.

Figure 3: Guidelines for learner-centered instruction (From APA, 1992)

Constructivist learning theory suggests that students learn best when they are allowed to construct their understanding of concepts. We base the phrase *constructing their understanding* on a description listed in Figure 3 from the American Psychological Association (pp. 1-6, 1992).

Use of a constructivist approach ensures that children are active in the learning process. In most textbook programs, students are passive learners. They acquire information by reading about science or by participating in experiences for which the answers are given on the next page of the book. Such learning is less meaningful because it does not relate to what students have observed, or experienced, or otherwise already know or have judged to be true.

Meaningful learning takes time. If students are truly to understand the world, they cannot simply read, memorize, and recite isolated bits of information and vocabulary words. They must take time to wrestle with new ideas, to discuss their ideas with their classmates and teacher, to collect data and use that data to draw conclusions, and finally to relate what they are learning to the world around them.

Science learning is a communal activity. Students learn science through comparing data from investigations of natural phenomena, comparing results and conclusions, negotiating among themselves meaning of personal explanations, and eventually by comparing personal explanations with scientific "textbook" explanations. Teachers should establish a science culture in their classrooms where students internalize the values and norms of science, such as withholding judgment, basing conclusions on data, and respecting others' ideas.

Cooperative learning. Cooperative learning is not so much learning to cooperate as it is cooperating to learn. In cooperative groups, students help one another articulate opinions, compare perceptions, share solutions, and develop skills for leadership and teamwork. Research indicates that such cooperation leads to higher achievement (Johnson, Johnson, and Holubec, 1993). Many studies have shown positive effects for both high- and low-ability learners, dispelling the myth that high-achieving students will not progress if they interact with students of lesser ability.

BSCS follows the model of cooperative learning developed by David W. Johnson and Roger T. Johnson of the Cooperative Learning Center, University of Minnesota, Minneapolis. There are seven basic tenets of this model:

- *Positive interdependence.* In cooperative groups, each student has a responsibility to the team. Goals or tasks are structured so that the students must concern themselves with the performance of all members of the group, not just their own performance.
- *Social skills.* At the foundation of cooperative learning are social skills that help students share leadership, communicate effectively, build trust, and manage conflict. Generally, the students do not come to the classroom with those skills; the skills must be defined clearly and taught in much the same way that academic material is taught.
- *Individual accountability.* Each member of the cooperative group is held accountable for the performance of all. It becomes the team's responsibility, not the teacher's, to ensure that everyone participates.
- *Heterogeneity.* Cooperative groups should be heterogeneous in terms of ability, sex, ethnicity, and other personal characteristics.
- *Leadership.* All members of the groups share leadership responsibilities. Each member has a job to do, and the group has no formal leader.
- *Partnership.* In their groups, the students focus on both the academic assignment and the skills they need to work together. They review the success of their assignment and how well they cooperated. and they try to improve both.
- *Teacher as consultant.* The teacher acts as a consultant to the students. Problems are turned back to the group for resolution. That aspect of cooperative learning is often difficult at first, but it is crucial to the success of cooperative learning in the classroom. Students must have ownership over the process as well as the content of the lesson.

Module 2: Curriculum

Teachers and curriculum developers organize elementary science curricula in a variety of ways. Most curricula are organized according to a listing of science topics; this type of elementary science curriculum covers the major facts and information of multiple scientific disciplines and is sometimes called the encyclopedic approach to science. Current efforts at science education reform, however, recommend either an issue-oriented or thematic approach to organizing science curricula, both of which the module on curriculum emphases will explore in depth. The curriculum module engages the participating teachers by having them analyze and discuss lessons that are organized according to different curriculum emphases. Teachers using the modules explore the ideas further by participating in lessons organized according to issue-oriented and thematic approaches. The teachers elaborate their understandings by adapting, implementing, and evaluating a unit using an issue-oriented or thematic approach.

A thematic approach. During the 1960s, the Elementary Science Study (ESS) and the Science Curriculum Improvement Study (SCIS) took radical approaches to restructuring elementary science curricula. ESS based its units on interesting science phenomena such as molds, structures, mirrors, and three-dimensional geometry. The SCIS program organized its curriculum on a few major themes of science such as systems, interaction, and relative motion to organize activities. SCIS is an example of a thematic approach to curriculum in which students explore materials or organisms, such as a pill bug, and try to construct an understanding of how pill bugs interact with the world and how they grow and reproduce.

The teacher development modules introduce the participating teachers to a thematic approach as a way of organizing science units. In a thematic approach, the curriculum is based on major conceptual themes of science such as patterns, change, diversity, energy, and equilibrium. (See section 3.7 for an overview of major conceptual themes of science.) The units are designed to help students construct personal understandings of the themes. The activities may engage students in answering a question or solving a problem and often may cross traditional disciplinary boundaries.

An issue-oriented approach. Since the early 1980s, the S/T/S theme has emerged as an important part of the contemporary reform of science education (Bybee, 1991; Bybee, 1986; Harms & Yager, 1981; Hurd, 1986, Roy, 1985; Rubba, 1987). An S/T/S orientation means the development of curriculum and instruction for the following:

- Presentation of science knowledge, skills, and understanding in a personal or social context.
- Inclusion in the curriculum of knowledge, skills, and understandings relative to technology.
- Extension of the inquiry goal to include engineering processes such as cost-risk-benefit analysis and decision making.
- Clarification of the knowledge, skills, and understandings related to the S/T/S theme that are appropriate to different ages and stages of development.
- Identification of the most effective means of incorporating S/T/S issues into extant science programs.
- Implementation of S/T/S programs into school systems.

In an S/T/S approach to curriculum, the activities often are organized according to major science and technology issues. Bybee and Mau, (1986) recommended the following list of global problems to organize an S/T/S program:

- World hunger and world resources
- Population growth
- Air quality and atmosphere
- Water resources
- War technology
- Human health and disease
- Energy shortages
- Land use
- Hazardous substances
- Nuclear reactors
- Extinction of plants and animals.
- Mineral resources.

The module on curriculum introduces teachers to the major S/T/S issues and gives teachers an opportunity to evaluate extant curricula to determine the extent to which they have an issues orientation. In addition, teachers have the opportunity to implement a unit they adapt for their classroom.

Module 3: Equity

National attention continues to focus on the needs of under-represented groups in mathematics and science (females, minorities, and the disabled). Although our society is experiencing increased demand for workers with technological skills, there is no concurrent increase in college enrollment in these disciplines or in the number of students interested in careers in mathematics, engineering, and natural science (Berryman, 1983; Finkbeiner, 1987; Vetter, 1987; Task Force, 1988). Teachers must become aware of the importance of encouraging students from under-represented groups and must become skilled in effective strategies for developing science-related skills, attitudes, interests, and successes in their students (Gardner, et al, 1989; Gilliland, 1988; Malcolm, 1984; Scott & Schau, 1985; Skolnick, et al., 1982; ETS, 1992; Wilson, 1992).

The equity module presents a variety of strategies that have proven effectiveness at increasing the participation and success of all students, but especially female and minority students. Equitable teaching strategies include

- cooperative learning;
- experiences that encourage the development of spatial and cognitive processing skills;
- topics that are relevant to the students' lives and activities that build on all students' prior experiences;
- activities that promote critical thinking;
- reinforcement of basic skills that will increase the students' chances of success in school;
- introduction to careers in science and technology; and
- language and art work that include a balanced representation of gender and race.

Individual students learn differently and respond differently to the learning environment. Strategies that are effective for one student are often ineffective for another student. We refer to the individual ways that students prefer to learn as learning styles — the ways students perceive, interact with, and respond to the learning environment and information. Students have mental habits and work habits that influence the way they pay attention to and accommodate information and how they make decisions. Some students learn best by reading, some by discussing, and some by engaging in activity.

Anthony Gregorc developed a model of learning styles that describes learners as having two ways of perception (concrete and abstract) and two ways of ordering information (sequential and random). Students differ in the degree to which they exhibit these characteristics. Another researcher, Bernice McCarthy (1990), developed the 4-MAT system as a method of organizing instruction to accommodate varied learning styles. The 4-MAT system follows a cycle of instruction that progresses from experience, to reflection, to conceptualization, to experimentation, and back to experience, McCarthy designed her system to meet the needs of four types of learners: innovative learners, analytic learners, common sense learners, and dynamic learners.

Teachers tend to teach to their preferred learning style. This means that unless the teacher attends to learning style differences in the classroom, she or he will not be giving all the students the opportunity to learn, at least part of the time, in their preferred style. Nevertheless, teachers can learn techniques that help students with different learning styles understand material that is presented in one particular style, and teachers can develop a variety of learning experiences to accommodate their students' diverse styles.

Several authors have indicated that strategies such as these do increase the participation and success of students who do not usually do well in or remain interested in science. Specifically, we have selected strategies based on the work of Gardner, Mason, Matyas (1989), Johnson & Johnson (1987), Kahle (1987), ERIC (1985), and NRL (1983).

Module 4: Assessment

Many learning outcomes, especially those promoted by the new science curricula, are not easily measured by traditional tests. Alternative strategies such as group projects, behavioral checklists, portfolios, interviews, and performance assessments are often more appropriate for ascertaining student achievement than are multiple choice, true-false, and matching tests. Many teachers would benefit from clearly established procedures and materials that allow them to advance beyond reliance on paper-and-pencil tests.

All too often efforts to improve science education exclude one of the driving forces for science programs – assessment. The national reform effort, however, recognizes that assessment is a critical component of science education reform (AAAS, 1989; NCISE, 1989; Pelavin Associates, Inc., 1991; Malcom & Kulm, 1991; Lawrenz, 1991). Leaders in education are concerned that current standardized tests used to assess student and program outcomes are inadequate measures of the more important outcomes of an effective science program. Science education reform currently is emphasizing the learning of major conceptual themes rather than factual information. Nevertheless, because nearly all current assessment instruments primarily use multiple choice, true-false, and matching types of questions, these instruments most effectively measure the lower levels of Bloom's taxonomy (knowledge, comprehension, application). Assessment instruments that address the outcomes of higher levels of thinking, understandings of major conceptual themes, and the ability to apply science understandings and approaches to solving real-world problems, unfortunately, are not very common.

Authentic assessment is the current phrase being used by those in the forefront of redesigning assessment. According to Frances Lawrenz (1991), authentic assessment involves maximizing congruence between the desired outcomes of the program and the assessment procedures. Lawrenz (1991) suggests that in addition to multiple choice tests, authentic assessment procedures include

- *Essay tests*. Essay tests provide information on a students' ability to organize and communicate information and provide the opportunity for students to present individual opinions and perspectives.
- *Practical assessment*. Practical assessment provides information on how well students can perform science skills such as using apparatus and measuring instruments, making observations, and designing experiments.
- *Portfolios*. A portfolio is a collection of documents, products, artifacts, and work-in-progress that students have produced as part of their learning. An artist's portfolio illustrates the nature of a student portfolio. Examination and review of a student's portfolio provides a rich and diverse source of information about not only what the student has learned but also about the process of learning.
- *Observations and interviews*. Interviews to probe students' understandings allow the teacher to probe deeply into individual student's understanding of complex science concepts. Observations of classroom activity provide information about how the students are learning and about how well they work together. Both procedures provide information the teacher may use to make program improvements.
- *Dynamic assessment*. In this approach, the assessing and teaching are intertwined, as they should be. The teacher uses a variety of ongoing assessment procedures to gather feedback from students; the teacher uses the information regularly to make mid-course corrections in instruction. Palencsar and Brown (1984) call this reciprocal teaching.
- *Projects*. Projects conducted by students can provide information about a student's ability to design, conduct, and communicate results of scientific inquiry. Teachers can assess the process by which the student developed the product as well as the quality of the final product itself.

Incorporation of Classroom Management into All Four Modules

All modules incorporate classroom management strategies that fall into two main categories. The first category concerns strategies that maintain discipline in the classroom. The second category concerns strategies that help the teacher manage the materials and physical layout of the classroom. Several authors (ISCS, 1973; Krumboltz and Krumboltz, 1972; Curwin and Mendler, 1988) discuss classroom management as a way of fulfilling the needs of students. Those needs include a safe environment, a quiet setting (when appropriate), a minimum of disruptions to the learning activities, and evaluation that is fair and accurate. Experienced teachers who have little difficulty managing their classrooms do so by establishing a classroom climate wherein students know what is expected of them and know what happens both when they meet and do not meet the expectations.

Managing materials in activity-based science classrooms is an onerous chore. *Classroom Organization* by ISCS provides specific strategies that, when employed, allow the teacher to manage materials with a minimum of disruption. Some of those strategies include giving students enough space to work safely, storing the equipment in a well organized way that allows for student access as well as teacher maintenance, and taking precautions for special or expensive equipment.

Teachers using the teacher development modules will have models to follow and schemes to explore as ways to improve the management of their own classrooms. By incorporating the classroom management strategies into all the modules, we demonstrate to the teachers that managing the classroom is an ongoing process that is a part of all classroom activities.

Incorporation of Educational Technology into All Four Modules

The teacher development modules introduce teachers to effective uses of educational technology for science education. Science instruction may be improved through technologies that teachers use to teach and students use to learn. During the past decade, educational technology has changed more than any other facet of instruction. With the advent of microprocessors, educators discovered new tools for teaching and learning.

In a study supported by International Business Machines (IBM), BSCS investigated the ways in which new educational technologies might enhance elementary school science and health (BSCS, 1989). As part of the IBM study, BSCS made recommendations about educational courseware for elementary school science and health. BSCS recommends that science teachers select and use courseware packages that (1) achieve the goals and objectives of the curriculum, (2) integrate with other print and hands-on instructional materials, (3) engage the students in active learning, (4) accommodate a range of reading, writing, and math skills, and (5) accommodate a variety of developmental levels. BSCS recommends that elementary science teachers consider including the following uses of educational technologies in their curriculum and instruction:

- *Information Processing Tools*. Students can use the microcomputer to acquire, process, analyze, organize, explain, and report scientific information. Using the microcomputer as an information processing tool is the most powerful and productive way that students can use the microcomputer. The microcomputer can connect to electronic probes to gather information about scientific phenomena, for example probes to measure temperature, light, motion, pH, pulse rate, and sound. Students may use database, spreadsheet, statistical, and graphing programs to organize and examine patterns and relationships in scientific data and system modelers to build graphical and quantitative models for natural phenomena.

- *Communication Tools*. Students may use word processing, graphing, and drawing programs to report their results, interpretations, and explanations of scientific investigations. With more advanced communication tools, science students may publish their work. Desktop publishing enables students to produce high-quality publications at a reasonable cost. Telecomputing, where the computer connected to an electronic network, enables students to disseminate the results of their work instantly to other students and scientists around the world.
- *Courseware for Learning Science Content*. Students may use the microcomputer as an instructional tool. Microcomputers can present science content through tutorials, simulations, and games. In addition, the microcomputer makes possible a true multimedia learning environment. The microcomputer connected to a laser videodisc player and/or CD-ROM player, at the student's request, can provide a wide variety of video images (still and motion), stereo sound, bilingual narrative, animation, and text.
- *Courseware for Practicing Science Skills*. Students may use the computer to practice science and mathematics skills (such as measuring, identifying and controlling variables, and interpreting graphs) and to drill on science and mathematics facts (decimal arithmetic, safety rules, and parts of the human body). (BSCS, 1989)

Incorporation of Science Content into All Four Modules

Science content is a component of all of the teacher development modules. There are two reasons for this emphasis: (1) elementary teachers have an inadequate understanding of science concepts and (2) instructional strategies are best learned in the context of specific science content. Science content ranges from simple facts (i.e., water boils at 100 degrees Centigrade at sea level) to major conceptual themes such as patterns of change. The current reform in science education emphasizes that students need to learn a few key science concepts in depth rather than what typically happens — superficial learning of science terms (AAAS, 1989 & 1993; NCISE, 1989; NRC, 1994).

Several reports have presented lists of the major science concepts that are the most important for inclusion in a K-12 education. *Science for All Americans* (AAAS, 1989) provides the following list of common conceptual themes of science and technology: systems, models, constancy, patterns of change, evolution, and scale. *Getting Started in Science: A Blueprint for Elementary School Science Education* (NCISE, 1989) recommends: organization, cause and effect, systems, scale, models, change, structure and function, discontinuous and continuous properties, and diversity.

The participating science teachers are introduced to science content as they complete the activities in the teacher development modules. Lessons from innovative curriculum development projects are used both to explore pedagogy and to present science content. In this way, each teacher development module will help teachers improve their understanding of science concepts. Furthermore, the module on curriculum introduces teachers to the major science conceptual themes that may be used to organize the elementary school science curriculum.

Incorporation of Implementation Strategies into All Four Modules

BSCS believes that a constructivist approach to instruction is appropriate not only for elementary students but for their teachers as well. We would like the teachers to become reflective practitioners (Schon, 1991; Grimmett and Erickson, 1988; Mohr and MacLean, 1987; Cruickshank, 1987; Clift, Houston, and Pugach, 1990) who are empowered to study and implement improvements to their instructional practice (content and pedagogy). The teacher development modules will include the following strategies to promote reflective teaching:

- *Reflection on learning*: teachers will use interviews of students, concept mapping, reflective note taking, analysis of case studies, and small group discussions to reflect on their own learning and the students' learning.
- *Reflection on self*: teachers will keep a journal, write a personal biography, and develop a metaphor for their own teaching style.
- *Reflection on action*: teachers will use micro teaching, videotapes of their own lessons, observations of expert teachers, study groups, peer coaching, and mentoring and will conduct classroom-based research.
- *Reflection on program improvement*: teachers will interpret results from interviews of students, parents, and other teachers, innovation configuration checklists, and student outcome data.

For changes in the teaching of science in the elementary classroom to occur, teachers must learn about and experiment with the new pedagogy, such as a constructivist approach to learning, cooperative learning, and activity-based science (Little, 1982; Joyce and Showers, 1988). Teachers also need to improve their pedagogical content knowledge -- knowledge about how to interpret science content for students. The introduction of teachers to the new pedagogy and science content for elementary science is central to the proposed project. Furthermore, because new approaches to teaching and learning rarely occur without the active leadership of district-level administrators and principals, BSCS espouses a comprehensive model for staff development that includes not only the development of teachers but also the development of leaders for change.

Module Organization

Each teacher development module provides information and examples to assist teachers in understanding, developing, and using new instructional strategies, science content, and approaches to the curriculum. The modules use multimedia approaches to delivering the content and skills. Each module consists of a guide for the course instructor; video segments on accompanying videodisc; directions for large group, small group, and individual exploration and application activities; and a variety of group and individual assessment tasks. The final versions of the instructor's guide and videodiscs will be professionally produced and marketed by a commercial publisher.

The project is producing three interactive videodiscs to provide models of the innovative teaching strategies that we introduce in the modules. Each videodisc includes scenes from real elementary school science classrooms. The scenes are selected to depict examples of effective teaching practices and examples of innovative science curricula. The videodiscs include interviews with students about the science learning experiences and with the video teachers who reflect on the instructional strategies and curricula and on the decisions they made while teaching. We are providing three methods of interaction with the videodisc: chapter stops and frame numbers printed in the learning guide for use with a hand-held controller, bar codes in the learning guide, and a computer interface.

Conceptualize Modules

The first step was to conceptualize the design and content of the modules. This was accomplished by convening a three-day conceptualization conference of project staff and experts in elementary school science teaching. Figure 4 lists the participants in the conceptualization meeting. The team leaders at the conceptualization conferences, who were not members of the project staff, are acknowledged experts in the topic of the modules. BSCS established one team to conceptualize each of the four modules. Each team included a master elementary school science teacher, a science teacher educator, a scientist, and a member of the project staff. BSCS staff recruited the master elementary school science teachers from Presidential Award Winners. As part of the selection process the prospective master teachers provided a videotape of their own teaching. These master teachers also were instructors for the classroom scenes for the experimental videodiscs. During the second year of the project, we selected a new set of teachers and collected additional video at their school sites.

The primary task of the conceptualization conference was to agree on design specifications for the modules answering questions such as: (1) what kinds of information will be included in the learning guide and in the videodisc? (2) where will the readings be located in the learning guide? (3) how will implementation strategies be infused into the learning guide? (4) will learning activities be provided in the main body or in the appendix? The design specifications were developed by the combined four teams, with subgroups focusing on design specifications for the videodisc and for the instructor's guide.

Develop Experimental Modules

Prepare master teachers. To obtain video for the case studies, we needed to videotape teachers modeling effective instructional strategies. During the first year, we brought three master teachers (see figure 4) to Colorado Springs to teach four classes, each a half day in two classrooms specially arranged for the purpose of gathering the video scenes. We made the decision that having only two classrooms, rather than many, in which to control the light and sound environment would result in much higher video and sound

Science Advisors	Curriculum Representatives	Science Teacher Educators
Ed Buchwald Professor of Geology Carleton College	Gail Foster BSCS	Audrey Champagne SUNY at Albany
Keith Kester Professor of Chemistry The Colorado College	Candace Julyan TERC	April Gardner University of Northern Colorado
Patricia Simpson Professor of Biology St. Cloud State University	Larry Lowery Lawrence Hall of Science	James Gallagher Michigan State University
Dean Zollman Professor of Physics Kansas State University	Sally Schuller National Science Resources Center	Paul Kuerbis The Colorado College
BSCS Staff Kathrine Backe Project Director	Karen Worth EDC	*Teachers* Alvin Begay Ft. Defiance, AZ
Wilbur Berquist Internal Evaluator	*External Evaluator* Norris Harms	Sharon Lee Strating Maryville, MO
Rodger Bybee Associate Director	*Videodisc Producer* Bert Kempers Media Design Associates	Sarah J. Yoshida Seoul, Korea
Jim Ellis Principle Investigator		David Christensen Cedar Falls, Iowa
Pam Van Scotter Editor		

Figure 4: Participants in conceptualization meeting

quality of the completed video materials. We used master teachers because we wanted to provide exemplars for effective science teaching. The first task in developing the experimental modules, therefore, was to prepare the small group of master teachers to model the exemplary instructional strategies. Two of these master teachers also served on the conceptualization teams. Consequently, they already were introduced to the innovative approaches to curriculum and instruction.

The teacher development program for the master teachers had four parts. The first part was a two-day seminar on the educational innovations that they are to implement. This seminar immediately followed the three-day conceptualization conference. Project staff were the instructors for the seminar. The second part was a one-week instructional planning course conducted by BSCS staff immediately prior to the summer science program. During the planning course, the master teachers continued to develop their understanding of the educational innovations, to collaborate with BSCS to plan the lessons they would implement during the summer science program, and to develop detailed lesson plans as guides for the camera crews. The third part was a coaching practicum during which the master teachers worked with each other and with project staff to coach each other while they served as instructors during the summer science program.

Gather classroom video. The second task was to conduct a summer science program for elementary school students, who served as the students for the videotaping. During the summer of 1993, BSCS conducted a two-week summer science program for elementary school students in the Colorado Springs area. The four master teachers, to whom BSCS staff previously introduced the innovative instructional strategies, taught these students, giving careful attention to modeling the exemplary instructional strategies. There were two class sections for intermediate students and two sections for primary students, with separate sections meeting in the morning and afternoon. Each section included a maximum of 20 students selected by BSCS staff to represent a diversity of abilities, social-economic status, and ethnic backgrounds. Each section met three hours every day for two weeks in classrooms in a local school building. To ensure their commitment, students paid a small registration fee to cover costs for consumable supplies and for snacks. Two of the master teachers were instructors in the morning and the other two planned the lessons for the next session; they switched roles in the afternoon. BSCS staff observed the lessons to provide guidance and suggestions for exemplary teaching behaviors and to record a log of teaching activity.

Media Design Associates (MDA) and BSCS collaborated to gather the video of classroom interactions during the summer science program. MDA staff employed three video cameras in each of the two classrooms. One was a fixed camera that was focused on the whole classroom. The other two cameras captured small group interactions among students and between the teacher and students. Video was collected continuously throughout all lessons during the two weeks. We collected additional video of interviews with teachers and students.

Produce first draft of modules. The third task was to write, edit, and produce the experimental versions of the modules. The team leaders from the conceptualization conference (Champagne, Gallagher, Gardner, and Kuerbis) collaborated with project staff members to write and edit the text. One BSCS staff member was responsible for the production of each module. The project director, using input from the team leaders and BSCS staff, had primary responsibility for the preparation of the first draft of the videodiscs. Technical aspects of the videodiscs were completed by professional videographers and video editors working with BSCS staff. The major steps in producing the videodiscs involved: (1) gathering the raw video of classroom interactions, (2) producing the window dub (time codes displayed on the tape), (3) making an editing decision list from the window dub, (4) producing a rough assembled video, (5) editing video and sound to produce final video, (6) adding narration and questions to guide discussion, (7) producing the check discs, (8) making masters of the videodiscs, and (9) production and release of disc replicas.

Each learning guide (the print material) was produced by a member of the BSCS staff in collaboration with one team leader. One member of the BSCS staff was the primary author on each module. First, we produced detailed outlines of all learning guides, which were reviewed by all members of the project staff and by the team leaders. Second, the team leaders wrote specific activities. Next, the first draft of the guides were reviewed by the project director, principal investigator, and team leaders. Once the check disc for the video was ready the project staff prepared a section in the instructor's guide with bar codes, chapter stops, and frame numbers corresponding to video segments for the videodisc. Lastly, the primary authors revised the manuscript and worked with the project secretary and editor to produce the experimental edition of the learning guide.

Pilot test modules. As the fourth task, BSCS staff organized a pilot test of the experimental version of each module with inservice teachers. During the spring of 1994, the BSCS staff recruited teachers from District 11 in Colorado Springs to participate in the pilot test of the experimental materials. BSCS staff organized the modules into separate courses and developed course syllabi. Participants enrolled for course credit through the University of Colorado at Colorado Springs. Additional sites throughout the United States pilot tested the materials with inservice and preservice teachers and provided feedback on the materials. The feedback from the pilot test in Colorado Springs and other sites contributed to decisions about collecting video from intact classrooms in the fall semester and about revisions of the print and video materials.

Revise and Produce Commercial Edition of Modules

Once the pilot test of the experimental modules was completed, the next major task was to revise and produce the camera-ready copy of the modules. First, BSCS staff analyzed the pilot test data and the content reviews. One clear recommendation from the advisory committee and participating teachers was that we should collect the remaining video in real classrooms during the school year. We therefore recruited four new teachers who obtained school and parental permission for us to collect video in their classrooms. No special attempt was made to select the students. We made a special attempt to identify classrooms from urban, rural, and suburban settings with diverse student populations. During the summer of 1994, BSCS staff conducted a second, one-week intensive instructional planning course for the master teachers who were to be the teachers for the video. We collected video for two weeks during the 1994 fall semester in the classrooms of each of the participating teachers.

During the spring and summer of 1995, BSCS staff, with assistance from outside consultants, will revise and produce the print material and the three videodiscs. The final project will be camera-ready copy for the learner's guide and the final masters of the videodiscs.

Evaluate the Modules

Once the final version of the materials are completed, each module will be field tested and evaluated in 32 inservice settings (16 school-based and 16 university-based) by instructors who were not involved in the conceptualization and development of the materials. The field test sites were recruited through the BSCS newsletter, through announcements placed in the newsletters of the Association for the Education of Teachers of Science (AETS) and the National Association for Research in Science Teaching (NARST), and the National Science Education Leadership Association (NSELA), and the National Science Teachers Association and on telecommunications networks of AETS, NARST, and the Council of State Science Supervisors (CSSS). Centers established by BSCS for the BSCS middle school project, the BSCS ENLIST Micros project, and the Colorado Science Teacher Enhancement Project will be given first opportunity to evaluate the materials because the innovations included in the teacher development modules also are the focus of the teacher development activities conducted by these Centers.

Each of the sites testing the final versions of the teacher development modules will be required to conduct a thorough evaluation of one or more of the modules. BSCS will set the basic requirements for the evaluation to which all test sites must conform, but each site also will submit a personalized evaluation plan for approval by project staff. Each test site will have the responsibility to produce a written evaluation report of each module it tested. BSCS staff will synthesize the information from the evaluation reports and include them in a final evaluation report for the project.

Disseminate Products and Findings

The project includes two methods of dissemination. The primary method will be to contract with a commercial publisher to publish and market the four teacher development modules (learning guides and videodiscs). BSCS will produce camera-ready copy of the learning guides and master videotapes for the videodiscs. Once these final materials are completed, BSCS staff will contact publishers of educational materials for teacher education and of elementary science curricula. BSCS currently has contractual arrangements with several publishers for other BSCS programs and has a record of successfully publishing innovative educational materials. BSCS will retain full content control for all the materials. The commercial publisher will use its expertise in marketing and distributing the materials nation-wide.

The second method of dissemination is for BSCS staff to demonstrate the materials at professional meetings of science teachers and teacher educators, including the National Science Teachers Association (NSTA), the Association for Supervision and Curriculum Development (ASCD), the Association for the Education of Teachers of Science (AETS), and the National Staff Development Council (NSDC). Furthermore, BSCS staff presented the evaluation results at the annual meeting of the National Association of Research in Science Teaching (NARST).

Method

Formative evaluation determines the progress being made with a program, product, or a learner. The purpose of the formative evaluation was to gather descriptive data from various sources, analyze that data, and then use the data as a mechanism for improving the content on the videodisc and in the print materials. The formative evaluation of the Teacher Development Modules was conducted during the field-testing of the videodisc and print materials. The qualitative process allowed us to gather qualitative and quantitative information from various sources. We used multiple strategies to obtain information that would provide guidance for the revision of the final materials. Figure 5 shows the design for the formative evaluation phase.

Formative Evaluation Design

We determined the accuracy and appropriateness of the content in each module through

◆ internal reviews of all modules by the team leaders (outside experts) that will ensure each topic area is included and emphasized on every module, and

◆ external reviews of each module by scientists and teacher educators who are experts in science content and in the areas of curriculum and instruction.

We determined the clarity of the instructional materials as well as the efficiency of using the video disc to present the information through:

◆ observation of teachers using the modules during the pilot test and field test courses conducted by BSCS,

◆ interviews of teachers following their use of the modules in the BSCS courses, and

◆ self-reports from teachers during the use of each module in the BSCS courses .

Audience

Science Education Faculty, Science Supervisors, Science Content Faculty, Inservice Teachers, and Preservice Teachers

Questions

Are Materials:

◆ Engaging?
◆ Manageable?
◆ Flexible?
◆ Adequate in scope?
◆ Teachable with my expertise?
◆ Of high quality?

Do Materials:

◆ Meet teacher's felt needs?
◆ Provide for active participation by teachers?
◆ Include assignments teachers can implement in their own classrooms?
◆ Improve knowledge of innovations?
◆ Change attitudes regarding science instruction?
◆ Change teacher behavior?

Figure 2

To evaluate the potential usefulness of the field- test materials, we developed several questionnaires to provide us with the reactions of participants in the courses as well as the reactions of the content reviewers. BSCS staff used the questionnaires when they (1) taught the courses locally, and (2) when obtaining content reviews from others outside BSCS in various settings. The questionnaires included a participant's evaluation form, an instructor's evaluation form, and a content review form. A detailed description for each of these questionnaires follows.

Participant Evaluation Form To solicit feedback on the appropriateness of the video segments and the content of each session from the participating teachers, we developed a from to use at each session. The participants assessed the effectiveness of both the print materials that guided the session and the videodisc segments. They responded to the following questions: (1) What their overall reaction was to the session? (2) What activities in today's session worked well and what one's did not? (3) How effective were the video segments at provoking you to think about science teaching? (4) Was this an appropriate session for you? If not, please explain. (5) Were the directions and handouts for the session clear and unambiguous? If not, please explain. (6) How well did the lesson achieve its stated goals and objectives? (7) How effective was the instructor? and, (8) What recommendations do you have for improving the session?

Instructor Evaluation Form The instructors provided their general critique to each session. The instructors reacted to both the print and video materials. Instructors responded by (1) indicating their general reaction, (2) describing any modifications (additions, omissions, revisions)they made as they taught the session and why they made those modifications, (3) assessing which activities worked well and which did not, (4) indicating how the participants responded to the video segments, and what suggestions they had for modifying those video segments? (5) indicating whether or not this was an appropriate session for the participants, and if not, explaining, (6) indicating whether or not the directions for the lesson were clear and unambiguous and if not, explaining, (7) describing recommendations for improving the session.

Content Review Form Reviewers external to BSCS used the content review form to critique the videodiscs and print materials and included narrative to expand ideas and suggestions. The content review form asked for a summary of each of the four modules, the three videodiscs, and the facilitator's guide. The reveiwers rated the various sections of print materials and videodisc for utility, clarity, readability, sufficiency, and accuracy. Each of the following sections were critiqued on a scale of -2 to +2 with -2 suggesting a relative weakness and +2 suggesting the relative strength in each of the areas. The following is a description of the content review form sections:

- *Introduction and Overview* section: the reviewer reacted to the written narrative that provided insight into the ideas and content of the entire module. The goals were listed for each of the modules along with an outline of the instructional model that guided the development of the print materials.
- *Stage I: Invite* sessions in the written material focused on engaging the participants in the course topic as well as assessing prior knowledge and practices.
- *Stage II: Explore* sessions in the written material asked the participants to explore effective approaches to science education.
- *Stage III: Proposed Explanations and Solutions* sessions in the written material focused on engaging the participants in developing their own explanations of good practice and in designing a plan for new strategies for teaching science in their classroom.
- *Stage IV: Taking Action* sessions in the written material provided the participants with the opportunity to put into practice their ideas through a classroom-based study.
- *Appendices* were the same for all modules and included descriptions of cooperative learning, concept mapping, How-Tos on reflective journaling, portfolios, the jigsaw approach, and peer coaching.
- *Facilitator's Guide* provided an overview and index of the chapters on the three videodiscs. The guide also listed accompanying questions that were appropriate to each segment of the videodisc chapters.

Population

The population that conducted the content review process for the Teacher Development Modules (TDM) included BSCS project staff, members of the advisory board, university faculty, teachers, and science supervisors. Demographic surveys were sent to all participants that had received a set of the TDM materials. From the thirty-four surveys distributed, twenty-four were returned. All percentages that follow are from this population. Of the 71 percent responding to the survey, 50 percent indicated that they only reviewed the materials, 30 percent indicated that they reviewed the materials and used them in a classroom setting, and 4 percent of the respondents indicated that they were involved in the initial phase of development.

In describing the setting of the populations, 41.7 percent were urban, 16.7 percent were rural, and 25 percent were suburban. Where content reviewers were in university settings, 41.7 percent were associated with universities with populations that were more than 20,000, and 25 percent were associated with universities of 5,000 or less.

Inservice and preservice teachers are the audience for the TDM materials. In the settings where the modules were used with preservice teachers, 58 percent indicated that 10-50 teachers were exposed to the materials and 4.2 percent indicated that more than 100 teachers were exposed to the materials. When the materials were used with inservice teachers, 62 percent indicated that 10-50 teachers were exposed to the materials, 4.2 percent indicated that 50-100 teachers were exposed to the materials, and 4.2 percent indicated that more than 100 teachers were exposed to the materials.

We asked the respondents to describe the racial/ethnic composition of those teachers participating. Those responding indicated that 8.3 percent had a racial/ethnic balance, 58.3 percent were largely Anglo, 4.2 percent were largely African-American, and 4.2 percent were Native Americans. In describing the gender balance of participating teachers, 62.5 percent were mostly female and 12.5 percent indicated a balance in the number of males and females.

Results

The following critique of the TDM material represents all the sources described in the method section. The critique is a synthesis of the content review form summary and the narrative comments summary. The content review form summary for the print materials has an accompanying legend that focuses on utility, clarity, readability, sufficiency, and accuracy of materials.

The first section was the *Introduction and Overview* of the print materials. Figure 6 provides a graphic representation of the overall response to this section. Most reviewers found the section helpful, and they rated overview and goals higher than the introduction, which the reviewers suggested could be expanded. Reviewers described the goals developed for each module as "complete and worthwhile." Reviewers found the focus questions especially helpful. The section provided a "good synopsis" of the modules.

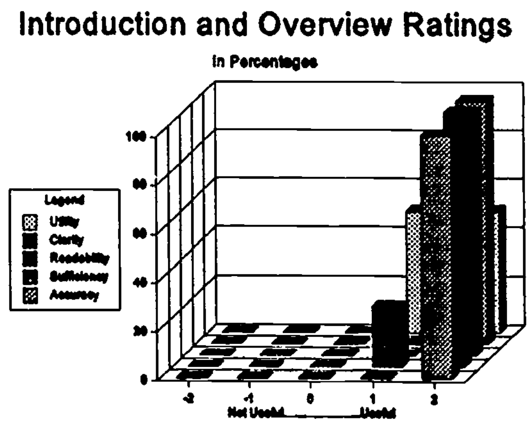

Figure 6

Figure 7 provides a graphic representation of the overall response to the *Stage I: Invite* section of the print materials. Most reviewers rated this section very high. The reviewers indicated that this section was good, motivational, and thought provoking. They indicated the section was a "particularly nice section to promote reflection on one's incoming beliefs." Recommendations for the revision of this stage included (1) the need for more overheads for the instructor so that there is a thorough coverage of the topics, and (2) the structure of the model should be introduced for those participants who are unfamiliar with this particular instructional model.

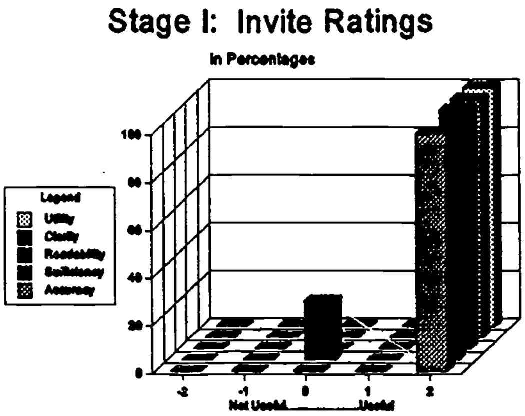

Figure 7

Figure 8 provides a graphic representation of the overall response to the *Stage II: Explore* section of the print materials. Reviewers described Stage I and Stage II as providing a necessary flow to each of the modules. Reviewers praised the variety of activities in this section. One reviewer felt that there could be fewer questions, and that the questions should cause the participants to be more reflective. They recommended that we get down to specifics somewhat more quickly so that participants have time to develop particular techniques and skills in addition to an appropriate perspective on their work. In addition, reviewers recommended that we emphasize the importance of the learners' prior knowledge about how they learn in the classrooms and that we use many explanations for why teachers should use multiple representations of knowledge to help children learn.

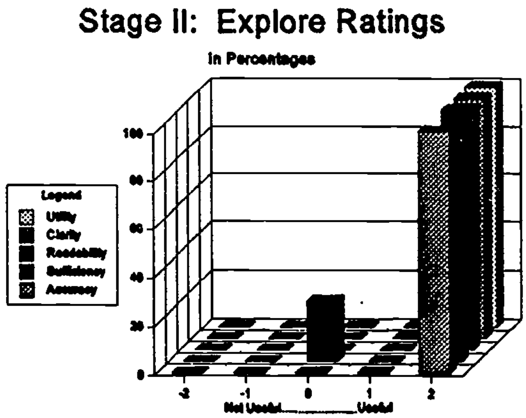

Figure 8

Figure 9 provides a graphic representation of the overall response to *Stage III: Proposed Explanations and Solutions*. The reviewers described this stage as being well developed, although it could have been expanded. Some indicated that the strategies used in these

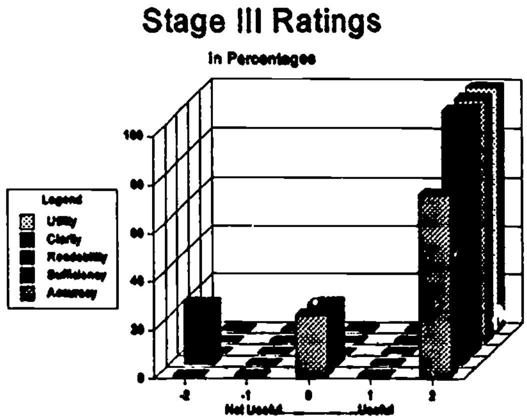

Figure 9

sections were focussing too much on "individualized work and teachers presenting findings to one another." Others recommended that the facilitator "add, supplement, and enrich what teachers can find out about the topics" and that outside readings and resources could be expanded for most modules." Reviewers noted that the material provides important perspectives and background, but that participants need more direct assistance in developing skills and techniques for implementing their new perspectives on teaching, learning, curriculum, and assessment. The guidance and planning for change seems helpful, however, more time needs to be spent on exploring "grounded" rationales for changes.

Figure 10 provides a graphic representation of the reviews of the *Stage IV: Taking Action* section of the print materials. The reviewers indicated that the activities were a great addition to this section, but the section would be more useful by expanding these activities and adding additional activities. One reviewer recommended that we assign individual activities as homework and to use class time for preparing for the assignment and discussing the results of that assignment. Some reviews indicated that participants need to spend more time planning, teaching, and assessing students' understanding, skills, and affect for all students. Some reviewers indicated that we needed to provide ideas on how you would adapt the materials for the preservice setting.

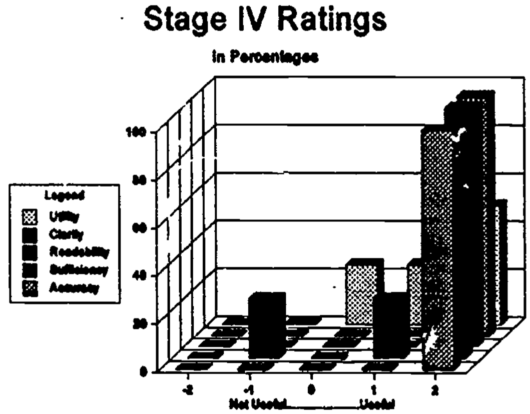

Figure 10

Figure 11 provides a graphic overview of the reviews of the *Appendices* that were the same in each of the modules. Reviewers felt that the appendices should vary from module to module to fit the specific needs of the materials. They suggested that in some cases the appendices were hard to follow and lacked consistency in location within each module. Reviewers suggested that there was a lot of valuable information that was part of the appendices and perhaps that information should follow each session within the print materials where it is to be used. The reviewers considered the writing style as compact and should appeal to teachers.

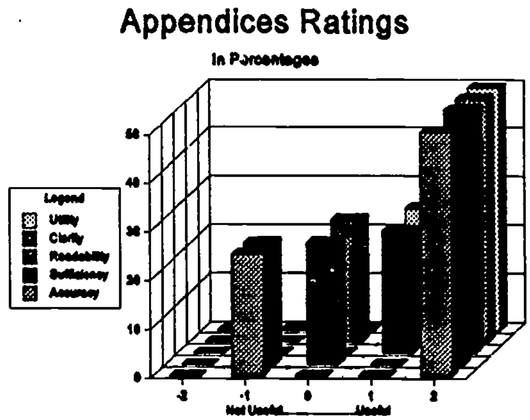

Figure 11

Figure 12 provides a graphic overview of the reviews of the *Facilitator's Guide to the Videodiscs*. This section received mixed reviews. Some reviewers indicated that the guide was particularly helpful, while another indicated that the guide was difficult to use. Although the idea of the guide was, in general, a good one, the format was confusing for some. One reviewer pointed out that without the guide, it would not have been possible to understand how to use the videodiscs with the print materials. This reviewer recommended that we provide readers with an advance organizer that describes in detail what the materials are and how to use them.

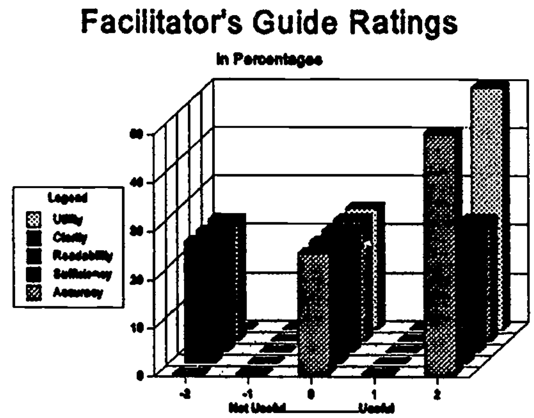

Figure 12

Figure 13 provides a graphic representation of the response to the overview for *Videodisc #1*. Reviewers indicated that the segments on this disc provide many opportunities for teachers to discuss the classroom scenes. One reviewer suggested that when we integrate math concepts, we should be attentive to the NCTM standards. Some suggestions offered were (1) to use more discussion questions, (2) to use different types of questioning strategies and ways to think about student responses, (3) to discuss what it is that a teacher does when students do not understand prerequisite knowledge, (4) to discuss how teaching strategies for science compare with teaching strategies for math, and 5) to identify the management issues involved in interviewing students about what they have learned.

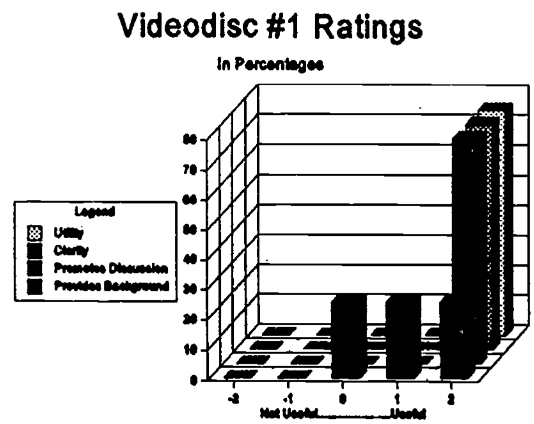

Figure 13

Figure 14 provides a graphic representation of the responses to the overview for *Videodisc #2*. Reviewers made comments to specific segments on the videodisc. The reviewers indicated that this disc had segments that provided opportunities to observe "questioning in the context of experimentation." Additionally, the contrasting styles of the teachers on the disc was thought to be an

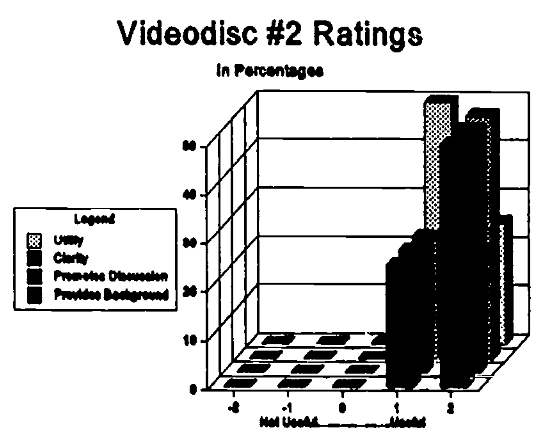

Figure 14

excellent means of promoting discussion. This disc provided another good opportunity to compare questioning and teaching styles. The reviewers indicated that more questioning strategies be employed. They also noted that the segments on this disc provided an opportunity to observe student responses, specifically, the students' "alternative conceptions", and how students read teachers.

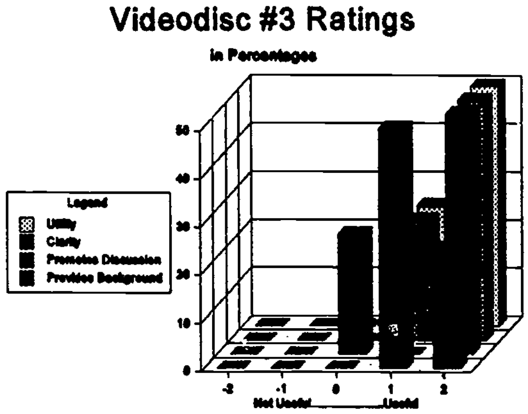

Figure 15

Figure 15 provides a graphic representation of the overview of *Videodisc #3*. This particular disc received positive comments about the segment on the disc called the Marley Story. The reviewers indicated that the teachers on this disc serve as a model for all. Again, reviewers mentioned that there are not enough questions for discussion in the video segments.

General Comments Although the reviewers made recommendations for revisions, the overall reaction to the print materials and videodiscs was that nothing should be omitted. The reviewers indicated that while both the written materials and the videodiscs are of high quality and useful, more could be done to coordinate the use of them. The modules could "give greater attention to helping teachers acquire the knowledge and techniques that are essential in building a learning community that supports the desired [type] of science learning encompassed by the [teacher's] vision."

Conclusions

BSCS project staff received ample feedback from content reviewers to guide the revision of the final print materials. Interest in the project is wide, and the feedback varied depending on the setting of the reviewer. Teachers teachers who participated in the field test of the courses responded well to the content of the modules and proposed exciting plans that they implemented in their classrooms. They encouraged us to offer the courses again and suggested that they knew of other teachers that would enjoy and benefit from the same experinces. They especially benefited from the use of the videodisc, which allowed them to step into another classroom and reflect on the teaching and learning environment.

Overall, reviewers and teachers responded very postitively to the modules. All reviewers voiced the need for such materials for both inservice and preservice teachers. They also indicated the importance of developing similar materials across all grade levels. The primary audience for the materials is the inservice teacher population. However, university faculty have encouraged us to develop the materials in a way that they could modify activities could for the preservice setting. Many of the university sites are continuing to use the materials with teachers and have indicated an interest in using the final materials at their sites.

Decisions Guiding the Revision

We collected the first round of video during a two-week summer program in Colorado Springs. We accepted the first one hundred students that applied for the program. Students were in one of four classrooms: two primary (cross-age, cross-grade) sections and two intermediate (cross-age, cross-grade)sections. We selected teachers from various areas of the country. Three camera technicians filmed in each classroom continuously throughout the two-week session. The feedback that we received on the first round of video indicated that teachers want segments from actual classroom settings. Consequently, we decided to film the next round of materials during the school year in real classroom settings. We selected classrooms and teachers from Colorado, Minnesota, and Illinois and Media Design Associates filmed during the fall of 1994. The classrooms represent rural, urban, and suburban settings.

In the final revision, the print materials will include bar coding and computer interfacing to further implement the suggestions recommended by reviewers. We will provide an index to the videodiscs with each module. We anticipate including all essential material for teaching a session in the specific session materials. This organization of the print materials will benefit those facilitators who are not familiar with the modules.

References

American Association for the Advancement of Science. *Project 2061: Science for all Americans.* Washing ton, D.C.: AAAS. 1989.

American Association for the Advancement of Science. (1993). *Benchmarks.* Washington, D.C: Author.

American Psychological Association. *Learner-Centered Psychological Principles: Guidelines for School Redesign and Reform.* Washington, D.C: American Psychological Association. 1992.

Berryman, S.E. *Who will do science?* Special Report of the Rockefeller Foundation. 1983.

BSCS. *New designs for elementary school science and health.* Dubuque, IA: Kendall/Hunt Publishing Company. 1989..

Bybee, R.W. The science-technology-society (STS) theme in science curriculum: Policies to practices. *Theory into practice.* Columbus, OH: Ohio State University. 1991.

Bybee, R.W. The sisphean question in science education: What should the scientifically and technologically literate person know, value, and do--As a citizen? In R. W. Bybee (Ed.) *Science-Technology-Society 1985 NSTA Yearbook.* Washington, D.C.: National Science Teachers Association. 1986.

Bybee, R.W., Buchwald, C.E., Crissman, L.S., Heil, D., Kuerbis, P.J., Matsumoto, C., & McInerney, J.D. *Science and technology education for the elementary years: Frameworks for curriculum and instruction.* Andover, MA: The National Center for Improving Science Education, The NETWORK, Inc. 1989.

Bybee, R.W., & Mau, T. Science and technology-related global problems: An international survey of science educators. *Journal of Research in Science Teaching, 23*(7), 599-618. 1986.

Carnegie Forum on Education and the Economy. *A nation prepared: Teachers for the 21st century.* The Report of the Task Force on Teaching as a Profession. Washington, D.C. 1986.

Clift, R.T., Houston, W.R., & Pugach, M.C. (Eds.). *Encouraging reflective practice in education: An analysis of issues and programs.* New York, NY: Teachers College Press. 1990.

Cruickshank, D.R. *Reflective teaching: The preparation of students of teaching.* Reston, VA: Association of Teacher Educators. 1987.

Curwin, R.L. & Mendler, A.N. *Discipline with dignity.* Alexandria, VA: Association for Supervision and Curriculum Development. 1988.

ERIC. *Increasing science achievement for disadvantaged students.* New York: Clearinghouse on Urban Education. 1985.

Educational Testing Service. *Sex equity in educational opportunity, achievement, and testing.* Princeton, NJ: ETS1992.

Finkbeiner, A.K. Demographics or market forces? *Mosaic, 18*, 10-17. 1987.

Gabel, D. *What research says to the science teacher, vol. 5: Problem solving.* Washington, D.C.: National Science Teachers Association. 1989.

Gardner, A., Mason, C., & Matyas, M. Equity, excellence, and 'just plain good teaching'. *The American Biology Teacher, 51*(2), 72-77. 1989.

Gilliland, H. A Culturally Relevant Education. In Gilliland and J. Reyhner (Eds.), *Teaching the native American*. Dubuque, IA: Kendall/Hunt Publishing Company. 1988.

Goodlad, J.I. *Teachers for our nations schools*. Sacramento: Jossey-Bass. 1991.

Grimmett, P.P., & Erickson, G.L. *Reflection in teacher education*. Vancouver, B.C. and New York, NY: Pacific Educational Press and Teachers College Press. 1988.

Hegelson, S.L. Problem Solving in Middle Level Science. In D. Gabel (Ed.), *What research says to the science teacher, vol. 5: Problem solving.* Washington, D.C.: National Science Teachers Association.

Harms, N., & Yager, R. *What research says to the science teacher, 3.* Washington, D.C.: National Science Teachers Association. 1981.

Hurd, P.D. A rationale for a science, technology, and society theme in science education. In R. W. Bybee (Ed.) *Science-Technology-Society: 1985 Yearbook of the National Science Teachers Association.* Washington, D.C.: NSTA. 1986.

Intermediate Science Curriculum Study. *Classroom organization: Individualized teacher preparation.* Silver Burdett General Learning Corp. 1973.

Jackson, Philip W. The reform of science education: A cautionary tale. *Daedalus, Science Literacy Issue*, 143-166. Spring 1983.

Johnson, R. & Johnson, D. Cooperative Learning and the Achievement and Socialization Crises in Science and Mathematics Classrooms. *Students and science learning.* Washington, D.C.: American Association for the Advancement of Science. 1987.

Johnson, D.W., Johnson, R.T., & Holubec, E.J. *Circles of learning: Cooperation in the classroom (4th ed.)*. Edina, Minnesota: Interaction Book Company. 1993.

Joyce, B., & Showers, B. Low-cost arrangements for peer coaching. *Journal of Staff Development* 8(1), 22-24. Spring 1987.

Joyce, B. & Showers, B. *Student achievement through staff development*. New York, NY: Longman. 1988.

Kahle, J.B. SCORES: A project for change? *International Journal of Science Education. 9*(3) 325-333. 1987.

Krumboltz, J.D. & Krumboltz, H.B. *Changing children's behavior*. Englewood Cliffs, NJ: Prentice-Hall, Inc. 1972.

Lawrenz, F. Authentic assessment. In NARST Research Matters - to the Science Teacher. No. 26. June, 1991.

Lawson, A., Abraham, M., & Renner, J. *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills*. NARST Monograph One. 1989.

Little, J.W. Norms of collegiality and experimentation: Workplace conditions of school success. *American Educational Research Journal, 19*(3), 325-340. 1982.

Loucks-Horsley, S., Kapitan, R., Carlson, M.D., Kuerbis, P.J., Clark, R.C., Melle, G.M., Sachse, T.P., & Walton, E. *Elementary school science for the '90s*. ASCD. 1990.

Malcolm, S. *Equity and excellence: Compatible goals*. Washington, D.C.: American Association for the Advancement of Science. 1984.

Malcolm, S.M. & Kulm, G. (Eds.). *Science assessment in the service of reform*. Washington, D.C.: American Association for the Advancement of Science. 1991.

McCarthy, B. Using the 4-MAT System to bring learning styles to schools. *Educational Leadership, 48*(2), 31-37. 1990.

Mohr, M.M., & MacLean, M.S. *Working together: A guide for teacher-researchers*. Urbana, IL: National Council of Teachers of English. 1987.

Mullis, I.V.S., & Jenkins, L.B. *The science report card: Elements of risk and recovery*. Princeton, NJ: Educational Testing Service. 1988.

National Center for Improving Science Education. Teacher Development and Support in *Getting started in science: A blueprint for elementary school science education*. Andover, MA: The Network. 1989.

Northwest Regional Laboratory. *Guide to nonsexist teaching activities (K-12)*. Phoenix, AZ: Oryx Press. 1983.

Patton, M.Q. Utilization-focused evaluation. Beverly Hills, CA: Sage. 1986.

Palencsar, A., & Brown, A. Reciprocal teaching of comprehensive-fostering and comprehension-monitoring activities. *Cognition and instruction, 1*(2), 117-175. 1984.

Pelavin Associates, Inc. Statewide testing programs. Paper presented to the Secretary's [U.S. Department of Education] Commission on Achieving Necessary Skills. 18 January 1991.

Resnick, L. Toward a cognitive theory of instruction. In Parls, S., Olson, G., and Stevenson, H. (Eds.). *Learning and motivation in the classroom*. Hillsdale, NJ: Erlbaum. 1983.

Resnick, L.B. *Education and learning to think*. Washington, D.C.: National Academy Press. 1987.

Roy, R. The science/technology/society connection. *Curriculum Review, 24*(3). January/February 1985.

Rubba, P. Perspectives on science-technology-society instruction. *School Science and Mathematics, 87*(3). March 1987.

Schon, D.A. (Ed.). *The reflective turn: Case studies in and on educational practice*. New York, NY: Teachers College Press. 1991.

Scott, K.P. & Schau, C.G. Sex Equity and Sex Bias in Instructional Materials. In S.S. Klein (Ed.). *Handbook for achieving sex equity through education*. Baltimore: Johns Hopkins University Press. 1985.

Skolnick, J., Langbort, C., & Day, L. *How to encourage girls in math and science*. Palo Alto, CA: Dale Seymour Publications. 1982.

Stufflebeam, D.L. The CIPP Model for program evaluation. In Madaus, G.F., Scriven, M.S., and Stufflebeam, D.L. (Eds.). *Evaluation models: Viewpoints on educational and human services evaluation*, 117-141, Boston: Kluwer-Nijhoff. 1983.

Task Force on Women, Minorities, and the Handicapped in Science and Technology. *Changing America: The new face of science and engineering*. Washington, D.C. 1988.

U.S. Department of Education. *America 2000: an Education Strategy*. Washington, D.C: Government Printing Office. 1991.

Viadro, D. Mix of Liberal Arts, Pedagogy is Urged for Teachers (in the preliminary report, "The Reform of Teacher Education for the 21st Century"). *Education Week*, p. 10. December 13, 1989.

Vetter, B.M. Women's Progress. *Mosaic 18*(1): 2-10. 1987.

Weiss, I. *Report of the 1985-86 national survey of science and mathematics education*. Triangle Park, NC: Research Triangle Institute. November 1987.

Wilson, Meg. *Options for girls: a door to the future*. Austin, TX: pro.ed. 1992.