DOCUMENT RESUME

ED 396 924 SE 058 544

TITLE	A Perspective on Reform in Mathematics and Science Education, Monograph #3.
INSTITUTION	American Association for the Advancement of Science, Washington, D.C.; Eisenhower National Clearinghouse for Mathematics and Science Education, Columbus, OH.; National Science Teachers Association, Arlington, VA.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
REPORт NO	ENC-96-013
PUB DATE	96
NOTE	65p.; For monograph #2, see ED 393 670.
AVAILABLE FROM	Eisenhower National Clearinghouse for Mathematics and Science Education, 1929 Kenny Road, Columbus, OH 43210.
PUB TYPE	Guides - Non-Classroom Use (055) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	*Demonstration Programs; *Educational Change; Elementary Secondary Education; Science Course Improvement Projects; *Science Curriculum; Science Instruction; Standards
IDENTIFIERS	American Association for Advancement of Science; *Project 2061 (AAAS); *Reform Efforts

ABSTRACT

This publication is third in a series prepared in cooperation with the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Council of Teachers of Mathematics (NCTM), by the Eisenhower National Clearinghouse for Mathematics and Science Education. This document focuses on the groundbreaking activities of the Scope, Sequence and Coordination (SS&C) Project initiated by NSTA. This project is a science curriculum reform movement designed to help K-12 teachers make their science programs more interesting and relevant to student needs. The document describes the basic premises on which the SS&C project is built, the programs at various sites that have been part of the project's implementation, and the results and ongoing efforts at those sites. It also offers advice about how to implement and overcome major obstacles of an SS&C program. Appendixes provide statistical data on the impact of SS&C on students, teachers, administrators, and the community; and a list of additional resources. (MKR)

A Perspective on Reform in Mathematics and Science Education

The National Science Teachers Association

The Eisenhower National Clearinghouse for Mathematics and Science Education

Monograph #3

National Science Teachers Association

NCTM

Project 2061
American Association for the Advancement of Science

Neither the Eisenhower National Clearinghouse for Mathematics and Science Education nor the U.S. Department of Education is endorsing one reform approach over another—the series is distributed as a public service.

A Perspective on Reform in Mathematics and Science Education

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Monograph #3

1996

Funded by the U.S. Department of Education
Office of Educational Research and Improvement

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for Mathematics and Science Education
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1929 Kenny Road
Columbus, OH 43210-1079

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

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Foreword

A major goal of the Eisenhower National Clearinghouse for Mathematics and Science Education (ENC) is to support national reform efforts to improve teaching and learning in mathematics and science. Integral to these efforts is the leadership of the National Science Teachers Association (NSTA), the American Association for the Advancement of Science, and the National Council of Teachers of Mathematics in developing and promoting these reforms. In cooperation with these organizations, the Clearinghouse has prepared a series of publications, each entitled *A Perspective on Reform in Mathematics and Science Education*.

This publication in the series, Monograph #3, focuses on the groundbreaking activities of the Scope, Sequence and Coordination Project (SS&C) initiated by NSTA. The publication describes the basic premises on which the SS&C project is built, the programs at various sites that have been part of the project's implementation, and the results and ongoing efforts at those sites. It also offers advice about how to implement an SS&C program and how to overcome major obstacles.

ENC is pleased to have collaborated with NSTA in producing this publication. We believe reform efforts are crucial to achieving the National Education Goal 5, "By the Year 2000, U.S. students will be first in the world in science and mathematics achievement," and we believe cooperation among the organizations reaching for that goal is imperative. We want to thank the Communications staff at Aspen Systems Corporation who were responsible for the production of this publication.

Dr. Len Simutis, Director
Eisenhower National Clearinghouse

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Invitation to Teachers

National Science Teachers Association

Scope, Sequence and Coordination (SS&C) is a science curriculum reform movement that was designed to help teachers make their science programs more interesting to students and more relevant to their needs. At the secondary level (grades 9–12), SS&C advocates a restructuring of the school science program. Proponents of SS&C believe that when program content is sequenced appropriately and classroom teaching is handled competently, all students can and will learn science. For some students, your teaching will be their preparation for advanced study and careers in science-related fields. For others, middle school and high school science courses will provide the science literacy they need as members of our technologically complex society. You do not need to choose which group to serve. A well-designed program serves all.

Our experience with SS&C indicates that well-prepared teachers achieve results with this program. A well-prepared teacher knows a few basic ideas well—how science is created and used by scientists and technologists, and how children learn. They also recognize that children learn science by behaving—on a very modest scale—like scientists. They must question, investigate, hypothesize, and reason. As a teacher, you must provide them with opportunities to perform these functions, tolerate the turmoil and uncertainty that is associated with such activities, guide their efforts by suggesting new approaches when progress is slow, and praise them when they are successful.

The strong reliance of this program on student creativity, the emphasis on hands-on investigation, and the self-satisfaction that often rewards careful work, stimulates student effort and leads to improved attitudes toward science and science classes. When students feel better about their work, they tend to work harder and learn more.

Is this all too good to be true? No! When the science course is properly designed and taught, not only do students and teachers feel good about what is happening, but what is happening will serve students well no matter what role in society they eventually will play. Will they do better on tests? Yes, if the tests are designed to measure what we really want them to learn—not facts and terms, but ways to think and reason; methods of discovering facts that matter; and useful ways to use the facts one has learned.

We believe that the principles of SS&C offer guidelines on how to construct a science program that students will enjoy, a program that will convince teachers they are successful because they will be able to measure student growth in conceptual knowledge, in creativity, in measurement skills, in reasoning, and in the ability to apply what is known. In the sections that follow, we explain SS&C principles, supply evidence that some early SS&C pioneers were successful in program implementation, and suggest strategies to use when implementing an SS&C-like program. You will find that SS&C leaders are very willing to share with you all that has been learned about curriculum design, the selection of appropriate instructional materials, classroom teaching, and the assessment of student progress.

What We Believe

Curriculum Design

We believe that SS&C curriculum should include concepts from every major science discipline—biology, chemistry, Earth science, and physics—spiraling to higher levels at each grade level, K–12. We believe that this design is superior to a curriculum that features a single science discipline, such as biology or chemistry for an entire year, for several reasons:

The science disciplines are strongly interrelated. If each discipline is taught independently, students may fail to recognize that many principles play a major role in all science disciplines, and that some areas of study, such as genetics, require a collective knowledge of concepts that were traditionally taught separately in biology, chemistry, and physics courses.

Topics should be taught in a manner compatible with the student's stage of intellectual development. It is unlikely that abstract concepts of biology, such as gene regulation of protein synthesis, can be understood by the average 10th-grade student. It is unnecessary to postpone the fundamental concepts of physics, such as density, until students have the mathematical sophistication characteristic of a 12th grader.

Most students terminate science study after 10th or 11th grade. These students may be better prepared for life if they had fundamental knowledge of the physical and biological sciences instead of credit for a year or more of biology and no exposure to the basic ideas of physics.

In a given year, the science topics studied by students should be coordinated or integrated. SS&C defines a science course as integra' .d if the topics are selected because of their int :insic interest, or because they require an interdisciplinary approach, not because they traditionally belonged to a particular science discipline. Our experience reveals that the integrated science approach works especially well at the elementary and middle school levels.

In contrast, a science course is coordinated if each topic treated is recognizable as a part of physics or chemistry or biology or Earth science, but the collection of topics belonging to a particular course is chosen and packaged to emphasize the interconnections among them. For example, photosynthesis (a topic studied by biologists) might be taught after energy content and absorption characteristics of light (a physics topic) and photoinduced chemical reactions (a chemistry topic) have been covered. We believe this approach can be successful at the senior high school level when it is designed and taught by two or more teachers who have the required diversity of expertise.

We believe that topics should be classified according to the level of intellectual development required for comprehension and sequenced in the curriculum in such a way that the majority of students are capable of mastering the essential ideas when first introduced. We believe that:

■ Students in grades 6, 7, and 8 should be introduced only to topics that are primarily concrete and phenomenological in nature.

■ The majority of students in grades 9 and 10 are ready for quantitative treatments of science topics, provided that the equations represent empirical, rather than theoretical, relationships among the variables that characterize the system under study.

■ Topics that introduce abstract concepts or formulate theoretical models in an effort to understand an observation or to make connections among apparently unrelated phenomena should not be included in the curriculum earlier than grades 11 and 12.

Two important guidelines emerge from these considerations:

■ Restraint must be exercised to avoid introducing unifying concepts, such as plate tectonics, into the curriculum before a groundwork of more fundamental ideas has been laid.

■ Com ... ideas, such as the particulate nature of matter, must be treated repeatedly over the years, each time at a higher level of sophistication than the previous time.

The curriculum should include a modest number of topics that are treated in some depth, rather than more numerous topics, many of which are treated superficially. Even among those who agree strongly with this statement, substantial disagreement exists about which topics should be included and at what depth they should be treated. Most commercial science textbooks, and the science courses that rely upon them, seem to contain too many topics and sometimes fail to treat the topics they include in meaningful depth. These guidelines do—and should—leave room for variations that reflect differences in the goals and resources of individual school districts.

The *National Science Education Standards,* to be released in the fall of 1995 by the National Research Council (NRC), provide a set of general guidelines for curriculum builders.

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Teaching Strategies

We believe that students learn best when they participate actively in the learning process. Student involvement can be achieved in two ways. Students benefit from and enjoy hands-on laboratory experiences. Such activities should become more challenging as the child matures:

- In grades 6 and 7, careful observation of the structures and events of interest to scientists should be the primary activity. Students can also be asked to describe their observations, orally and in writing.

- By grade 8, students can be asked to generalize. What are the common features of this set of objects? In what ways are the behaviors of these two systems similar?

- In grades 9 and 10, students should learn to plan and conduct controlled experiments. How can you hold all but one of the independent variables constant? What happens to the dependent variable when each independent variable, in turn, is increased?

- In grades 11 and 12, students should be encouraged to draw inferences from their observations and propose hypothetical models of how a system works that are consistent with their observations and help to explain them.

We believe that students should have opportunities to influence what topics they study (such as selecting from a list of equally appropriate topics) and how they are studied (e.g., choosing from among library searches, interviewing experts, or conducting experiments when a particular kind of information is sought).

We believe that all class assignments should challenge student ingenuity. Reading assignments can pose questions that need to be answered rather than require the reading of specified passages. Problems can be posed that do not have unique solution paths.

A primary goal of science education is to help students understand important concepts, such as the quantization of atomic energy levels or "survival of the fittest." Technical terms must eventually be learned, but learning them is no substitute for understanding. An SS&C chant to help teachers remember this vital point is "Ideas first; names later."

Assessment of student progress must be conducted in ways that are consistent with course goals and other teaching strategies. We believe that:

- Multiple assessment methods should be used. Student knowledge should not be reduced to a number that reflects scores on objective, paper and pencil tests.

- Because hands-on laboratory work is a major component of student activity, performance assessment should be included among the assessment techniques used.

- Teacher evaluation of student behavior in the classroom and laboratory is a legitimate assessment tool. Assessment methods need not be objective to be valid.

- While paper and pencil tests should play a role in student assessment, tests that measure only the recall of facts and terms are of little value.

Cooperative grouping was not listed as one of the essential features of SS&C when the program was first described by Bill Aldridge (Executive Director of the National Science Teachers Association [NSTA]). However, we have since learned that it is used effectively by many SS&C teachers at the middle school level. Among its virtues are: (1) It fosters cooperation among students that results in bringing different talents to a task and mimics the real world, where science is often pursued as a group endeavor; and (2) Weak students accept help from their peers more readily than from a teacher. While helping the weaker students to improve, the stronger students benefit also as they explain ideas to, and reason with, their colleagues.

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Administrative Issues

We believe that students should not be tracked. When children are beginning their study of science, it is an unknown who will go on to science-related careers. (This belief does not imply that all students be treated exactly alike. Fast learners can be challenged without separating them from the regular, high-quality science class.)

Science teachers need opportunities to upgrade their subject-matter knowledge and to interact with other teachers who are designing curricula, selecting instructional materials, and experimenting with unfamiliar assessment techniques. School administrators should offer an ongoing teacher development program, and encourage and support travel to professional meetings.

Science classes are most effective when conducted partly in a laboratory mode of observation and experimentation and partly in a discussion mode about the results of laboratory work and the relevant concepts. The teacher must be able to change modes whenever student learning demands. Such an arrangement implies the need for (1) a physical layout that accommodates both laboratory and classroom environments, and (2) a class schedule that allows for double periods at least twice each week, or some comparable arrangement that provides for hands-on observations and experiments.

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History of Scope, Sequence and Coordination

Early Visions

Scope, Sequence and Coordination was conceived by NSTA's Executive Director Bill Aldridge in 1989. His article entitled "Essential Changes" outlined the basic idea in the *NSTA Reports*! January 1989 issue. The article stimulated hundreds of letters and phone calls from school administrators and teachers who were eager to cooperate in the testing of this revolutionary curriculum model.

Discussions between NSTA and the National Science Foundation (NSF) staff led to support for three meetings. The description of these events that follows is taken from a report written by the project documentarian, Iris Weiss, President of Horizon Research, Inc.:

> *NSTA anticipated that the changes advocated by the SS&C reform would require substantial funding over a number of years. In March 1989, NSTA submitted a proposal to NSF for $88,930 to conduct a series of planning meetings during the spring and summer of 1989. The proposed meetings included: (1) a meeting to plan an SS&C Advisory Board Conference; (2) an SS&C Advisory Board Conference; and (3) a meeting for a smaller group to begin detailed planning for reform. The objective of these initial meetings was to plan strategy for creating the SS&C model and to develop criteria for establishing reform centers.*

First Stages of Implementation

The first awards aimed at implementation were made by the U.S. Department of Education (ED) in September 1989 to the California Department of Education, Baylor College of Medicine in Houston, and NSTA. The plan called for California and Houston project leaders to work with selected schools in their geographic areas as they designed new science curricula, identified and adapted appropriate instructional materials, and trained teachers to conduct science classes in ways advocated in the Aldridge article. NSTA, meanwhile, worked with textbook publishers and science educators to assist in locating instructional materials to support this radically new curriculum that cooperating schools were beginning to adopt.

From the beginning, the California and Texas sites operated differently. First, there were vastly different numbers of cooperating schools at the two sites. California started with about 100 schools (this number now exceeds 200). In contrast, SS&C staff at Baylor worked initially with three schools. The grade levels at which SS&C was initially implemented also differed. In California, most school districts focused initially on grade 9, though efforts were made at other grade levels by some schools. The three Houston schools introduced the program in grade 7, with the understanding that the new approach would be extended into grade 8 in the second year, and into higher grades in subsequent years.

The major difference between the two sites, however, lay in the locus of decisionmaking authority. In California, each school accepted responsibility for designing and implementing its own curricular reform. The central project staff provided modest funds that allowed the schools to relieve the school planners from some classroom duties, and it organized many opportunities for teachers from the participating schools to interact. In contrast, the Baylor project staff included curriculum specialists who, with help from lead teachers from the three schools, designed curricula and adapted instructional materials that were used at all three schools. Summer meetings and shorter meetings during the academic year were held to prepare the teachers for their new duties. In addition, staff members from the project office visited classes often and helped teachers overcome difficulties, such as the acquisition of essential equipment or the design of appropriate student assessment instruments.

In the meantime, NSTA staff encountered difficulties in fulfilling their commitments. One early idea was that commercial publishers would be eager to help by repackaging existing instructional materials in a format suitable for the multidisciplinary character of SS&C curricula. This hope turned out to be unfounded. Inasmuch as teachers in the California schools and the Baylor staff in Houston were successful in finding suitable materials without assistance from SS&C headquarters in Washington, D.C., NSTA focused its efforts on developing a curriculum development guide. Eventually called *The Content Core: A Guide for Curriculum Designers*, this book suggested topics in each discipline that should be studied at various grade levels, and indicated the depth of treatment and, to some extent, the pedagogical style appropriate for SS&C courses.

Other Major Steps in SS&C Implementation

NSTA leaders knew that SS&C would not receive an adequate trial without additional funding. Therefore, they orchestrated efforts to establish new implementation centers, and turned to NSF for support. Approximately a dozen regions in the United States had indicated a strong desire to test the program; NSTA assisted each of these regions in preparing a proposal to NSF. NSF made 3-year awards in August 1990 to the California Department of Education, Baylor College of Medicine, and NSTA to continue work already begun under the earlier grants from ED. In addition, the University of Iowa, a North Carolina project with leadership on state university campuses at both Greenville and Wilmington, and the University of Puerto Rico received similar NSF grants to implement SS&C in local schools.

Each of these new sites added its own spin to the basic SS&C design. Iowa built on an existing Chautauqua program that was based strongly on science, technology, and society themes. (Chautauqua is an NSF program of support for brief [less than 1 week], intense teacher-enhancement events that focus on single-science topics.) Like California, Iowa placed final responsibility for curriculum design and choice of instructional materials with each individual school. Iowa City project staff did, however, encourage the development of new instructional modules by local teachers, conduct summer workshops for teachers who elected to become part of the SS&C project, and provide considerable guidance in the assessment of student growth. They helped teachers measure not only the learning of science content and processes, but also changes in student attitudes, creativity, and world views.

In Puerto Rico, SS&C acquired several new characteristics. First, science was integrated with mathematics. Second, the courses were taught in Spanish, so instructional materials in that language had to be developed. Third, parents were drawn into the science education process. Puerto Rico is not the only site where parents were kept informed about project goals and procedures, but the doing of science in the home and parent awareness of student enjoyment of SS&C science was better documented in Puerto Rico than elsewhere. As in Texas, materials were developed at a central location, and teachers were taught to use these materials at teacher enhancement sessions held during the summer and on weekends during the academic year.

The major innovation in North Carolina's version of SS&C was an initial focus on grade 6. (Other sites, with only minor exceptions, did not implement below grade 7.) This site developed materials at a central location (Greenville), and chose to adopt a unifying theme for an entire year of work (*Where in the World Are We?* was the theme for grade 6). A major emphasis was put on teacher/teacher and teacher/staff interactions. Summer institutes were led in part by experienced teachers, and—with the help of a statewide emphasis on educational technology—teachers and project staff were linked electronically.

A sixth implementation site, Alaska, was added to the SS&C family when ED supported a request from the Anchorage School District to reform the science education programs in Anchorage and three other school districts in the state. Because this award was not made until late in 1991, Alaska lagged behind other sites in accomplishments, but benefited from the experience other sites had acquired. It adopted an eclectic mix of strategies used at other sites. The management structure can be described as goal setting by the central project office in Anchorage and decisionmaking with regard to curriculum and instructional materials at the local school level. Efforts have been made to develop instructional materials by a team consisting of representatives from all participating schools. However, schools also rely on locally produced materials and even more on imported products, notably *Science Plus* (Atlantic Science Curriculum Project, Harcourt, Brace, Jovanovich) materials.

Formative Evaluation

Each site did collect data of various kinds as part of its commitment to formative evaluation. Although much of this data are interesting and helps to document the program's success (see Appendix A), it is regrettable that lack of uniformity in method from site to site prevents meaningful comparisons, and that little effort was made outside Iowa to establish whether SS&C students learned more science, or learned it better, than students taking traditional science courses.

We stated that the data are eclectic. It is also true that when the data reflect positively on the project, it is not possible to tell what influence, if any, a particular feature of the innovation contributed to the outcome. However, even with these limitations, the data reveal clearly that both students and teachers were, on the whole, favorably impressed with this new science program and benefited in substantial ways from their participation.

All six SS&C implementation sites conducted formative evaluation. Although the evaluators interacted among themselves and an evaluation adviser who had been engaged by the Coordinating Center, site-specific data varied. Only Iowa, North Carolina, and Puerto Rico gathered quantitative information on student gains in subject-matter knowledge and changes in attitudes, as well as changes in teacher behaviors and attitudes. Alaska conducted surveys and interviews that led to qualitative information on attitudes toward the program and toward specific instructional units. California SS&C leaders, having responsibility for the science education of all California students, have much data relevant to reform efforts in their state but little that pertains exclusively to SS&C students. As a result of these differences, the data below are incomplete in every category, and more fragmentary in some categories than others. We have not, of course, included all the available data from any one site in this document; readers interested in some phase of our efforts not reflected in the statements below or the tables in Appendix A, should contact one or more of the project directors for more information.

Impact of SS&C on Students

Iowa. Evaluation of student performance in Iowa reveals that SS&C students perform significantly better than non-SS&C students in the five domains investigated: concepts, process, application, creativity, and attitude (see Appendix A for data).

North Carolina. Sixth and 7th graders enrolled in SS&C classes seemed to have positive attitudes toward science. For example, when given the choices "always true," "sometimes true," and "false" in response to statements about science, only 3 percent of 6th graders and 9 percent of 7th graders responded "false" to the statement: "I enjoy my science class." For most statements, 6th-grade attitudes were more positive than 7th-grade attitudes. For example, in response to the statement "The things we do in science class are interesting," 43 percent of 6th graders marked "always true" whereas the comparable response for 7th graders was 23 percent. Significantly, few students see science as more appropriate for boys than for girls.

Students were also asked to list school subjects they "like a lot" and those they "do not like." Science came out on top of the "like-a-lot" list, though the margin between science and math, which was in second place, was much larger for 6th graders than for 7th graders.

Another North Carolina study explored student perceptions of science class activities. A large percentage of SS&C students answered "yes" to the question "Does your science teacher ask questions that make students think?" The majority of students indicated that experiments involving materials were performed in science class a few times each week, and they also claimed that science activities had been shared with someone at home on several occasions (see Appendix A for data).

The researcher who conducted the North Carolina SS&C studies noted the following conclusion in her report:

> *In the project's second year, students responded favorably. Ninety-five percent of the students enjoyed their science classes at least some of the time. Eighty-three percent felt science is not more for boys than girls, and 96 percent felt the things they did in science class were interesting at least some of the time. Half of the students reported liking science a lot. The next most-liked class was math, at 39 percent. Most students had at least some comfort in sharing ideas with their teams, according to teachers. Sixty-three percent of students reported using materials at least once a week, and 75 percent reported working in teams at least once a week.*

Puerto Rico. Seventh-grade SS&C students in Puerto Rico made substantial gains in such tasks as construction of a graph and units of measurement. More than 95 percent of the SS&C students indicated increased motivation toward science and mathematics. More of these students are now leaning toward careers in science and math, and express preferences toward science and mathematics courses (see Appendix A for data).

Alaska. After participating in SS&C for 1 year, SS&C students in Alaska appeared to experience improved attitudes toward school in general and toward science in particular. Changes in attitude toward science were more significant than toward the overall school experience, suggesting that science experiences may have been central to the change. Attitude changes were greater among students at SS&C schools, and at participating schools, the changes were more significant for the SS&C classes than for non-SS&C classes.

The Alaska study also compared student performance on nine topics among SS&C classes at SS&C schools, non-SS&C classes at SS&C schools, and non-SS&C classes at non-SS&C schools. On eight of the nine topics, students in SS&C classes performed better than the other two groups, and on four of these topics the differences were statistically significant (see Appendix A for data).

Impact of SS&C on Teachers

Iowa. SS&C teachers in Iowa exhibited significantly greater confidence in their abilities to teach science effectively after 1 year of SS&C teaching, whereas non-SS&C science teachers exhibited little change in confidence during the same time period. A study revealed that SS&C teachers teach differently than non-SS&C science teachers. They ask more questions in class, they stimulate more student questions, and they spend less time in front of the classroom and more time working with individual students and small groups. After a year of teaching SS&C science, Iowa teachers reported attending more meetings of science teachers and having more interactions with school administrators and with parents to discuss the science program.

Prior to teaching SS&C science, teachers were asked to list elements that are important to effective science teaching. Less than half included the following elements on their lists:

- Concrete before abstract.
- Societal issues applications.
- Technological applications.
- Coordination of science disciplines.

After a year of SS&C teaching, a majority of teachers included all four of these items on their lists of important elements (see Appendix A for data).

North Carolina. SS&C appears to change teacher behaviors. More than 90 percent of SS&C teachers reported each of the following student activities as important to their current teaching style:

- Developing hypotheses.
- Collecting data.
- Writing about their learning.
- Exploring through hands-on activities.
- Working in cooperative groups.

Control-group teachers also reported using these techniques but in smaller numbers (58 percent to 79 percent). In contrast, only 5 percent of SS&C teachers listed "reading a textbook" as important whereas 74 percent of control teachers did, and 20 percent of SS&C teachers viewed lecturing as important to their teaching whereas 53 percent of the control teachers labeled it as an important technique. The following changes in teaching behavior are those about which SS&C teachers felt most positive:

- Use of hands-on lessons.
- Use of cooperative groups or teams.
- More teacher interaction with students.
- More student activity.
- Use of a variety of student assessment techniques.

(See Appendix A for data.)

Puerto Rico. Evidence about teachers' attitudes has been gathered through questionnaires and indepth interviews. Consistent findings indicate that teachers are enthusiastic about the new curriculum and appear convinced that it is more effective in promoting student learning than the traditional curriculum.

One indicator of the profound changes in teacher skills developed through participation in the SS&C project is that many teachers have assumed a role in disseminating the SS&C curriculum by speaking at teacher training sessions.

Alaska. Teachers in participating schools want to continue teaching in the SS&C program. Seventh-grade teachers described how they changed as teachers, and they attributed an increase in student interest to the emphasis in the SS&C program on teaching all science disciplines each year and to the constructivist approach to classroom teaching.

Impact of SS&C on School Administrators, Parents, and the Community

Iowa. Throughout the 3 years that SS&C has been active in Iowa, steady increases have occurred in the number of interactions between project staff and school administrators. Interactions with parents have also increased. For example, the number of meetings scheduled to discuss SS&C with parents at the various SS&C sites rose from four in 1990 to 10 in 1993, and the number of parents involved directly with classroom instruction more than doubled throughout the same time span. Parents reported that their children appeared more interested in science and that they themselves were increasingly involved in science activities at the school.

Other Iowa studies have tracked the numbers of scientists who are involved in reviewing teacher-generated instructional materials, the number of interdepartmental linkages created within schools to foster integrated curriculum planning, and the number of community actions that resulted from the adoption of an SS&C curriculum. After SS&C was adopted, these numbers increased markedly and continue to increase (see Appendix A for data).

Puerto Rico. Parents have been receptive to the changes that have occurred in their children's science and mathematics programs. They requested, and were granted, opportunities to visit the school and experience some of the activities described to them by their children.

Alaska. Principals in SS&C schools want to continue participation in the project. They observed that 7th-grade science teachers exhibited a renewed interest in teaching, and asserted that SS&C had strengthened the school program. Several principals cited specific examples of changes in the classroom strategies of teachers and also commented on the improved student attitudes toward science classes.

Current Project Activities

SS&C at the middle level is currently in transition. The unified project, consisting of five implementation sites coordinated by NSTA and supported by NSF, has ended. However, various pieces of the middle school project are continuing with new sources of support.

Building on the middle school level of SS&C, NSTA currently is conducting a carefully focused project to develop and evaluate the SS&C program in grades 9–12. The SS&C high school project closely adheres to the basic SS&C tenets. At the same time it is committed to the emerging *National Science Education Standards* currently being developed by the National Research Council of the National Academy of Sciences.

Working with the public draft of the *National Science Education Standards* circulated in November 1994, SS&C project leaders and teachers developed a framework to serve as a guide for implementing SS&C at the high school level.

New Thrusts

A Research Study of SS&C Precepts

As described earlier, each of the six SS&C implementation sites added unique features to the original SS&C middle school design. To a large extent, therefore, the original ideas have not received an adequate test. There is still interest in knowing whether fundamental ideas, like the sequencing of topics from all disciplines according to the student levels of sophistication, make a major impact on how well students learn. The current project is designed for the conducting of a time-lag study that measures the efficacy of the SS&C design in high school science education programs.

A Teacher Center

Although most SS&C effort to date has been invested in teacher enhancement, the majority of these interactions with teachers has focused on future instructional materials and methods the teachers would use in the classroom; little time was devoted to improving the teachers' subject-matter mastery. Yet, it always appeared evident that most middle school teachers are weak in at least one of the major science disciplines, usually physics, and are often completely unfamiliar with recent developments, such as genetic engineering, that are assuming an ever-greater importance in modern science and its technological applications. This need for subject-matter knowledge will only grow as new curriculum standards are widely implemented. SS&C leaders plan to create a Teacher Center that will arrange 4-week summer institutes, each of which will focus on a particular topic for which a need has been established among a significant number of middle school teachers. A need in this context means that the teacher applicant will teach the topic in the near future but did not study it as an undergraduate.

This plan is, we believe, unusual in two respects: (1) The summer institutes will emphasize subject matter. It is true, of course, that a focus on subject matter is a traditional characteristic of summer institutes. It is also true that recent institutes have tended to feature pedagogical issues over content. We intend to reverse that trend. (2) No program will be planned until a need for it has been established. We anticipate that the *National Science Education Standards* will call attention to many topics that teachers cannot comfortably include in their science courses, even though school districts are committed to offering a curriculum that is in compliance with the new standards.

Dissemination of Our Experience With Reforms in Science Education

SS&C has changed the nature of dissemination. In the past, a curricular innovation was embodied in instructional materials. Implementing the reform meant adopting the materials. In contrast, the SS&C reform consists of principles that guide the design of a curriculum, the selection of appropriate instructional materials, and the adoption of pedagogical methods for science teaching in grades 6–12.

Success with a reform based on SS&C principles, therefore, requires guidance from those who understand the principles and have experience in implementing them in school systems. To capitalize on this valuable resource, an effort will be made to bring SS&C leaders together with the leaders of schools that are committed to reform but have yet to take the first steps. Because most SS&C leaders are still working with the original SS&C test schools, this new task becomes feasible only if both efforts—working with the original schools and advising new schools—can be done simultaneously. To make this joint effort possible, the idea of "shadowing" was created. We will identify schools similar to—but geographically not too distant from—the schools already being served. Administrators and teachers in the new schools will be exposed at every opportunity to each phase of what is already happening in the schools that adopted SS&C some years ago.

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Plans for the Future

Materials Development and Adaptation

SS&C was never intended to be a creator of instructional materials. From the beginning, the project leaders were interested in promoting curriculum reform; they believed (with minor exceptions) that an adequate amount of suitable materials already existed. Thus, one task that individual implementation sites—and in the cases of California and Iowa, each SS&C school—accepted early on was to find materials that fit with the topics they had elected to include, and adapt them to local needs and resources. The amount of time devoted to this adaptation process, and the degree to which the activity resulted in materials that are exportable to other sites, varied from site to site.

Puerto Rico. Because SS&C classes in Puerto Rico are taught in Spanish, project leaders were forced to choose between either translating existing materials or developing original materials. Because they had also committed themselves to an integration of mathematics and science, suitable materials were hard to find in any language. As a result, most hands-on activities, and the instruction sheets that describe to teachers how to guide students as they perform these activities, were generated locally by project staff with the assistance of lead teachers. To the extent that students were asked to read textual material, these assignments made use of existing tests. It is important to understand, however, that the SS&C

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approach to learning science relies heavily on the performance of *hands-on* activities and the conclusions that students reach from the results of their observations, and relatively little on reading and memorizing text descriptions of experiments performed by others and facts that resulted from such work.

At this time, materials suitable for use in grades 7 and 8 exist, have been and still are being field tested in cooperating Puerto Rico schools, and are being revised with the help of feedback from SS&C teachers. Translations into English have been completed for some revised materials. Although substantial interest exists in these materials, it is too early to know whether they will be used heavily outside Puerto Rico. The development activity, as described above, will continue at higher grade levels in future years.

Texas. The Baylor College of Medicine staff began a search in 1989 for suitable instructional materials to support their chosen 7th-grade curriculum. The process they adopted involved the piecing together of several related activities into a unit called a block. Seven or eight such blocks constitute 1 year of the science curriculum. Block titles for grades 7 and 8 are listed below:

Grade 7
Environment
Floating and Sinking
Earth and Sky
Hot Stuff
Human Physiology
Inventions
Animal Behavior
Hidden

Grade 8
Streams
Disappearing Acts
Hidden Structures
Envelope of Life
Fueling Around
Parts
Time

While ideas for the various activities were usually borrowed from existing materials, the amount of adaptation required to put these teacher guides into a format judged to be readily usable (with the help that was provided by teacher enhancement events) by Houston middle school teachers was significant. The resulting products are, therefore, a valuable resource. These products are available at a cost (handling only) from SS&C's Texas project office (Division of School-Based Programs, 1709 Dryden, Suite 519, Houston, TX 77030, [713] 798-6880).

Blocks for grade 9 have also been developed and tested once. They are still being revised and retested, and until this procedure is complete, these materials will not be made available for external use. While development of materials for grades 10, 11, and 12 is planned, completion of this task will require funding that is not yet in hand.

North Carolina. Like Texas, North Carolina has developed and tested teacher guides for the early grades of an integrated science curriculum. The North Carolina process, and the products that resulted from it, differ from the process undertaken in Texas for several reasons. North Carolina's first efforts were, and thus the most polished products are, at the 6th-grade level. Also, because North Carolina started a year later than Texas, the amount of well-tested material and testing at any one grade level is less in North Carolina. In fact, the retesting of revised materials is not yet complete, so no efforts have yet been made to market the materials outside of North Carolina.

In addition, the block structure of the Houston curriculum results in noticeable topical transitions when one shifts from one block to the next. For example, while doing the *Floating and Sinking* exercise, Houston students are immersed in physical science concepts such as density and force. When they change to Animal Behavior, dominant concepts are biological in nature.

In contrast, North Carolina is attempting to build an entire year of work on a single theme. There are still transitions as one moves from topic to topic, but these transitions are meant to be more gradual. For example, early in grade 6 when students are first trying to understand *Where in the World Are We?*, the emphasis is on making observations that locate the student's position on Earth. Later, the scope is broadened so that the Earth's position in the solar system becomes of paramount importance.

Teachers who would like to obtain examination copies of North Carolina's grades 6 and 7 materials should contact the North Carolina Project for Reform of Science Education, the School of Education, Speight Hall 154, East Carolina University, Greenville, NC 27858-6172, (919) 328-4260.

Iowa. Because the Iowa SS&C implementation site is one that left details of science curriculum design to each individual SS&C school, University of Iowa project staff have not generated classroom materials.

However, project leaders think of the entire SS&C effort as not only a curriculum reform project but also as a teacher development project. They want the local teacher to remain free of an externally imposed curriculum. Although no State framework currently exists, it is still true that once a textbook has been adopted, the number of decisions a teacher and his or her students must make is few. To overcome this "tyranny of the textbook," project leaders are encouraging the Iowa SS&C teachers to select from a wider variety of resource materials than published textbooks, and to create their own modular units on topics of interest to them and their students.

To produce and test a module that is successful in capturing student interest and also in earning the respect of teacher colleagues is a high-level goal among Iowa SS&C teachers. A typical sequence for an Iowa homegrown module is: (1) The author tests the model's first draft with one class of his or her own students; (2, If the test goes well, the author shares a revised version of the module with colleagues at a meeting of Iowa SS&C teachers; (3) One or more of the colleagues tries the module in an SS&C school in another part of Iowa; and (4) A revised version of the now multiply tested module is submitted to the SS&C Coordinating Center, reviewed by the SS&C Review Board, and distributed to other SS&C implementation sites.

As a result of this process, a dozen or more Iowa modules, and the number is growing, have been tested in more than one school and reviewed for both scientific accuracy and pedagogical excellence. A partial list of module titles are *Weather or Knot; Raindrops Keep Falling on My Head; Black Gold; The Human Machine; Station E.A.R.T.H.; Gone Fishin'; 3, 2, 1, We Have Liftoff; An Invitation To Fly; Crazy Critters; Superman Everyday; Project: Green Thumb; Zapped: A Shocking Experience; The House We Live In;* and *Branching Out.*

Teachers interested in seeing one or more of these modules, or other Iowa-produced modules, should write to The Iowa SS&C Project, Science Education Department, 769 Van Allen Hall, University of Iowa, Iowa City, IA 52242.

The development of materials that support the study of topics in the science, technology, and society area has become a way of life for teachers who interact with the science education staff at the University of Iowa. Future plans call for disseminating this and other SS&C pedagogical practices to other science teachers in Iowa and neighboring States.

California. The design of the SS&C project in California calls for each participating school to design its own curriculum and select its own instructional materials. While some teachers develop some materials on their own, no state- or national-level review mechanism has been created nor is there a plan for testing them in schools other than their places of origin. The norm in California is to either select pieces from a variety of instructional materials or to adopt project materials such as Salter's science textbooks (available from Heinemann Educational in Oxford, England). Because these procedures satisfy California teachers, no plan exists to modify current practice.

Alaska. Like teachers in California, the SS&C's teachers in Alaska, for the most part, plan to adopt project materials; *Science Plus* is a favorite. Interest also exists for teaching environmental science with an emphasis on local themes. To the extent that this interest is expressed, development of modules by lead teachers will be necessary. Plans for such development already exist; sample products should be available soon for review by interested teachers outside Alaska.

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Teacher Enhancement

As stated earlier, SS&C is a set of principles that guide curriculum design, lesson planning, the choices of instructional materials, and classroom teaching strategies. Within each of these categories, options are available to teachers, any one of which could result in a course or an activity completely consistent with SS&C principles. Indeed, SS&C looks very different in Texas than it does in Iowa, and also within Iowa, a difference exists between Davenport and Council Bluffs. How can we be sure, then, that any particular science program is an SS&C program? The answer, of course, is that each SS&C teacher must understand and believe in the essential characteristics of an SS&C program, and know how to plan and deliver a course that is faithful to the SS&C philosophy. Most teachers, with traditional science teaching serving as their only model, need a substantial amount of help when they first implement an SS&C program. Thus, teacher enhancement events, both long (several weeks) summer workshops and short (1- or 2-day) academic-year meetings have been the major mechanism for building a framework within which SS&C can flourish. Teacher enhancement events will also be the primary mechanism as project leaders shift their efforts from testing specific SS&C designs in a limited number of schools to disseminating the SS&C reform among a larger number of schools.

The emphasis of these efforts will differ somewhat among the various SS&C centers.

The NSTA Coordinating Center

The SS&C leaders at NSTA headquarters are dedicated to the movement toward national standards for curriculum design, teacher education, and student assessment. They foresee a rapid acceleration of the science education reform movement when the final *National Science Education Standards* are released. Many schools have wanted reform since 1983 when *A Nation at Risk* revealed weaknesses in the science education program that had become the U.S. standard.

While the intervening decade has seen much activity, it has seen great uncertainty as well about what kinds of changes to make in local science programs. Now that judgments about the science content needed for science literacy, successful teaching techniques, and suitable assessment strategies are converging, schools will begin to implement reforms they have heretofore delayed. Topics will be introduced into science curricula that were previously omitted, omitted in part because the topics are not treated in commercial textbooks and in part because teachers did not learn the relevant science during their preservice teacher training experiences.

Soon, then, teachers will recognize a need to learn science topics that are, in the judgment of scientists and science educators, essential to science literacy and, therefore, appropriate components of the school curriculum. NSTA plans to meet that need by arranging a series of 4-week summer institutes for science teachers at grade levels 6–9. The topics will be selected after a needs assessment makes clear which topics, included in one or more of the new standards documents, have not yet been mastered by significant numbers of teachers. Beginning in 1994, three such institutes will be held in each of 3 successive years. At each site, 50 participant teachers will work with a staff, which consists of one university scientist and two middle school teachers who are widely recognized as successful in managing an up-to-date science program in their home schools. Time will be devoted about equally to (1) A study of the scientific concepts associated with the topic; (2) Hands-on laboratory work related to the topic but selected from activities appropriate for use in middle schools; and (3) A survey of available instructional materials designed for use in the middle schools.

Implementation Sites Dedicated To Testing SS&C at Higher Grade Levels

Building on the middle school level experiences with SS&C, the National Science Teachers

Association is conducting a carefully focused project to develop and evaluate the SS&C program at the high school level. Fifteen high schools having diverse populations and resources are participating in the project. The first year of the project is devoted to teacher enhancement activities and identification of instructional materials. Actual classroom implementation will first occur during the 1995–1996 school year. A time-lag study will be used to show SS&C's effectiveness.

The project closely adheres to the basic SS&C tenets while at the same time conforming to the emerging *National Science Education Standards*. SS&C will be the first curriculum teaching reform that will prepare students to achieve the national standards for science education. Additional information on the schools and the project can be obtained from the SS&C office.

Implementation Sites Dedicated To Spreading SS&C Reform Into New States

The California, Iowa, and North Carolina SS&C sites have developed a plan for helping schools in states neighboring their own to implement an SS&C science program. The plan, relatively simple, consists of three parts:

- Whenever the original site holds an SS&C event such as teacher workshops, teachers from cooperating schools in the new state will be invited to participate, with the costs paid from a teacher enhancement grant.

- Any one of the new schools can secure consulting services on issues of implementation from one of the experienced leaders from an original site.

- All materials that have been developed and tested at an original site will be made available without cost to teachers in the newly reformed schools.

Research

What is the effectiveness of the specific changes that were described in Aldridge's original article as the essence of SS&C reform? Because each of the six implementation sites and the 343 schools that have been testing the SS&C program has designed a version that is unique to the local site, it is not possible to tell whether improvements in the performances and attitudes of students and teachers result from the essential changes that all sites have in common or from one or more of the special features initiated at a particular site. A plan now exists to conduct a controlled experiment that is designed to answer the research question posed at the beginning of this paragraph.

The experimental design calls for approximately 15 schools to implement controlled science instruction to students in grades 9–12. None of these schools has used the SS&C in prior years, though some are located in states that are SS&C implementation sites. The experiment will begin at the grade 9 level, but will be enlarged to encompass higher grades in subsequent years.

At each school, a class will study coordinated science using instructional materials, pedagogical methods, and assessment instruments provided by project staff. Serious efforts will be made to prevent significant variations from the specified course plan. Each school will have at least one control section—a class of students who are initially comparable in ability and science background to students in the experimental class. (Pretests will be conducted to measure how well this is achieved.) The control section will be taught science in whatever way is normal for that school. Subject-matter posttests, attitude questionnaires, and other measures of student change will be administered; the results of experimental and control classes will be compared.

Clearly, the experiment is a difficult one. A major problem will occur whenever the subject matter taught differs for the experimental and control classes. One plan to cope with this difficulty is to use subject-matter tests of general science knowledge—similar to those used for the National Assessment of Educational Progress (NAEP) project—rather than tests designed to match actual course content. As a further precaution, course content for both experimental and control sections will be compared with the science content of the posttest, and an "opportunity to learn" score will be assigned to each class and factored into the analysis of comparisons that will provide the data upon which conclusions will be based. If these precautions are observed, valid—and interesting—results should emerge from this effort.

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Getting Started

Steps To Implement an SS&C-Like Science Program

S*tep 1.* Study the philosophy behind the program. Be sure that school administrators and the majority of science teachers agree with the basic principles behind the reform.

What should one study to learn this philosophy? The quickest way is to read *"Essential Changes in Secondary Science: Scope, Sequence, and Coordination"* in the *NSTA Reports!* January 1989 issue. Reprints of the article can be obtained by writing SS&C, NSTA, 1840 Wilson Boulevard, Arlington, VA 22201-3000.

A more thorough study can be made by reading *The Content Core: A Guide for Curriculum Designers or Relevant Research; Scope, Sequence and Coordination of National Science Education Standards: An Addendum to the Content Core;* and *A High School Framework for National Science Education Standards*, all of which were assembled and edited by staff at the SS&C National Coordinating Center and can be ordered from the NSTA Publications Office at the above address.

Which SS&C principles are controversial? Many of the SS&C principles reflect views on science teaching that are widely held and are thus unlikely to encounter massive opposition. Several of the principles, listed below, have proven more controversial.

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■ Science courses in grades 6–9 should be integrated or coordinated. That is, they should include topics from all the major science disciplines.

Some science educators believe it is preferable to focus on a single discipline for an entire year (or at least for half a year), and then shift to another discipline in a later year. Persons who hold this view usually cite practical reasons to support the position. Here are a few of the frequently cited arguments:

— Textbooks rarely treat multiple disciplines in an integrated or coordinated manner.

— To master science content, it is necessary for a teacher candidate to concentrate on one—or at most, two—disciplines. Preservice teacher education programs do not allow time to do more.

— Colleges expect incoming freshman to have taken two or three science courses from among those traditionally taught at the high school level—Earth science, biology, chemistry, and physics. Multidisciplinary science courses will be viewed by college admissions officers as weak.

These arguments have some merit, but none by itself is persuasive, and, even collectively, do not, in our opinion, outweigh the arguments for reform. Counterarguments for each of these points will be presented in the next section of this booklet.

■ Abstract concepts and theories should not be introduced until grades 11 and 12.

Once one knows a subject well, a tendency exists to present it to others in a general-to-specific order. Statements are made about how some system behaves that encompass all possible examples. Then specific cases are examined that can be recognized as familiar to a beginning student. While this seems like a logical way to proceed, research reveals that students learn best when taught in the opposite way. Concrete examples should be studied first. After many such examples have become familiar, the student will be able to recognize common features, and will appreciate that a generalized statement of these common features is a powerful way to organize his or her knowledge. Thus, our insistence on concrete before abstract is based on solid research.

Even among persons who agree with this teaching order, some will disagree with our plan to teach science phenomenologically through grade 8. Indeed, the age at which a child is first able to grasp an abstraction is something we must learn from experience, and experiences sometimes appear to differ from one observer to another. For example, each physicist we consulted agreed that 8th graders, when taught atomic structure, will memorize the names of the constituent particles and learn to draw circular electron paths about a point nucleus, but they will not formulate a useful concept of what an atom is or when the concept is helpful in explaining countless observations.

In contrast, Earth scientists disagreed about when to introduce plate tectonics. Some felt that introducing it early (7th grade) made it easier to teach about such topics as mountain building or earthquakes. Others felt that students would not be able to grasp the idea of continental plates moving about on the Earth's surface until after they had been exposed to information about such topics as rock formation, densities of various materials, or sources and transfer of thermal energy. The plan recommended in *The Content Core* is a consensus arrived at after consultation with many scientists, science educators, and teachers.

■ Students should not be tracked.

This tenet is one that encounters a large amount of resistance. Two arguments against it are offered frequently:

— The best science students can learn rapidly. They will be held back if mixed with average and weak students.

Our response to this argument is, first, we agree that the best science students need greater challenges than others. However, we believe they can be challenged without separating them from their classmates. Second, even if it is a fact that more can be done for the top students if they are homogeneously grouped, this desirable result cannot compensate for the harm that is done by giving up on the other students. Tracking students into a weak science strand removes any possibility that they will learn enough science to be successful in a science-related career. Since we have good evidence that all students can learn science, it is unconscionable to condemn them before a real opportunity to learn has been provided.

— Future scientists, and college-bound students generally, need to learn much more science, and learn it more deeply, than other students.

This statement is clearly true if one includes the entire educational experience. Specialization, that is, indepth learning of a limited scope of subject matter, must begin somewhere for those students who will, eventually, become experts in an academic discipline. We feel strongly, however, that the high school years—even grade 12—are too early to begin specializing. What is taught in a high school science course—or what should be taught—is essential for science literacy, and everyone needs to be scientifically literate. Our approach will *not* harm the future scientist. Virtually every college science teacher agrees that students make excellent progress in college-level science courses if their background includes a broad exposure to the basic concepts of science that are important to all the science disciplines and to the methods scientists use to study topics that interest them.

Step 2. Design a science curriculum for grades 6–12 or for some subset of those years.

The lead science teachers in a particular school or school district must plan a science curriculum. It is important that several years be planned simultaneously; unless this is done, the benefits of thoughtful sequencing of topics—a major feature of SS&C or any well-designed science program—will not be realized.

Help with curriculum design can be obtained in two ways: First, turn to documents that are designed to provide guidance with curriculum planning. Among recent releases that take an up-to-date perspective on science education reform efforts are these:

- *The Content Core.* Prepared by SS&C project staff and available through NSTA.
- *Scope, Sequence, and Coordination of National Science Education Standards: An Addendum to the Content Core.*
- *A High School Framework for National Science Education Standards.*
- *National Science Education Standards.* Prepared by National Research Council staff and scheduled for release in the fall of 1995.

Second, consult with SS&C staff to obtain additional information about the middle school and high school projects. A second way to obtain information about sites is to talk to the SS&C project director. A letter or phone call to NSTA (see p. 55 for address and phone number) could put you in touch with the author, and a 15-minute conversation could answer many of your questions.

The final curriculum design should be a product of local effort for at least two reasons: (1) Teachers tend to resist reform efforts designed by persons who have no knowledge of the character of their local schools; and (2) A science program will function smoothly only if the schools have the resources—well-trained teachers, instructional materials, and classroom and laboratory facilities—that were anticipated by the program designers.

Curriculum planning takes time and effort. Therefore, school administrators must support those persons selected to design the curriculum by providing released-time or summer salaries. To plan a grade 6–8 program would require the equivalent of four persons working full time for 6 weeks.

The team must be carefully selected and clearly charged. Before the effort begins, it is important that team members understand what is expected of them and express a willingness to cooperate with each other to achieve a clearly stated goal.

Step 3. Identify sources of appropriate instructional materials. This task is not as critical as curriculum planning, because decisions made can be more easily reversed. Nevertheless, whatever decisions are made about instructional materials will greatly influence how teachers and students feel about the science courses affected.

The decisionmaking process will be most satisfactory if conducted in stages:

■ Some preliminary decisions should be made by the curriculum planners. It would be irresponsible to design details of a curriculum, such as when a particular topic will be first introduced, without having established the existence of materials that make it possible to implement the plan. In particular, if some portion of the program is to rely heavily on a particular textbook or set of project materials, this kind of decision needs to be made at the same time the curriculum is designed.

■ Some decisions concerning instructional materials should be left to the teachers who are assigned to teach each course. Teachers will inevitably put their own spin on the way a course is taught. Although it is a good idea to clarify when the course assignment is made that the course must fit into a sequence that has been planned by peers of the individual teachers, the principal making the assignment recognizes that the assigned teacher is a professional who is capable of choosing from among acceptable options to produce the best possible experience for her or his students.

■ To assist classroom teachers with the task of identifying acceptable options, a list of instructional materials suitable for each grade level of the adopted curriculum should be prepared. This task could be assigned to the original curriculum planners, to a committee of lead teachers, or to an external consultant. An invaluable resource for whomever undertakes the task will be the Eisenhower National Clearinghouse, located at The Ohio State University under a contract from ED.

Step 4. Enhance teacher readiness to teach the science courses in the new curriculum. Three distinct aspects characterize a well-designed enhancement event:

■ Teachers need to understand the philosophy that underlies the curriculum design and to hear the school goals for the science education program articulated and rationalized. Change is scary. If teachers do not understand and accept the reasons for change and the intended outcomes of the new program, they will tend to continue doing what has worked for them in the past. Even one or two such teachers can seriously weaken the impact of the new program. Because classroom teaching is an activity that is relatively free of peer review, it is not easy to detect weak links in the chain of science courses. It is imperative, therefore, to bring all teachers on board before the reform is launched.

■ Teachers often need help in learning the science when new topics are inserted into the curriculum. Summer institutes and academic-year workshops are effective mechanisms for upgrading the subject-matter knowledge of teachers. Opportunities for teachers to attend such programs are provided by NSF-supported institutes and by workshops scheduled at meetings of professional societies such as NSTA. However, when a school district initiates a major reform that affects many teachers in several different buildings, the best way to guarantee that teachers are well prepared is to offer a professional development program especially designed for the needs of the local teachers. This can be accomplished in at least two ways:

—Write a proposal to the Department of Education in the home state requesting Eisenhower funds that are allocated to the state by the federal government for such purposes.

—Ask NSTA SS&C staff to design and deliver a workshop according to specifications written by local school administrators. NSTA provides this service at cost. Depending on the length of the event and the number of participants, costs may range from $5,000 to $15,000. Considering that the program would be tailor made to meet local needs and the staff would be experienced implementors of the SS&C program, this investment may prove to be cost effective. It is also true that private foundations dedicated to the support of the elementary and secondary schools in the vicinity of their headquarters will provide support for such events, but requests for such grants must be made well in advance of the event.

■ Teachers need to become familiar with any new instructional materials and teaching techniques imposed on them by the adoption of the new curriculum. Experience has shown that the best way to achieve this goal is to role play. Teacher participants play the role of students, and one or more master teachers hired to conduct the workshop plays the role of teacher. Both classroom and laboratory scenarios should be acted out in this way, but the laboratory work—being the most demanding and least familiar for the teachers—should command the lion's share of the time.

It is not only possible but desirable to offer enhancement events that address all three of the needs listed above. NSF recently made an award to NSTA to design such institutes for middle-school teachers who are engaged in science curriculum reform. Depending on the match between the topics selected for these NSTA institutes and the curricula adopted by local schools, the new series of institutes (nine will be offered over 3 years) could provide exactly what a local school district needs to prepare its teachers for the implementation of a new science program.

Overcoming Obstacles

Negative Attitudes

R***esistance to change.*** The biggest single obstacle to the implementation of any curriculum reform is teacher resistance to change. Administrators should remember that (1) Resistance to change is normal, and teachers who exhibit it may be very good teachers; and (2) One way to overcome this resistance is to keep the teachers not only well informed about planned changes but to involve them in decisionmaking about implementation of those changes as well.

Teachers with a vested interest in the status quo. Teachers may prefer the status quo because (1) They may have helped to plan the existing curriculum and feel reluctant to have it replaced, (2) The existing arrangement may provide a teacher with a position of power that a reform would threaten, or (3) Teachers may believe that the change under consideration will not be an improvement.

The best strategy may be to listen to the concerns of such teachers, but to emphasize the inevitability of change. Every effort should be made to secure their cooperation, even though they may not feel positive about such changes. Recruiting them on planning committees is one way to do this. Perhaps the most effective way to avoid unnecessary problems is to schedule frequent meetings with teachers to provide information about the planned changes, and also to provide opportunities for them to learn the skills that they will need to be successful with the new program.

Lack of Appropriate Instructional Materials

Even SS&C leaders were concerned that the absence of suitable instructional materials would make it difficult or impossible to implement the reform mandated by the SS&C design. Experience has shown, however, that these fears were largely groundless.

Two facts have allowed SS&C programs to be successful, even though it is still true that no existing textbook is ideal for an SS&C course at any grade level.

Success in teaching SS&C does not rely on the existence of a textbook. Instead, teachers use a variety of shorter materials—modules, worksheets, readers, and activities that can be described orally to the students—some obtained from commercial publishers, some prepared by one of the SS&C development staff, and some homegrown by local teachers. Far from feeling disorganized by this eclectic method of acquiring materials that fit the local curriculum design, teachers report feeling liberated from what was in effect, a tyranny of the textbook. Students also appear to enjoy the variety, recognize that what they are asked to read is pertinent to the objective of the lesson, and seem delighted that the reading assignments are of reasonable length and contain little that must be memorized. Only parents appear dismayed that their children do not carry home science textbooks, and they must be assured that real science learning is taking place even in the absence of textbooks.

New materials, often produced under federal grants, that can readily be adapted to the SS&C style of science teaching are becoming available. While some of these have been developed in the United States, materials from Canada and the United Kingdom are also popular among some SS&C teachers. It does take more of an effort to assemble materials from many sources than to adopt a single textbook. However, help is available. Looking to the leaders of SS&C implementation sites for advice is one way to get help. The Eisenhower National Clearinghouse will make it relatively easy to survey existing materials and obtain reviews prepared by subject-matter experts and previous users.

Parent Opposition

Parents are understandably concerned about the education of their children. If curriculum changes appear to them to reduce the probability that students in the new program will be admitted to college or will be successful in their quest for satisfactory employment, parents will often oppose the changes. It is important to communicate with parents at face-to-face meetings and through newsletters. These communications must make several distinct points:

The changes being imposed are part of a nationwide reform movement.

The quality of the new science courses is high. Colleges will not refuse to admit students with these courses on their transcripts instead of the traditional biology, chemistry, and physics courses. (Of course, the school must back up these assertions by contacting the colleges most attended by their graduates to be sure their admissions officers understand and accept the new science courses.)

Courses entitled—or described as—"integrated science" or "coordinated science" are not intrinsically weaker than chemistry or physics courses. The case is not easy to make (often because many parents may remember that in their school days weak students were put into something called "general science"). The nature of these new courses and the reason for teaching multiple science disciplines each year must be explained carefully and, when this is done, parents usually understand and will become advocates of the new program.

Students are learning much that is new to them about science from doing experiments and analyzing their results. The burden of transmitting new ideas to them is no longer carried primarily by textbooks. Also, the teacher is no longer expected to be the repository of all the scientific truth students are expected to learn; rather, the teacher is a guide that helps students learn new concepts through their own efforts.

Concern About Meeting Standards

Many schools, aware of the need to reform, are confused by multiple models that appear to be pulling them in different directions:

State frameworks have been adopted by many states. Sometimes the guidance they provide is quite detailed and thus limits rather severely the freedom a school might otherwise have in implementing a science curriculum reform.

NSTA is urging schools to consider Scope, Sequence and Coordination. *The Content Core* and *The Framework* provide districts with assistance in designing curriculum consistent with the emerging *National Science Education Standards*.

The National Academy of Sciences will soon release the National Science Education Standards. These standards will surely make a major impact on how future science programs are shaped.

School curriculum reformers are asking themselves (1) *Which of these sources of advice should guide our local efforts to reform?* and (2) *Is it possible to design a curriculum that reflects the best features of all these programs?* We believe strongly that the correct answers are *School leaders should be familiar with and think seriously about all of these guides*, and *Yes, the various sources of advice, while not identical, are not fundamentally contradictory.* Of course, the task differs from locale to locale, and is as yet incompletely defined, because the Academy standards are not yet in final form. Even so, we are confident that a school could, if it wished, design a version of an SS&C program that is completely consistent with its own state framework, and with standards promulgated by the National Research Council.

Assessment Practices Must Change as Curricular Goals and Teaching Techniques Are Reformed

Distinct aspects to this obstacle must be addressed separately.

External examinations conducted for accountability reasons. Most teachers are obligated to administer to their students statewide or districtwide examinations designed to determine how well the local science program measures up against those of other schools or against some externally established norm. Sometimes the goals of the external agency that has imposed its standards on the local school are incompatible with the goals of the reform program the school would like to adopt. Even more often, the time devoted to preparation for these exams is viewed by teachers as stolen from activities they feel would better accomplish the objective of teaching students the concepts that would make them scientifically literate. Because it is likely that reform in standardized exams administered for purposes of accountability will lag behind the kind of curricular reform we have been discussing in this article, adoption of a curriculum reform will probably exacerbate both of these problems. School administrators need to communicate with both the external agency that imposes the standardized exam and the local teachers who implement the curricular reform to prevent any mismatch from growing to the point where failure at one end or the other of this tug of war is inevitable.

Paper and pencil tests administered by local teachers to determine what students learn. If course content changes, the knowledge that students are required to demonstrate on an examination must change in a similar way. Less obvious and thus more of a problem is the need to make the style of examinations commensurate with newly adopted teaching methods. For example, if the new science program puts an emphasis on the analysis of information gathered by observation and investigation, it would be inconsistent to design a test that primarily rewards the recall of factual information.

The spectrum of assessment techniques used by the local teacher for the purpose of assigning grades. Psychometricians have successfully spread the myth that the only valid way to measure student performance is with objective tests. Instinctively, teachers know that they can learn a lot about what a student understands by simply watching the way the student works, but they have been told not to rely on such subjective judgments when determining grades.

We do not wish to argue for a grading system that is predominantly subjective. However, we do wish to urge the use of multiple assessment strategies. Objective paper and pencil tests should be part of the arsenal. Teachers should also trust their subjective observations, provided all students are observed systematically and judged consistently against articulated standards.

Other evaluation techniques should be familiar to the teacher and used when appropriate. For example, the heavy emphasis in most reformed science programs on hands-on activities calls for the use of performance assessment in a laboratory setting. Teachers also report that a portfolio can be an effective evaluation tool, one that has the virtues of motivating appropriate student effort and rewarding consistent productivity and improvement.

Tests that determine a student's access to some future educational opportunity or financial reward. The SAT is important to a college-bound student because it may determine whether he or she will be admitted to the college of choice. Other high-stakes tests may have little to do with school curriculum design but nonetheless play important roles in the students' academic careers. Most schools pay little attention to preparing students specifically for such tests, and that is as it should be, in our view. Even so, the school will be criticized if its students consistently perform poorly on such tests. School administrators and teachers need to monitor student performance on such exams and take steps when the students suffer because of a mismatch between the nature of the school curriculum and the demands of the tests. Under the appropriate circumstances, a few possible responses are to (1) Reexamine the local science curriculum to determine if topics omitted are frequently the focus of test items, (2) Organize study sessions designed to help students prepare for whatever high-stakes test is of interest to a significant number of them, or (3) Exert pressure on agencies that administer the tests to restructure them, to be more compatible with the paths being followed by major reform movements. Successful restructuring is possible, because these paths are parallel, as we have noted before, and is already being done by major testmakers such as the Educational Testing Service (ETS).

Appendix A

Statistical Data

Impact of SS&C on Students

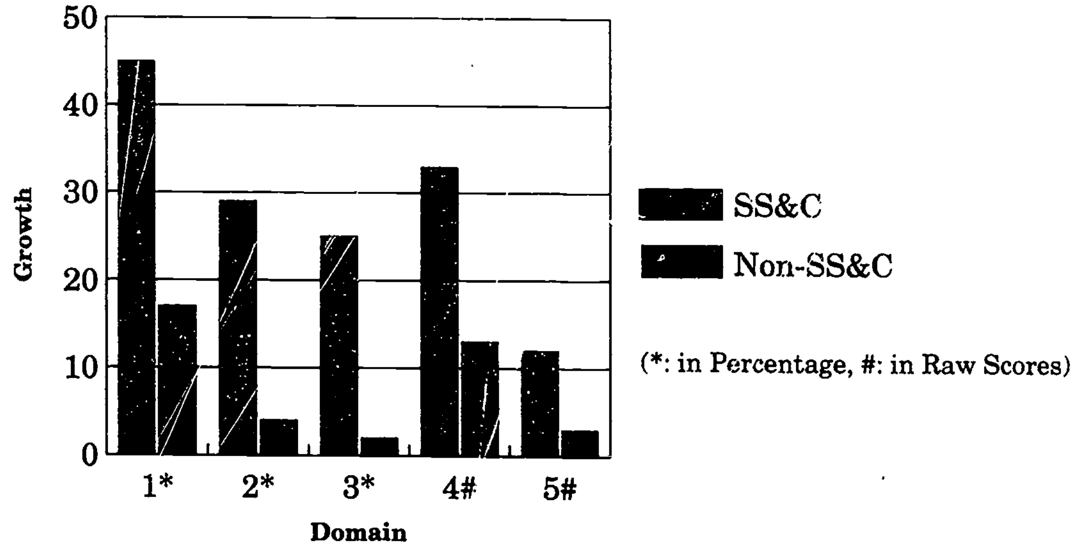
Data From Iowa

Results of Analyses of Covariance[a] (ANCOVA) by Comparing Student Posttest Scores in SS&C and Non-SS&C Classes With the Pretest Scores Used as the Covariate

		SS&C Group			Non-SS&C Group			
Domain	**Grade**	**N**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**F**
Concept**	6	1976	72.3	18.3	429	49.6	14.8	89.7*
	7	1650	73.4	19.2	440	49.3	15.3	92.3*
	8	1644	72.8	17.9	451	50.3	15.2	89.3*
Process**	6	1976	70.8	17.3	429	50.9	16.2	90.1*
	7	1650	72.3	18.3	440	52.4	15.8	82.5*
	8	1644	70.6	17.5	451	52.3	15.3	76.5*
Application**	6	1976	73.4	26.9	429	46.8	16.2	82.3*
	7	1650	74.6	27.3	440	48.6	14.7	80.1
	8	1644	75.3	27.2	451	49.4	15.1	76.5*
Creativity	6	1976	58.9	29.4	429	46.5	15.5	29.4*
	7	1650	57.4	28.3	440	49.1	16.1	30.6*
	8	1644	56.6	27.2	451	52.2	15.8	21.7*
Attitude	6	1976	60.4	16.8	429	50.9	15.9	29.6*
	7	1650	62.1	17.3	440	48.9	16.0	28.3*
	8	1644	59.5	17.0	451	49.3	15.4	20.9*

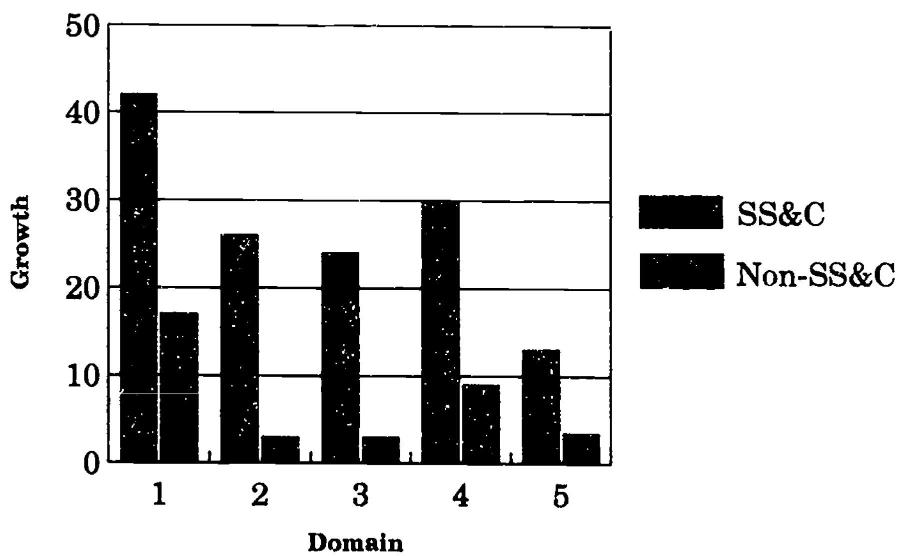
* Significant at the confidence level 0.05
[a] Prior to the Analysis of Covariance (ANCOVA), a transforming formula (Lu, 1993) has been used to meet the assumptions of ANCOVA
** These scores were computed in percentage that is based on the nature of the research design

A Comparison of Learning Growth for the 6th Grade Students in SS&C and Non-SS&C Approaches



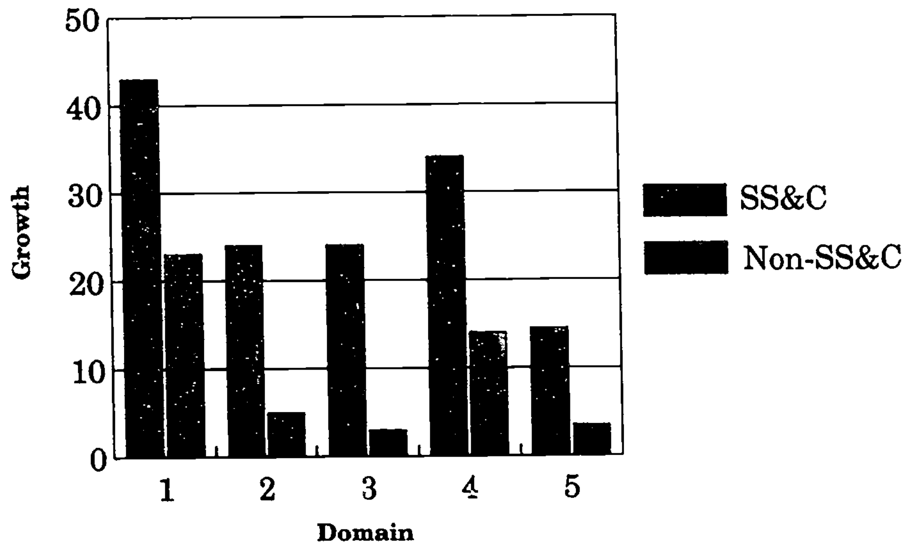
1: Concept Mastery; 2: Process Skills; 3: Application of Science Concepts; 4: Creativity; 5: Attitudes Toward Science

A Comparison of Learning Growth for the 7th Grade Students in SS&C and Non-SS&C Approaches



1: Concept Mastery; 2: Process Skills; 3: Application of Science Concepts; 4: Creativity; 5: Attitudes Toward Science

A Comparison of Learning Growth for the 8th Grade Students in SS&C and Non-SS&C Approaches



1: Concept Mastery; 2: Process Skills; 3: Application of Science Concepts; 4: Creativity; 5: Attitudes Toward Science

Performance of SS&C and Non-SS&C Students in Five Domains When Grouped by Ability

Domain	Non-SS&C (N=445)				SS&C (N=1650)				F1	F2	F3
	High		Low		High		Low				
	Pre	Post	Pre	Post	Pre	Post	Pre	Post			
Concept	7.7	16.2	4.3	10.9	7.9	16.2	4.1	10.6	0.03	0.2	5.3*
Process	5.4	7.1	2.9	3.8	5.6	11.9	3.0	8.1	121.4*	39.2*	22.9*
Application	4.4	7.0	2.2	3.7	4.5	15.4	2.3	10.1	123.3*	44.4*	14.3*
Creativity	84.7	88.4	51.9	54.4	88.1	153.0	2.9	99.6	166.8*	46.3*	3.3
Attitude	16.1	17.4	13.3	12.6	15.8	23.4	12.7	19.3	116.3*	22.4*	15.0*

F1: F values of Analysis of Covariance (ANCOVA) between low ability student posttest scores in SS&C and non-SS&C classes with the pretest scores used as the covariate
F2: F values of analysis of covariance (ANCOVA) between high ability student posttest scores in SS&C and non-SS&C classes with the pretest scores used as the covariate
F3: F values of analysis of covariance (ANCOVA) between high and low ability student posttest scores of SS&C with the pretest scores used as the covariate
* Significant at the confidence level 0.05

Performance of SS&C and Non-SS&C Students in Five Domains Separated Into Male and Female Groups

Domain	Non-SS&C (N=445)				SS&C (N=1650)				F1	F2	F3
	Female		Male		Female		Male				
	Pre	Post	Pre	Post	Pre	Post	Pre	Post			
Concept	5.4	12.5	4.4	11.2	5.2	12.1	4.7	11.4	0.1	0.04	0.4
Process	3.8	4.9	3.7	4.0	3.7	9.1	3.4	8.5	87.6*	76.1*	0.6
Application	2.9	4.8	2.4	3.9	2.9	11.5	2.6	10.9	83.2*	74.6*	0.1
Creativity	63.3	66.3	52.7	55.0	63.5	16.7	153.0	243.0	129.5*	98.5*	0.7
Attitude	12.5	12.6	15.2	14.4	11.3	19.7	15.4	20.6	86.3*	63.4*	82.2*

F1: F values of Analysis of Covariance (ANCOVA) between female student posttest scores in SS&C and non-SS&C classes with the pretest scores used as the covariate

F2: F values of Analysis of Covariance (ANCOVA) between male student posttest scores in SS&C and non-SS&C classes with the pretest scores used as the covariate

F3: F values of Analysis of Covariance (ANCOVA) between male and female student posttest scores of SS&C with the pretest scores used as the covariate

* Significant at the confidence level 0.05

Data From North Carolina

Attitudes About Science—Percentage of Students Who Responded to Questions Concerning Their Attitudes About Science, by Grade

Attitudes		Always True	Sometimes True	False
I enjoy my science class.	6th grade	31%	66%	3%
	7th grade	25%	66%	9%
The things we do are interesting.	6th grade	43%	55%	2%
	7th grade	23%	69%	8%
My science class is boring.	6th grade	5%	43%	52%
	7th grade	12%	54%	33%
I think I am good at science.	6th grade	25%	67%	8%
	7th grade	26%	62%	12%
Science is more for boys.	6th grade	3%	10%	87%
	7th grade	5%	19%	76%

Attitudes About School Subjects—Percentage of Students Who Responded "Like a Lot" to Questions Concerning Their Attitudes About School Subjects, by Grade

Like a Lot	6th Grade	7th Grade
English	32%	26%
Math	39%	39%
Science	57%	41%
Social Studies	33%	31%

Percentage of Students Who Responded "Do Not Like" to Questions Concerning Their Attitudes About School Subjects, by Grade

Do Not Like	6th Grade	7th Grade
English	21%	24%
Math	21%	29%
Science	7%	14%
Social Studies	31%	32%

Program Elements—Percentage of Students Who Responded "Yes" to Questions Concerning Their Program Elements, by Grade

Product Element	Response	6th	7th
Does your science teacher ask students questions that make them think?	Yes	94%	81%
	No	2%	5%
	Don't know	4%	14%
Did you ever do any science activities with someone at home?	Yes, did a lot	23%	5%
	Yes, did a few	64%	55%
	No, didn't do any	14%	39%
How often did you do experiments or activities that involved working with materials?	Every day	12%	6%
	Few times a week	53%	55%
	Few times a month	27%	27%
	Few times all year	8%	11%
	Never	0%	2%
How often did you work in a team with a few other students?	Every day	34%	32%
	Few days a week	44%	39%
	Few days a month	16%	20%
	Few times all year	5%	8%
	Never	.5%	1%

Comfort Level—Percentage of Student Responses to Questions Concerning Their Comfort Level, by Grade

Item	Response	6th	7th
Do you enjoy trying to answer the questions your teacher asks in science class?	Yes, always	18%	11%
	Yes, sometimes	72%	72%
	No, never	11%	17%
If you don't understand something the teacher says, do you feel comfortable asking a question?	Yes, always	40%	48%
	Yes, sometimes	49%	41%
	No, never	11%	11%
When you work in teams, do you feel comfortable sharing your ideas or answers with the students on your team?	Yes, always	52%	48%
	Yes, mostly	32%	33%
	Yes, sometimes	12%	13%
	No, never	4%	6%

Attitudes About Taking Science in the Future—Percentage of Student Responses to Questions Concerning Their Possibly Taking Science in the Future, by Grade

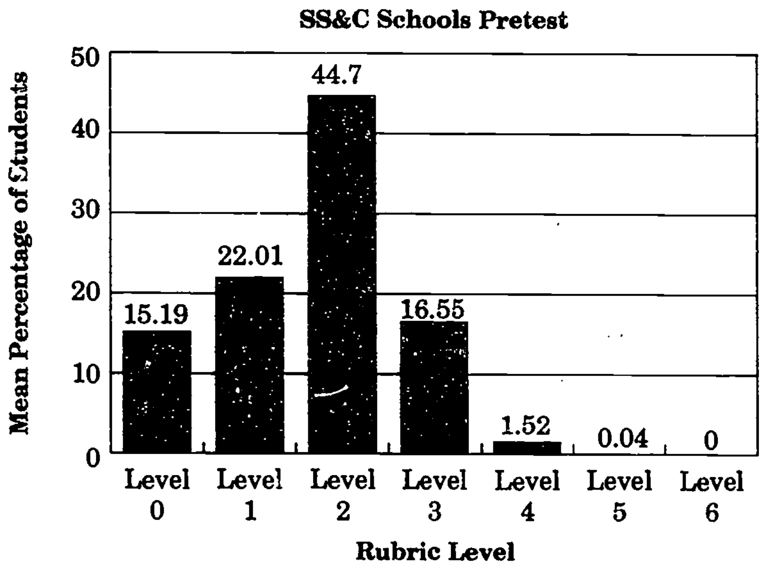
If it was up to you, in high school would you take . . .

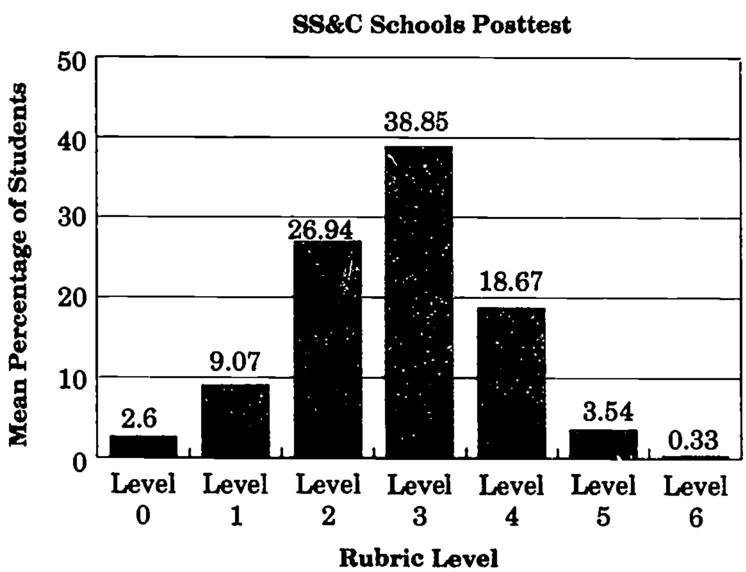
Subject		**Yes**	**No**	**Maybe**
Biology	6th grade	39%	22%	40%
	7th grade	42%	26%	31%
Chemistry	6th grade	61%	15%	25%
	7th grade	60%	16%	24%
Physics	6th grade	28%	29%	44%
	7th grade	29%	35%	36%

Conclusion:
In the project's second year, students responded favorably. Ninety-five percent of the students enjoyed their science classes at least some of the time. Eighty-three percent felt science is *not more* for boys than girls, and 96 percent felt the things they did in science class were interesting at least some of the time. Half of the students reported liking science a lot. The next most liked class was math at 39 percent. Most students had at least some comfort in sharing ideas with their teams, answering teacher questions, and asking questions when they did not understand something their teacher said. Sixty-three percent of students report using materials at least once a week and 75 percent working in teams at least once a week.

Data and Statements From Puerto Rico

7th Grade Open-Ended Questions
Depth on Concept Understanding Science





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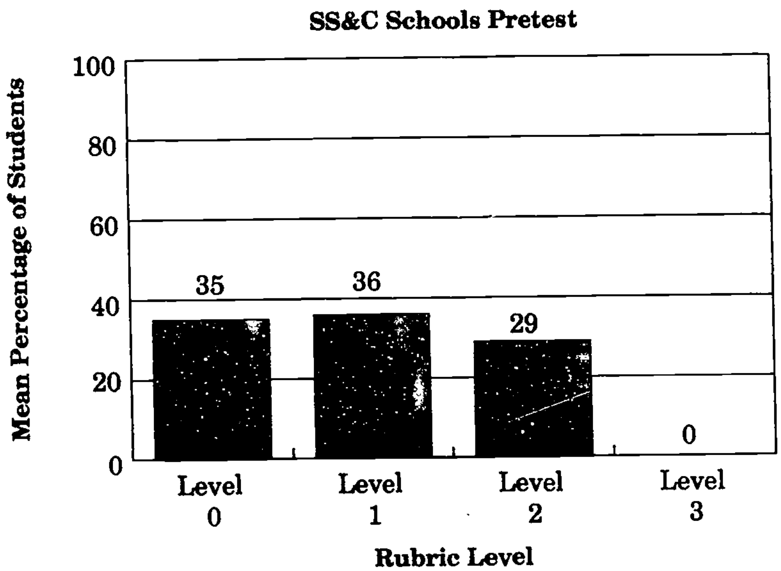
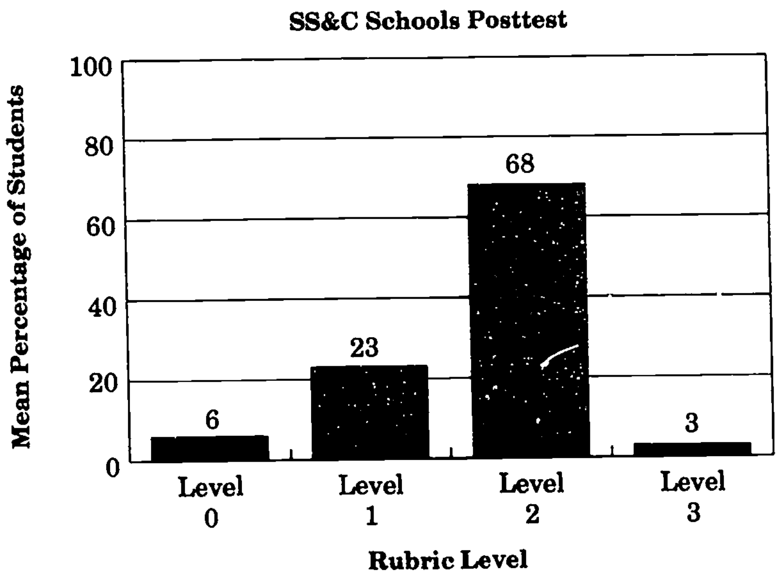
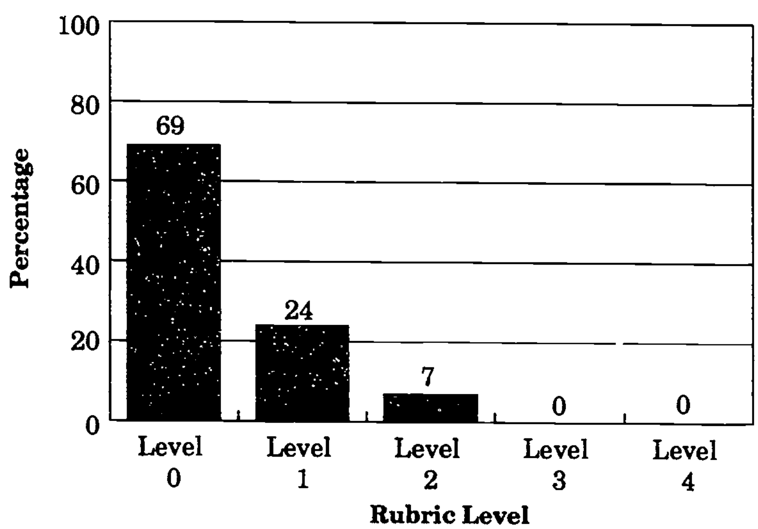
7th Grade Science Performance Assessment Construction of Data Table



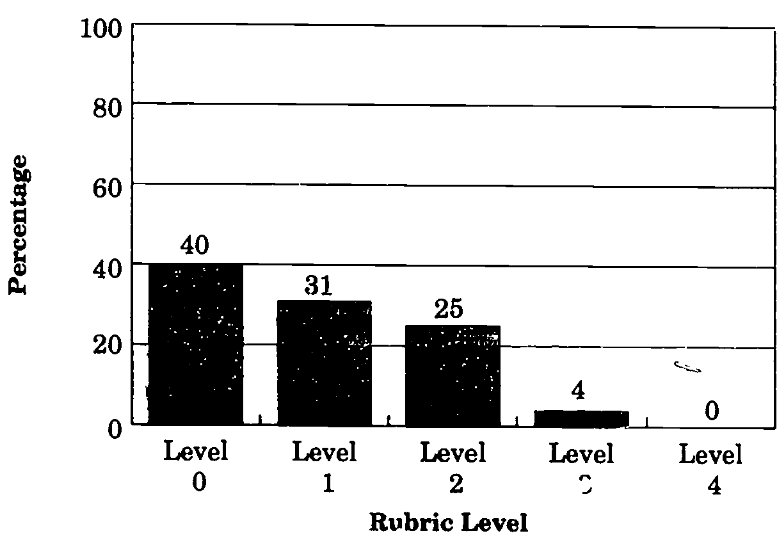


7th Grade Science Performance Assessment Construction of a Graph

SS&C Schools Pretest



SS&C Schools Posttest



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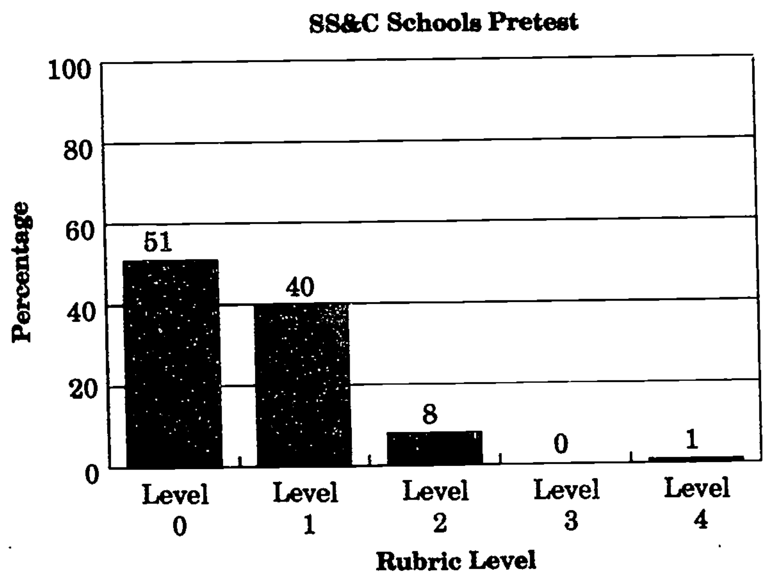
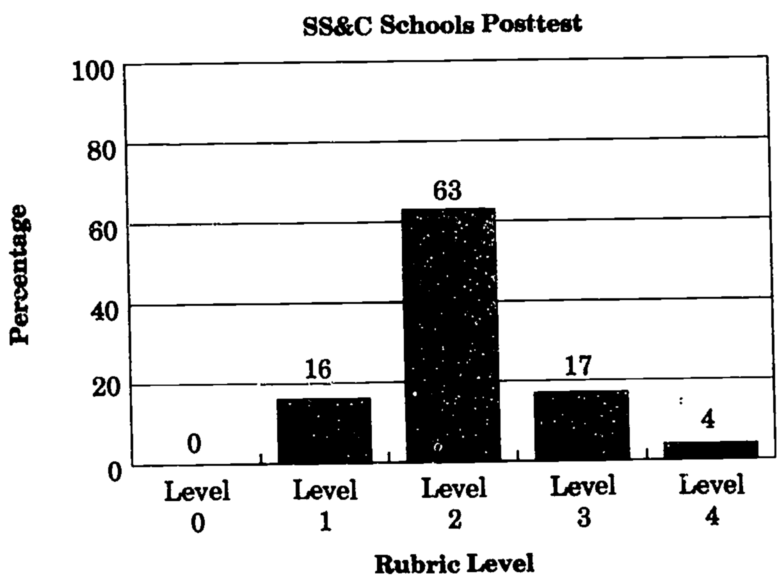
7th Grade Science Performance Assessment Instrument Identification, Units of Measurement, Properties, Area, Volume, Mass, Weight





More than 95 percent of the SS&C students indicate increased motivation toward science and mathematics.

More students are now leaning toward careers in science and math and express preferences toward science and math courses.

Data From Alaska

Student Attitudes Toward Science and School, by SS&C Participation

Group		Average Science Attitude[1]	Average School All[2]
		(N)	
Group	1) S.S.C.	29.38 (443)	20.21 (464)
	2) Non S.S.C.	26.67 (264)	19.63 (276)

[1] (p<.0001, dif.1)
[2] (p<.025, dif.1)

Student Attitudes Toward Science, by Teacher and School

Treatment	Participating Teachers	Nonparticipating Teachers
Participating School	29.90 (346)	28.80 (50)
Nonparticipating School	24.62 (13)	26.53 (87)

Main Effects	S.S.	D.F.	M.S.	F	P<
Place	482.49	1	432.48	11.68	.001
Treatment	12.88	1	12.88	.34	.555

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Achievement—Grade 7, By Participation and Nonparticipation

		SS&C Schools		
	Overall	SS&C Classes	Non-SS&C Classes	Non-SS&C Schools
Force				
Average	5.30	5.95	4.89	4.77*
Standard Deviation	2.09	2.06	2.00	1.98
Number Tested	399	161	172	66
Science Process				
Average	20.69	21.49	20.55	19.09
Standard Deviation	7.25	5.99	8.03	7.74
Number Tested	406	164	176	66
Energy				
Average	1.81	2.03	1.66	1.56*
Standard Deviation	.62	.60	.58	.52
Number Tested	264	120	104	40
Physical Properties				
Average	2.98	3.05	2.92	2.95
Standard Deviation	1.08	1.11	1.06	1.08
Number Tested	278	116	115	47
Astronomy				
Average	2.89	2.98	2.89	2.68
Standard Deviation	.93	.91	.94	.94
Number Tested	349	147	145	57
Earth Science				
Average	2.98	3.04	2.96	2.81
Standard Deviation	1.04	.99	1.02	1.17
Number Tested	193	66	90	37
Water Cycle				
Average	3.18	3.34	3.11	2.90*
Standard Deviation	.82	.78	.77	.95
Number Tested	321	140	131	50
Cell Biology				
Average	2.58	2.80	2.53	1.75*
Standard Deviation	1.08	1.07	1.07	.70
Number Tested	107	45	54	8
Ecological Systems				
Average	2.71	2.48	2.68	2.97
Standard Deviation	.89	.87	.91	.84
Number Tested	83	20	41	22

* Probability greater than 0.05

Impact of SS&C on Teachers

Data From Iowa

Changes in Teacher Confidence to Teach SS&C Science, 1990–93

Grade Level	N	SS&C Group Pretest Mean*	S.D.	SS&C Group Posttest Mean*	S.D.	N	Non-SS&C Group Pretest Mean*	S.D.	Non-SS&C Group Posttest Mean*	S.D.	F
6	48	33.9	3.0	19.3	1.9	20	34.9	2.3	34.7	2.0	120.6**
7	43	34.5	2.8	18.9	1.8	16	35.2	2.1	34.8	1.9	119.3**
8	42	35.1	2.8	20.1	1.9	12	34.2	2.0	33.5	1.9	100.4**

* Based on the nature of the questionnaires, lower means indicate greater understanding of basic science

** Analyses of Variance with Repeated Measures were used to compute the results that were all significant at the confidence level 0.05

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Constructivist Teaching Behaviors[a] Exhibited by SS&C Teachers

Behavior Descriptor	Mean Non-SS&C	Mean SS&C	S.D. Non-SS&C	S.D. SS&C	t-value
Number of Teacher Questions Raised	4.5	15.4	0.8	1.8	26.7*
Time Spent Dispensing Information	18.9	6.1	3.5	1.3	15.8*
Time Spent in Front of Classroom	36.7	15.9	3.2	2.0	21.9*
Time Spent With Individual Students or Small Groups of Students	5.9	32.4	2.6	5.3	23.1*
Number of Student Questions Used to Affect Instruction	0.8	14.9	0.3	3.1	14.8*
Time Spent Using Student Questions for Instruction	3.6	27.5	1.8	3.4	29.4*

* All of these comparisons are significant at the confidence level 0.05
[a] Based on the videotapes recorded in classrooms

All SS&C teachers are encouraged to make video recordings of their teaching to compare their observations with those reported in the table above. Other analyses that provide evidence of the other forms of constructivist practices are routinely identified and discussed.

Teacher Reports of the Impact of SS&C on Their Professional Contacts

Type of Interaction	Pre-SS&C	1990–1991	1991–1992	1992–1993	F
Number of Meetings With Science Teaching Peers Annually*	4.4	21.2	29.8	35.0	20.3**
Number of Planned Interactions With Administrators Related to Science Program	7.1	15.1	17.6	18.8	17.4**
Number of Parental Interactions Annually	24.1	42.3	53.6	66.7	24.5**

Note: N=34
* A meeting = minimum of 2 hours
** Significant changes were computed by Friedman Two-way ANCOVA (Non-Parametric Statistics) at the confidence level 0.05

Elements Rated Most Important for Effective Science Teaching by Iowa SS&C Teachers*

Element	Spring 1992 (%)	Spring 1993 (%)	H
Hands-On Activities	63%	96%	30.7**
Daily Life Applications	69%	96%	28.3**
Concrete Before Abstract	39%	72%	43.2**
Societal Issues Applications	48%	88%	37.4**
Technology Applications	45%	88%	34.2**
Science Disciplines Coordinated	32%	64%	33.5**

* Based on the results of a study done by Horizon Research, Inc. in 1992 with N=55, and a repetition of this study done by the University of Iowa Staff in 1993 with N=25
** Significant changes were computed by Kruskal-Wallis (a Non-Parametric Statistics Approximation to a Chi-Square Test) at the confidence level 0.05

Data From North Carolina

Percentage of Teachers Indicating Their Students Performed Each Activity at Least Once a Week, by Teacher Type

Activity	Project 6th (N=20)	Project 7th (N=13)	Project Total (N=33)	Control (N=19)
Students develop hypotheses	90%	85%	88%	69%
Students collect data	90%	92%	91%	63%
Students write about their learning	95%	92%	94%	58%
Students explore through hands on	100%	92%	97%	79%
Students work in cooperative groups	100%	100%	100%	79%
Students use a computer	21%	23%	22%	5%
Students relate science to societal issues	75%	62%	70%	68%
Students read a textbook	5%	15%	9%	74%
Students read science articles	55%	54%	55%	68%
Students are given at-home activities	35%	0%	21%	21%
Students listen to a lecture	20%	30%	24%	53%

Percentage of Teachers Indicating They Had Made Changes in an Area in the Past 2 Years, by Teacher Type

Area	Project 6th (N=20)	Project 7th (N=13)	Project Total (N=33)	Control (N=19)
Curriculum materials	88%	90%	88%	81%
Instructional methods	88%	83%	86%	94%
Student assessment	63%	85%	72%	50%
Use of technology	50%	83%	64%	63%
Parent involvement	69%	42%	57%	69%
Use of cooperative learning	81%	77%	79%	75%

Top Five Changes Made in the Past 2 Years About Which Project Teachers Feel Particularly Positive

Change	Frequency
Use of discovery/hands-on lessons	14
Use of cooperative groups or teams	12
More interaction with the students	5
More activities	3
Use of different types of assessments	2
Allowing students to be more in control	
Asking better questions	
Use of problem-solving activities	

Statement From Puerto Rico

Evidence of teacher attitudes has been gathered through questionnaires and indepth interviews, and it is consistently found that they are very enthusiastic about the new curriculum and are convinced that it is more effective in promoting student learning in comparison to the traditional curriculum.

An indicator of the profound changes in teacher skills developed through participation in the SS&C project is that many have assumed a major role in disseminating the SS&C curriculum through their participation as spokespersons in numerous teacher training activities.

Statement From Alaska

Teachers in participating schools indicated a desire to continue teaching in the SS&C program. Seventh grade teachers described how they changed as teachers, and they attributed an increase in student interest to the SS&C emphasis on teaching all science disciplines each year and to the constructivist approach to classroom teaching.

Impact on School Administrators, Parents, and the Community

Data From Iowa

Involvement of School Administrators in Iowa SS&C

Year	1990–91	1991–92	1992–93
Presentations at State Administrators Conference	1	3	4
Meetings with all administrators at each site	6	8	8
Visits with administrators in schools	15	22	28
Administrators involved in SS&C meetings (number in parenthesis)	3(10)	6(17)	9(21)
Special mailings to administrators	7	12	16

An Indication of the Involvement of Parents in Iowa SS&C

Year	1990–91	1991–92	1992–93
Special meetings at sites for parents	4	7	10
Parent involvement with classroom instruction	20	32	41
Special mailings to parents	8	14	19
Newsletter with parent focus	1	1	2
Parent involvement as students plan for community involvement/actions	33	46	56

Reactions and Impressions of Iowa SS&C From Parents

Year	1990–91(N=63)	1991–92(N=76)	1992–93(N=82)
More mention of science at home	60	73	79
More collaboration with students on science projects	53	61	65
More involvement in school activities in science	59	72	79
More evidence of learning	50	61	72
Evidence of new interest in science	51	59	74

Scientists Involved Locally and at the State Level for Reviewing Modules

Year	1990–91		1991–92		1992–93	
Area/Grade Level	Local	State	Local	State	Local	State
6th grade	5	9	12	18	15	15
7th grade	5	6	16	18	17	18
8th grade	3	5	10	10	23	20
Above 8th grade	0	4	7	5	12	12

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Indication of Impact of STS Approach at Iowa SS&C Sites

Area	Year 1990–91			Year 1991–92			Year 1992–93		
	1[a]	2[b]	3[c]	1[a]	2[b]	3[c]	1[a]	2[b]	3[c]
Chariton	8	21	12	8	22	14	8	22	16
Creston	6	16	10	6	17	11	7	19	14
Council Bluffs	7	20	5	7	21	8	7	18	10
Davenport	6	23	8	6	26	12	7	30	16
Mason City	6	18	7	6	19	10	6	21	14

[a] Number of other departments involved in the school
[b] Number of teachers involved from other disciplines/grade levels
[c] Community actions arising from STS projects

Statement From Puerto Rico

Parents have been very receptive to the changes that have occurred in their children's performances in science and mathematics. They requested a series of sessions at which they could perform the same activities as their sons and daughters do in SS&C classes.

Statement From Alaska

Principals in participating schools all indicated a desire to continue in the SS&C project. They felt that their 7th grade teachers had a renewed interest in teaching and that the school science program had been strengthened. Many cited positive examples of change in teacher and student attitudes.

Appendix B

Getting Additional Help

Resources

The most valuable resource the SS&C project has to offer others who may be planning or beginning to implement a school science curriculum reform is the experience of its leaders. To obtain information on the availability of consultants and resources to assist in science education reform, contact the SS&C office:

Scope, Sequence and Coordination
National Science Teachers Association
1840 Wilson Boulevard
Arlington, VA 22201-3000
(703) 312–9256/(703) 522-1698 (fax)

The following data pertains only to the middle school project. For additional information you may contact the project directors:

Charles R. Coble
School of Education, Speight Building
East Carolina University
Greenville, NC 27858
(919) 328-6172/(919) 328-4219 (fax)

Thomas P. Sachse
2367 Academic SURGE Building
Division of Education
Davis, CA 95616
(916) 754-8078/(916) 754-8086 (fax)

Linda W. Crow
Baylor College of Medicine
Division of School Based Programs
1709 Dryden, Suite 519
Houston, TX 77030
(713) 798-6880/(713) 798-6899 (fax)

Robert E. Yager
Science Education Center
769 Van Allen Hall
University of Iowa
Iowa City, IA 52242
(319) 335-1189/(319) 335-1188 (fax)

Manuel Gomez
Resource Center for Science and Engineering
University of Puerto Rico
Rio Piedras, PR 00931
(809) 765-5170/(809) 756-7717 (fax)

Robert Nanny
SCI Bartlett High School
Room C222
25-500 North Muldone Road
Anchorage, AK 99506-1698
(907) 269-8343

The Eisenhower National Clearinghouse for Mathematics and Science Education

The Eisenhower National Clearinghouse for Mathematics and Science Education (ENC) is funded through the U. S. Department of Education to provide K–12 teachers with a central source of information on mathematics and science curriculum materials. ENC was established in 1992 through a contract with The Ohio State University and is located in Columbus, Ohio.

ENC encourages the adoption and use of K–12 curriculum materials and programs that support state and national efforts to improve teaching and learning in mathematics and science. It provides better access to resources by creating, maintaining, and cataloging a comprehensive, multimedia collection of materials and programs. The ENC catalog and other products are distributed nationally using both traditional formats and advanced computing and telecommunications technologies. Specifically, ENC provides the following products and services:

■ ENC's Resource Finder is a catalog of mathematics and science curriculum materials from federal government agencies and many other sources. The cataloged materials include print; other media (including video, audio, graphic images, and software); kits; and online electronic resources. Catalog entries include a wealth of information, such as an abstract, cost of the item, and information on availability. The catalog database is available online via Internet and a toll-free number and, beginning in 1996, on CD-ROM.

■ By accessing ENC Online, users can readily obtain a variety of Internet resources, including a database of Federal programs serving mathematics and science education, the ENC catalog of curriculum materials, resources from other education databases, and information and materials on education reform, including this publication.

■ A repository of curriculum materials in Columbus, Ohio, for educators and others to examine the complete ENC collection and a smaller repository, the Capital Collection & Demonstration Site, in Washington, D.C., at The George Washington University.

■ A reference service to answer questions concerning curriculum resources and a technical help desk to answer questions about online access available through the toll-free telephone number.

■ A variety of print materials, including topical catalogs on selected materials in the ENC collection, information about federal programs serving mathematics and science education, informational materials about ENC, and materials about reform in mathematics and science education.

■ Twelve demonstration sites, located in conjunction with the 10 Eisenhower Regional Consortia, at The Capital Collection & Demonstration Site, and at ENC. Demonstration sites provide an opportunity for users to preview the ENC Online Information Service as well as a variety of software and other materials.

■ Beginning in 1996, two CD-ROM collections per year. The first collection will include materials that support education reform, such as curriculum frameworks and information on standards, assessment, and professional development, and the second will make print and software curriculum materials available for classroom use. Each disk will also include the complete ENC catalog and an Internet directory that can be used to demonstrate the benefits of Internet access.

Access to ENC Online Services

The ENC online information service includes the electronic catalog of mathematics and science curriculum materials and a set of Internet resources for K–12 teachers. With a computer and a modem or Internet access, anyone can use ENC Online.

Internet:
With an Internet connection, use the telnet command to connect to **enc.org** and login as **guest**. It is also possible to connect to ENC at **http://www.enc.org** using World Wide Web software. If connecting through the World Wide Web, a login is not necessary.

Modem:
With a modem, dial **(800) 362-4448** for toll-free access. (Although not a toll-free call, (614) 292-9040 also provides access.)
Set communication software to:
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No parity, 8 data bits, 1 stop bit.
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For Additional Information About ENC:
General Information, Reference Service, or Technical Help
Toll-Free Telephone: (800) 621-5785 (voice)
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E-Mail: info@enc.org
Fax: (614) 292-2066
Hours: Monday–Friday: 8 a.m.–5 p.m./ET

Technical Help Desk
Direct Telephone: (614) 292-9590 (voice)
E-Mail: help@enc.org
Hours: Call the toll-free number for hours when the Technical Help Desk is staffed.

Reference Desk
Direct Telephone: (614) 292–9734 (voice)
E-Mail: library@enc.org
Hours: Call the toll-free number for hours when the Reference Desk is staffed.

Mailing Address
Eisenhower National Clearinghouse for Mathematics and Science Education
The Ohio State University
1929 Kenny Road
Columbus, OH 43210-1079

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