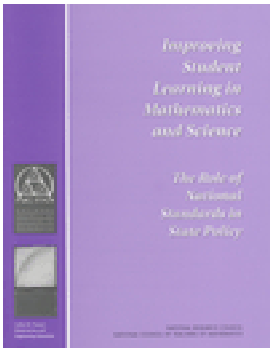

Improving Student Learning in Mathematics and Science: The Role of National Standards in State Policy

National Council of Teachers of Mathematics, Center for Science, Mathematics, and Engineering Education, National Research Council

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Improving Student Learning in Mathematics and Science

The Role of National Standards in State Policy

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National Research Council

A report of the

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and the

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National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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The National Academy of Sciences (NAS or the Academy) is a private, nonprofit, self-perpetuating society of distinguished scholars, engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. The National Research Council (NRC) was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the NRC has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The NRC is administered jointly by both Academies and the Institute of Medicine.

The Center for Science, Mathematics, and Engineering Education (CSMEE or the Center) was established in 1995 to provide coordination of the NRC's education activities and reform efforts. Specifically, the Center engages in activities relating to issues in kindergarten through twelfth grade education, undergraduate education, school-to-work programs, and continuing education, in the disciplines of science, mathematics, technology, and engineering. The Center reports directly to the Governing Board of the NRC.

National Council of Teachers of Mathematics

The National Council of Teachers of Mathematics (NCTM or the Council), founded in 1920, is a nonprofit professional association dedicated to the improvement of mathematics education for all students in the United States and Canada.

It offers vision, leadership, and avenues of communication for those interested in the teaching and learning of mathematics at the elementary school, middle school, high school, college, and university levels. With more than 110,000 members, NCTM is the largest mathematics education organization in the world.

Each year, the NCTM conducts a large national conference and seven to nine regional conferences, where teachers of mathematics and others interested in mathematics education can attend lectures, panel discussions, and workshops and can see exhibits of the latest mathematics education materials and innovations. Many NCTM members are also members of one or more of the 260-plus local and special-interest groups formally affiliated with NCTM that work in partnership with the Council to meet mutual goals. All NCTM members receive Council publications including regular issues of the News Bulletin and Student Math Notes and one or more of four journals: *Teaching Children Mathematics, Mathematics Teaching in the Middle School, Mathematics Teacher,* and *Journal for Research in Mathematics Education.* NCTM also publishes books, videotapes, software, and research reports, which are available for sale to members and non-members.

As a professional association, the NCTM derives its strength from the involvement of its members, who are drawn from the broad community of stakeholders interested in the field of mathematics and mathematics education. The standards documents published by the Council, *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), and *Assessment Standards for School Mathematics* (1995a), shape the Council's vision of mathematics for all children and provide the foundation for much of this publication.

Acknowledgments

I*mproving Student Learning in Mathematics and Science* was originally conceptualized as a modest effort to recount the stories and intended strategies of the National Council of Teachers of Mathematics (NCTM) Standards and the National Science Education Standards developed by the National Research Council (NRC). Through a productive collaboration between the NRC's Center for Science, Mathematics, and Engineering Education and the NCTM, and with the rich and thoughtful input of the expert panels and reviewers, we have produced a substantial set of recommendations for the improvement of state policy, based on national standards.

The development and completion of *Improving Student Learning in Mathematics and Science* mark a number of "firsts" for the Center and the NCTM. At the Center, this is a first experience with the NRC's "principal investigator" model, in which the primary responsibility for intellectual leadership for a report comes from principal investigators, rather than a traditional study committee. For NCTM, this formal collaboration with the Center marks a first joint venture in presenting standards-related issues with another content discipline. The product that has resulted has benefited greatly from being "the first" in each of these contexts.

We owe special thanks to the members of the expert panels who gave generously of their time and expertise in the Reston and Irvine meetings and who undertook with patience and flexibility their roles in a new NRC process. Other experts who reviewed the preliminary draft by mail were most generous and helpful in improving the substance and potential utility of the report. We thank also the staff of the Center and the NCTM and the leaders at NCTM who worked diligently to meet the deadlines of the National Education Goals Panel and to ensure the quality and accuracy of the report. The efforts of Rodger Bybee, Linda Rosen, Jack Price, Paul Trafton, Susan Loucks-Horsley, Joan Ferrini-Mundy, Jeanette Offenbacher, and Kristance Coates are especially appreciated.

Gail Burrill
Donald Kennedy
July 1997

Preface

In Spring 1997, the National Education Goals Panel (NEGP) requested a report on standards-based reform from the Center for Science, Mathematics, and Engineering Education (the Center) of the National Research Council (NRC) and a report from the National Council of Teachers of Mathematics (NCTM). The request stemmed from NEGP's belief that the organizations that developed the national standards for science and mathematics had envisioned strategies for implementing those national standards that could significantly inform NEGP's thinking and planning. The Center and NCTM were asked to focus on implementation of national standards at the state level through mechanisms such as state standards, curriculum frameworks, professional development, and textbook adoption.

Improving Student Learning in Mathematics and Science: The Role of National Standards in State Policy analyzes current efforts in and makes recommendations for state policy. We first provide an introduction to standards-based reform, followed by a strategic framework for designing standards-based reform initiatives. This sets the stage for presenting the activities to date of the national standards in mathematics and science education. The report then offers recommendations for state policy in the areas of (1) ***state infrastructure****;* (2) ***textbooks and other instructional materials****,* including publishers' reactions to the mathematics and science standards; (3) ***curriculum****,* including materials that offer teachers practical guidance for lessons, courses, and school science and mathematics programs; (4) ***teaching****,* including efforts to improve teacher credentialing and licensure; and (5) ***assessment****,* including efforts to develop tests aligned with standards. The recommendations are for state-level policy makers, including governors, state legislators, chief state school officers, state school board members, and state mathematics and science supervisors.

This report draws on the following papers commissioned by NEGP: *Reflections on State Efforts to Improve Mathematics and Science Education in Light of Findings from TIMSS* (Zucker, 1997), *Overcoming Structural Barriers to Good Textbooks* (Tyson, 1997), and *Persistence and Change: Standards-Based Reform in Nine States* (Massell, Kirst, & Hoppe, 1997).

This report represents the first collaboration of its kind between the NCTM and the NRC. Donald Kennedy, Chair of the Advisory Board of the NRC Center for Science, Mathematics, and Engineering Education, and Gail Burrill, President of NCTM, served as Co-Principal Investigators for the project. Staff of the NRC and several NCTM leaders assisted the Co-Principal Investigators in preparing background materials and preliminary recommendations for the report. These materials and preliminary recommendations were examined and discussed by two expert panels and, later, critiqued via mail by other experts. Both panels were convened in May 1997: the first at NCTM offices in Reston, Virginia, and the second at the NRC's Beckman Center in Irvine, California. The expert panelists and mail critics provided advice and suggestions for the final report. These individuals included scientists and mathematicians, policy makers, and educators from every level of the system; they encompassed the educational and policy domains of this report and were chosen with regard to appropriate balance. Individuals who participated in the expert panels and critiqued the preliminary document are listed in Appendix A.

The decision to do this work as a collaboration between the NCTM and the NRC was a natural and beneficial one. The mathematics and science education communities have common goals and a strong relationship that make this a mutually beneficial partnership. Moreover, the recommendations, which cut across the two disciplines, have the potential to help states move significantly forward in their implementation of high quality standards-based education.

Table of Contents

Executive Summary

The National Education Goals-set by the President and the nation's governors in 1989 and endorsed by two presidents, the U.S. Congress, and key business leaders-place a high priority on achievement in mathematics and science by all our nation's students. The national standards for mathematics education developed by the National Council of Teachers of Mathematics (NCTM) and for science education developed by the National Research Council (NRC) have played an important role in helping states address those national goals. This report recommends specific, decisive actions to further state efforts as they guide and support local educators to reform mathematics and science teaching and learning in their schools.

The NCTM's *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), and *Assessment Standards for School Mathematics* (1995a) and the NRC's *National Science Education Standards* (1996a) provide a vision for what students should know and be able to do and what educators need to do to support that learning. At a time when international comparisons have renewed attention to the need for a coherent, powerful direction for science and mathematics education, it is useful to examine how state initiatives can draw from the national standards as they continue their progress in reform.

The NCTM and NRC have pursued a variety of activities to place the national standards in the hands and minds of those across the nation with responsibility for and interest in mathematics and science education. Their strategies are described using a framework that includes:

- ***dissemination*** of standards to key individuals, agencies, and districts;
- ***interpretation*** of the standards, that is, providing background, briefings, examples, and supplementary materials to help individuals gain a deeper understanding of standards and standards-based curriculum and the role of standards in educational improvement;
- ***implementation*** of changes in curriculum programs; in criteria for selection of textbooks; in recruitment, certification, and continuing education of teachers; and in state and local assessments of students' progress;
- ***evaluation*** of changes to monitor and adjust policies, programs, and practices to increase their impact; and
- ***revision*** of the standards in response to changing needs and data on their impact.

The strategies used by the NCTM and NRC have established a national foundation for state reform initiatives, which have taken as many directions as there are states, and made steady progress towards the goal of standards-based education. But the task does not end with national standards. There is substantial progress yet to be made, and realizing the goals described in national standards is now in the purview of state governments. Given their constitutional responsibility for education, the states must act vigorously, in order to ensure widespread implementation of standards-based education. This report suggests that the progress currently being made should be continued and, indeed, strengthened in the specific areas of curriculum, textbooks and other instructional materials, teaching and assessment, and building the infrastructure for improvement within states. The following recommendations are offered to state-level policy makers, including governors, state legislators, state school boards, chief state school officers, and state mathematics and science supervisors:

1. STATE INFRASTRUCTURE

Strengthen the state infrastructure for improvement in mathematics and science education with coherent, focused standards and with the policies, structures, and resources to support their achievement.

1-A Develop high standards for all students, through consensus, including a process for periodic review.

1-B Build a coherent system for mathematics and science education within the state in which every component and level of education is aligned and has a common goal: that all students will meet these high standards.

1-C Establish a long-range plan for improvement that involves the broader community as well as mathematics and science educators and provides sufficient support for local educators as they work to implement the standards.

1-D Ensure that state-level leadership positions in mathematics and science education exist and are filled by staff with expertise in the disciplines and in supporting change.

1-E Provide guidance and policy support to districts and schools in restructuring the use of school time to create opportunities for teachers to work together for improvement of mathematics and science education in their system.

2. TEXTBOOKS AND OTHER INSTRUCTIONAL MATERIALS

Develop policies and strategies that promote the use of standards-based textbooks and other instructional materials and that build state and local capacity for selecting and using the materials appropriately.

2-A Implement state policies that support the development of selection criteria for instructional materials based on standards and consistent with curriculum frameworks.

2-B Commission evaluations of textbooks and other instructional materials and disseminate results to local adoption committees.

2-C Implement professional development programs that help school personnel effectively select textbooks and other instructional materials and integrate them into the science and mathematics curriculum and instructional practice.

3. CURRICULUM

Structure policies and support to focus districts and schools on designing science and mathematics curricula that are high-quality, well-articulated, and standards-based.

3-A Provide technical, financial, and material support to local districts for the design and implementation of programs in which all students have opportunities to meet standards for mathematics and science.

3-B Base high school graduation requirements, university placement tests, and university admission requirements on standards.

3-C Put in place in every school classroom new technologies that support standards-based teaching and learning of mathematics and science.

4. TEACHING

Create policies and practices to ensure that well-qualified, highly competent teachers, whose *practice is grounded in the mathematics and science standards, are in every elementary school, mathematics, and science classroom in the state.*

4-A Accredit only teacher preparation programs that reflect the recommendations of mathematics and science standards.

4-B Incorporate as a requirement for licensing that teachers demonstrate teaching practices that are based on standards and are appropriate to the particular learning situation.

4-C Support the continuing professional development of accomplished teachers through mechanisms such as the National Board for Professional Teaching Standards.

4-D Fund ongoing, high-quality professional development opportunities for teachers of science and mathematics based on standards for student learning and professional teaching.

5. ASSESSMENT

Establish testing and assessment programs consistent with the goal of high expectations for all students to learn standards-based mathematics and science.

5-A Ensure that assessments of student learning are aligned with standards-based curriculum and assessment principles.

5-B Develop at the state level, or encourage local districts to develop, strong accountability systems that go beyond single-measure tests.

5-C Collect and use information about learning conditions and the opportunities students have to learn.

5-D Assist schools and the general community to understand and use the results of assessments and develop action plans based on results.

5-E Promote teacher assessment and student self-assessment in classrooms, based on standards.

These recommendations represent some ways to blend the experiences and strategies of the NCTM and NRC, as developers[1] of the national standards, with those of the states, as the nation moves towards its goals of high achievement in mathematics and science for all students. The magnitude of the task of reform cannot be overestimated, nor can its potential benefit to our nation's youth.

[1] Throughout this report we have used the term "developer" as an abbreviation for the role that the NCTM and NRC played in the national mathematics and science standards, respectively. The intent is neither to indicate nor to imply that these organizations or their staffs developed the standards themselves. Instead, as described at length in the discussions of the development and dissemination of the standards documents, these organizations orchestrated the work of thousands of individuals and groups who contributed to the development and critique of the standards.

Introduction

National Standards for Mathematics and Science Education

The American public recognizes the critical importance of education and the need for improving student learning. That same public places great confidence in the education they experienced and sometimes questions contemporary innovations, such as standards, activity-based curriculum, technology, and performance assessments. As society examines the values, processes, and problems of popular education, a particular hallmark of the period since the 1980s has been standards-based reform.

ORIGINS

Major reports dating from the turn of the century have had significant influence on mathematics and science education. However, prior to the mid-1980s, there were few instances of professional organizations of K-12 educators producing anything as far reaching as a set of "national standards" for school curriculum and practice in a particular content area. In 1986, the Board of Directors of the National Council of Teachers of Mathematics (NCTM) recognized a convergence of forces leading to a need for new directions in K-12 mathematics education. The demands of the information society and new societal goals for education, including mathematically literate workers, lifelong learning, opportunity for all, and an informed electorate, provided the impetus for the creation of three standards documents in mathematics. These were the *Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989); Professional Standards for Teaching Mathematics* (NCTM, 1991); *and Assessment Standards for School Mathematics* (NCTM, 1995a), hereafter called NCTM Standards. The standards documents promote the mathematical empowerment of all students through the creation of curricula and learning environments very different from what had been current practice. A history of their development can be found in McLeod, Stake, Schappelle, Mellissinos, and Gierl (1996).

In 1991, the National Research Council (NRC) was asked by the president of the National Science Teachers Association (NSTA) to coordinate efforts to develop national standards for science education. Between 1991 and 1995, the NRC produced several drafts of the standards and set in motion a process designed to develop national consensus for the standards. The NRC's *National Science Education Standards* (1996a), hereafter called the NRC Standards, present a vision of a scientifically literate populace by outlining what students need to know, understand, and be able to do after 13 years of school science. The NRC document also contains standards for teaching science, professional development of teachers, assessment, science content, school programs, and the educational system. Collins (1995) has provided a history of their development.

COMMON FEATURES

The mathematics and science standards have a number of features in common:

— They emphasize ***all*** students; that is, explicit statements of equity permeate the documents.
— They emphasize ***understanding***, that is, students must comprehend the material they study and not merely memorize a series of facts.

— They focus on developing a ***depth of knowledge*** about fundamental mathematical and scientific content and processes.
— They include ***content, teaching, professional development, and assessment****;* that is, they recognize the need to define more than what students should know and be able to do.
— They emphasize ***content more than curriculum****;* that is, the documents do not define the order, structure, and organization of school mathematics and science programs. Curriculum decisions are left to states and local school districts.
— They emphasize a ***comprehensive, focused, and coherent approach*** to mathematics and science education.

National standards reflect the consensus of experts from around the country, at the time of standards development, about what students should know, understand, and be able to do in mathematics and science and propose educational approaches. The national standards documents were developed by the professional communities of mathematicians, scientists, educators, and teachers, with extensive input and review. They are intended to suggest strategies for the improvement of mathematics and science teaching and learning in the K-12 arena. Research about mathematics and science teaching and learning guided the standards development (NCTM, 1991; NRC, 1996a; Romberg, 1992; Schoen, 1988). The documents represent valued goals; measures of their effectiveness will be available only after the idea of standards is widely accepted and enacted.

It is important to note that the NCTM Standards are under revision, with release of the revised document scheduled for the year 2000. This revision was part of the original plan for the development of the NCTM Standards and will preserve the spirit of the original documents. There is ongoing discussion in the mathematics and mathematics education communities about the important details of this revision.

A Strategic Framework for Standards-Based Reform

Developing national standards is an important and complex undertaking. Yet, once these standards are developed, they do not immediately influence policy and practice. Research on dissemination and change clearly indicates that actions by many individuals and organizations are needed if meaningful and lasting changes are to occur in a system (Hutchinson & Huberman, 1993). And, the larger the system (e.g., the nation vs. a school), the larger and more coordinated the effort needs to be. The framework provided in this section is intended as an organizing tool for considering how standards-based reforms can be undertaken by a system (Bybee, 1997).

Similar to many models for change and improvement, the Strategic Framework for Standards-Based Reform (see Figure 1) has several different dimensions, and each dimension has particular goals. In the framework, the developer of the standards plays a role, as do other participants in the education system. For example, national organizations such as the National Research Council (NRC) and the National Council of Teachers of Mathematics (NCTM) played a major part in initial dissemination of the national standards, but they do not implement the standards. The framework is intended as an organizer for thinking about what strategies are needed and for clarifying where responsibility and authority lie for making changes in the various components of the educational system. Although the framework is designed as a means of thinking about national standards, it is equally appropriate as a means of thinking about state standards.

Dissemination involves developing a general awareness of the existence of the standards document among those responsible for policy making, programs, and teaching. It includes addressing the questions, "What are the standards?" "Why are they needed?" and "How could they be used to shape policy and practice?" ***Interpretation*** is about increasing understanding of and support for standards. It involves careful analysis, dialogue, and the difficult educational task of challenging current conceptions. Deeper and richer understanding of standards is the goal. ***Implementation*** involves changing policies, programs, and practices to be consistent with

FIGURE 1. A Strategic Framework for Standards-Based Reform

Dissemination	Goal: Developing Awareness	"Getting the word out"
Interpretation	Goal: Increasing Understanding and Support	"Getting the idea"
Implementation	Goal: Changing Policies, Programs, and Practices	"Getting the job done"
Evaluation	Goal: Monitoring and Adjusting Policies, Programs, and Practices	"Getting it right"
Revision	Goal: Improving the Efficacy and Influence of Standards	"Doing it all again"

From: Bybee, R.W. (1997). *A strategy for standards-based reform of science and mathematics education.* Unpublished manuscript.

standards. People modify district and school science and mathematics curriculum, revise criteria for the selection of instructional materials, change teacher credentialing and recertification, and develop new assessments. Enacting new policies, programs, and practices builds new understandings that can feed back into interpretation. In the *evaluation* dimension, information gathered about impact can contribute directly to improvement. Monitoring of and feedback to various parts of the system result in an evolution of policies, programs, and practices. At some point, as a planned element of the process, *revision* of standards occurs, incorporating the new knowledge developed through implementation and evaluation and drawing heavily on input and discussion generated in the field by the original documents.

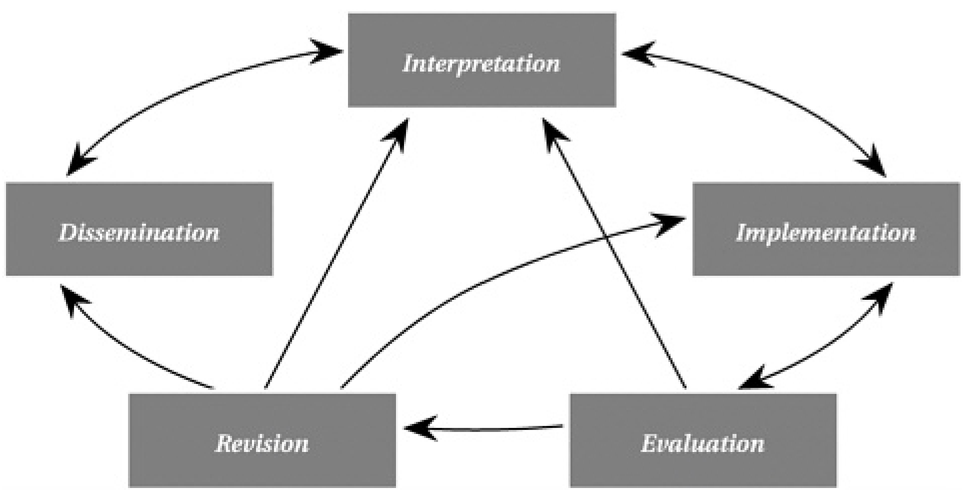
There exists some logical sequence to the dimensions. For example, people need to become aware of standards before they deepen their understanding through interpretation activities. Likewise, implementation without understanding can lead to change that is mechanical, superficial, and-in the extreme--can imperil reform with the dismissal that "it doesn't work." Effective implementation requires interpretation and understanding. Revision without adequate evaluation will not reflect what is learned from the original effort.

Note, however, that while the framework may seem linear, its dimensions are intertwined. For example, since practice informs understanding, implementation can lead to a new or deeper interpretation of the standards or elements of them. Evaluation and reflection pervade all other dimensions. Figure 2 attempts to capture the simultaneously cyclical, iterative, and nonlinear nature of the framework's dimensions.

The different dimensions of the framework are played out with different audiences, as shown in Figure 3 (Bybee, 1997). These audiences are organized into four categories that reflect each audience's primary role in the system: policy, program, practice, and political and public support.

The framework helps to address the question of how different stakeholders participate in standards-based reforms. Creating a matrix using the different dimensions on the horizontal axis and the possible participants on the vertical axis, activities can be arrayed in the cells. For example, an *interpretation* activity for *colleges*

FIGURE 2. Relationships Among the Dimensions of the Strategic Framework



and universities could be the development of an addendum that focuses on the role of inquiry in the NRC Standards. The addendum would help postsecondary faculty and administrators understand the standards more deeply so they could improve the design of their teacher preparation programs. Not all participants need to be engaged in every dimension. Some audiences, such as the general public, might be made aware of the standards with no further engagement. Although many audiences can be involved in many dimensions, the challenge of standards-based reform is to strategically engage the key participants in such a way as to create the most leverage for change in the system.

Although the developers of standards likely have major responsibility for dissemination, they can be assisted by state agencies, special coalitions, or cadres of leaders especially equipped to do so. Responsibility and authority for implementation do not necessarily lie with the organizations that developed standards. The organizations can provide support and expertise, as well as help in networking various implementers, but they are not always positioned to change policies and practices directly. State supervisors, curriculum developers, teacher educators, and classroom teachers assume major responsibility for implementation. Revision again becomes the responsibility of the developers, with substantial input and interaction with others in the system.

In the next section of this report, we use dimensions of the Strategic Framework to describe the strategies that the NCTM has used to support the NCTM Standards and to describe what directions the organization is now taking. The strategies planned and launched by the NRC's Center for Science, Mathematics, and Engineering Education (the Center) in light of NCTM's seven years of prior experience with national standards are described in the following section. Note that NCTM is a professional association of more than 110,000 members, with affiliated groups, an ongoing structure of conferences, and a large publication enterprise. The Center, as a unit of the NRC, works through its boards and committees of volunteers, together with staff, to advise in policy areas. The organizations are different in structure, mission, and scope of activity, and their strategies differ accordingly.

FIGURE 3. Participants in Standards-Based Education

Policy	Governors and State Legislators State Education Departments State and Local School Boards School Districts Schools
Programs	Colleges and Universities Publishers Curriculum and Assessment Developers School Districts Business and Industry Informal Educators Professional Organizations
Practices	Teachers Students
Political Support	Scientists and Engineers Business and Industry Federal, State, and Local Governments Parents General Public Teacher Unions

Adapted from: Bybee, R.W. (1997). *A strategy for standards-based reform of science and mathematics education.* Unpublished manuscript.

NCTM and the National Standards for Mathematics Education

The mission statement of the National Council of Teachers of Mathematics (NCTM or the Council), developed in 1995, centers on standards:

> *The mission of the National Council of Teachers of Mathematics is to provide vision and leadership in improving the teaching and learning of mathematics so that every student is ensured an equitable Standards-based mathematics education and every teacher of mathematics is ensured the opportunity to grow professionally.* (NCTM, 1995b)

The NCTM Standards evolved over several years, beginning with the 1980 report *An Agenda for Action* (NCTM, 1980), an important precursor to the NCTM Standards documents. A set of events and circumstances took place in the 1980s that spurred the need for standards and for national direction in mathematics education. The education directorate at the National Science Foundation (NSF) was eliminated in 1982. *A Nation at Risk* (National Commission on Excellence in Education, 1983) called for broad reconsideration and reform of the U.S. education system. Also, recommendations for standards and the need for national guidance for mathematics education emerged out of the Conference Board on the Mathematical Sciences, leading to the founding of the Mathematical Sciences Education Board (MSEB) in 1985 at the National Research Council (NRC). Internal work at NCTM was also pointing toward a need for direction (McLeod et al., 1996). In 1986, the NCTM Board of Directors commissioned the first of the three sets of standards, the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). The development of the document was funded entirely with NCTM resources.

The *Curriculum and Evaluation Standards for School Mathematics* was conceived as a vision of ideal practice and developed by a committee of NCTM members who thought carefully about the issues on behalf of the field. The decision to produce three separate standards documents reflects the understanding of the NCTM leadership that it was important to work on all parts of the educational system. A major aspect of the development process was consensus building across the country and across all dimensions of the mathematics education community. A 1987 draft was circulated to 10,000 members of NCTM; input was sought through professional meetings, regional affiliated groups, and NCTM's internal committees. The input was seriously considered and analyzed as the *Curriculum and Evaluation Standards for School Mathematics* was prepared. The resulting document carried the endorsements of a large number of professional organizations, although the entire concept of "standards" was new to the field at the time, so it is difficult to know how endorsement was construed. After the document was released, activities centered on the dissemination, interpretation, and implementation. These were coordinated by an NCTM Standards Coordinating Committee that provided oversight for the Council's activities.

The MSEB, chaired in the late 1980s by Shirley Hill, a past president of NCTM, was an important collaborator with the NCTM in the standards process. In particular, the publication of Everybody Counts (NRC, 1989) is often credited with effectively making the case for the need to improve mathematics education with a broad range of audiences-and thus helping to set the stage for openness to the NCTM Standards in a wider arena.

DISSEMINATION

Dissemination of the NCTM *Curriculum and Evaluation Standards for School Mathematics* has taken many different forms. The document was provided free to all NCTM individual members and sold by the organization. As of June 1997, NCTM has distributed or sold over 647,000 copies of the Standards documents.[2] An executive summary of the *Curriculum and Evaluation Standards for School Mathematics* was prepared and distributed to members of Congress, governors, university administrators and mathematics department chairs, school principals, PTA presidents, and school board chairs. Separate flyers were prepared for parents and policy makers as well as teachers and a general audience. A public relations firm was engaged to promote the release of the document. NCTM leaders received "public relations" training. The Council produced a kit which included speaker's guide that included a video of prominent individuals, such as musician Wynton Marsalis explaining the importance of mathematics and the NCTM Standards.

The NCTM cooperated with other groups in dissemination. The Association of State Supervisors of Mathematics (ASSM) undertook "Leading Mathematics Education into the 21st Century," a joint project of the ASSM, NCTM, National Council of Supervisors of Mathematics (NCSM), Council of Presidential Awardees of Mathematics, and the MSEB. The project involved five regional conferences across the country, at which NCTM leaders and standards writers made presentations about the document to the participants, who were then expected to return to their local areas as teams and do further dissemination. This project produced a comprehensive speaker's kit and led to over 50,000 documented contacts with teachers over two years.

The *Professional Standards for Teaching Mathematics* (NCTM, 1991) and *Assessment Standards for School Mathematics* (NCTM, 1995a) were developed with much input from the field, and the documents were widely circulated while in draft form. About half of the funding for the *Professional Standards for Teaching School Mathematics* was provided by the NSF. The *Assessment Standards for School Mathematics* was funded with NCTM resources only. Copies of these documents have been given free to each NCTM member. Copies of all three sets of standards are currently available from NCTM. The *Curriculum and Evaluation Standards for School Mathematics* is available on the World Wide Web.[3] In addition, the Council has produced two short publications, *Making a Living, Making a Life* (1996b), intended for a general audience and explaining the importance of standards-based mathematics for all children, and *Mathematics: An Introduction to the NCTM Standards (1996a),* intended for those in the mathematics education community to use as a starting point for discussion about standards.

The NCTM curriculum standards have been in the field for eight years. Various national surveys have assessed the level of awareness among teachers about the documents. In a 1993 survey, Weiss, Matti, and Smith (1994) found that 56 percent of secondary teachers, 28 percent of teachers at the 5-8 grade level, and 18 percent of teachers at the K-4 grade level were "well aware" of the NCTM Standards. In the Third International Mathematics and Science Study (TIMSS) conducted in 1995 (National Center for Educational Statistics, 1996), results showed that at eighth grade, 95 percent of U.S. teachers claim to be either very aware or somewhat aware of current ideas about teaching and learning mathematics, which could be taken to mean familiarity with the NCTM Standards. Awareness levels appear to be increasing.

[2] This count includes 335,000 copies of *Curriculum and Evaluation Standards for School Mathematics,* 172,000 copies of the *Professional Standards for Teaching School Mathematics, and 140,000 copies of the Assessment Standards for School Mathematics.*

[3] Available through the Eisenhower National Clearinghouse at www.enc.org/reform/journals/ENC2280/nf_280dtocl.htm

INTERPRETATION

For the NCTM Standards documents to have influence in the field, it was clear that there was a need to have illustrations and examples of how the ideas of the documents could be brought to life in classrooms. The Addenda Project was initiated in 1988 to "provide teaching lessons to exemplify the Standards" (McLeod et al., 1996). NCTM's efforts to provide assistance to the field in the area of interpretation also occurred through its journals and conventions. A journal for middle school teachers, *Mathematics Teaching in the Middle School,* was initiated by NCTM, and the journal for elementary teachers was renamed from the *Arithmetic Teacher* to *Teaching Children Mathematics,* thus reflecting the enriched content emphasis of the NCTM Standards for elementary students. Each journal devoted a standing column to understanding the Standards, and special focus issues were produced dealing with standards topics such as data analysis or discrete mathematics. Review criteria for selection of articles for the NCTM school-level journals included alignment with the Standards. (This criterion is currently under discussion.) Sessions at the regional and annual meetings held by the Council were focused on standards themes. A cadre of NCTM leaders were trained in making standards-based presentations.

While NCTM initiated the types of interpretation activities appropriate for a large professional reorganization, other entities were again part of the process. The MSEB produced *On the Shoulders of Giants* (Steen, 1990) and *Measuring Up* (NRC, 1993b) to help teachers understand and think about assessment in ways consistent with the NCTM Standards. *On the Shoulders of Giants* provided a new way for mathematics educators to think deeply about content issues raised in the NCTM Standards. *Measuring Up offered insights and examples of assessment tools that are aligned with the NCTM Standards.* Textbook publishers chose to incorporate standards ideas in a variety of ways. Beginning in 1991, the NSF funded several major curriculum development projects at the elementary, middle and secondary levels in mathematics that were to be standards-based. As these projects are just now nearing completion, the field will soon have a set of examples of curricular interpretations of the NCTM Standards. As of 1996, forty states had content standards for mathematics based on their interpretations of the NCTM Standards and many are aligning assessment programs with these standards (Council of Chief State School Officers, 1996a, 1997a). Since 1990, the frameworks used in the National Assessment of Educational Progress (NAEP) have been adjusted to reflect elements of the NCTM Standards, including emphasis on "mathematical power," "reasoning," and "communication" (Reese, Miller, Mazzeo, & Dossey, 1997).

A by-product of these various interpretations of standards is that the field has more specific examples of what standards-based practice might mean. Mathematicians, in particular, are now becoming increasingly aware of the role that the Standards can play and are taking special interest in the revision of the NCTM Standards.

IMPLEMENTATION

The NCTM is not positioned to "implement the Standards." Rather, the role of the organization is to provide leadership in thinking about implementation, to serve as an organizational focus and catalyst for the ideas of others, and to facilitate interaction between members in their attempts at implementation.

Prior to the release of the NCTM Standards, each major committee of the Council was charged to present a set of possible projects or initiatives that would promote implementation of the Standards. The NCTM Board selected several of these options and supported the development of plans that were then carried out by NCTM members through their home institutions, with funding from a variety of sources.

These initiatives included a project to develop secondary teachers' understanding of discrete mathematics,[4] one of the new content areas introduced by the Standards. A project on number sense[5] helped teachers develop number sense in their students. A geometry project[6] produced materials to help teachers reflect on the geometry in their curriculum. The Research Catalyst Conferences[7] were designed to bring new researchers together with mentors to design lines of research around standards-specific topic areas.

Each of the more than 200 NCTM-affiliated groups was asked by the NCTM Regional Services Committee to prepare a plan indicating what they were doing in their group to move the Standards forward. These plans were shared and discussed at the regional caucuses and delegate assembly during the annual NCTM meeting. The Mathematics Education Trust--NCTM's foundation-funded small projects designed and submitted by teachers to facilitate implementation by individual members. At each regional NCTM meeting, a President's reception was held for affiliated group leaders from that region. Those leaders were asked to share their progress towards implementation.

Implementation activities have also been connected to other organizations. Over the years, NCTM has worked closely with ASSM and with the NCSM on linking initiatives to promote understanding of the NCTM Standards. The NCTM instituted a yearly publisher's conference where presentations on the Standards were given and opportunities were provided for discussion between NCTM representatives and publishing editors. The NCTM used its involvement in the folio review for teacher preparation of the National Council for Accreditation of Teacher Education (NCATE) to ensure that the review documents and process were consistent with the NCTM Standards.

However, studies have found that while teachers believe they are implementing standards, independent assessments of their lessons do not reveal standards-based practice (Cohen, 1990). For example, in the U.S. sample of videotaped teachers from the Third International Mathematics and Science Study (TIMSS), 75 percent of the teachers indicated that the videotaped lesson was in accord with current ideas about teaching and learning mathematics (Stigler et al., in press). Yet, analysis of those lessons along standards-like dimensions failed to show quality, as defined by the researchers. Although evidence points to awareness of and belief in the NCTM Standards, it is less clear that implementation and deep understanding are in place. Changing behaviors and practices is inherently tied to deep systemic structure.

EVALUATION

The NCTM's Research Advisory Committee recognized very early on in the standards development process the need to plan for studies that would monitor and assess the impact of standards. An NCTM Monitoring Task Force produced a report that outlined plans for monitoring and recommended that NCTM help catalyze such work, but not necessarily play the lead role (Gawronski, Porter, & Schoen, 1989). As an early effort, NCTM commissioned a study by Weiss, *The Road to Reform in Mathematics Education* (1992), which reported on early awareness levels among teachers about standards. The Recognizing and Recording Reform in Mathematics (R^3M) Project[8] was initiated by NCTM as an effort to study sites that were engaged in substantial efforts at

[4] The Discrete Mathematics Project was funded by the NSF's Teacher Enhancement Program. It was based at Boston College, under the direction of Margaret Kenney.

[5] The Number Sense Project was based at Western Maryland College, with funding from the U.S. Department of Education, under the direction of Francis (Skip) Fennell.

[6] The Geometry Project was based at Western Illinois University, funded by NSF, under the direction of Melfried and Judith Olson.

[7] The Catalyst Conferences were funded by NSF, under the direction of Patricia Campbell at the University of Maryland.

[8] The R3M Project, funded by the Exxon Education Foundation, was based at NCTM and directed by Joan Ferrini-Mundy.

improving their mathematics programs. The study described early efforts at mathematics education change, some of which were initiated before standards were available. The R^3M findings indicated that the pedagogical elements of standards were taking hold in classrooms in more visible ways than the mathematical elements and that standards documents were used more for validation than for direction in some early implementation efforts (Ferrini-Mundy & Schram, 1997).

Various organizations have studied questions of the overall effects of standards-based reform (Consortium for Policy Research in Education, 1996; Massell et al., 1997). The findings generally are that such reforms are slow to take hold in substantial ways in schools. In very specific projects that have introduced interventions in schools that might be considered standards-based, there is a trend of evidence of improved student achievement (Campbell, 1995; Cobb et al., 1991; Hiebert & Wearne, 1993; Stein & Lane, 1996; Stein, Lane, & Silver, 1996). Results of evaluations of the new NSF-funded mathematics curriculum projects, including the Interactive Mathematics Project (Webb & Dowling, 1996, 1997) and the Connected Mathematics Project (Hoover, Zawojewski, & Ridgeway, 1997), indicate strong achievement on both traditional and reformist assessment measures. The NCTM and MSEB have worked collaboratively over the years to consider the question of monitoring, although no comprehensive effort has ever been undertaken. The MSEB will be involved in a new project of the NRC's Center for Science, Mathematics, and Engineering Education, called Efficacy and Influence, that focuses on the national mathematics and science standards, and possibly those for technology, geography, and health. The first stage of this project will be to conceptualize a framework and perspective for addressing the question of how to study the effects of standards-based reform. The NRC will work with other researchers and evaluators who are studying the standards-related effort to consider how information collected annually might feed directly into improvement and revision efforts. A synthesis report will be produced in mathematics.

REVISION

In 1994, the NCTM Board of Directors charged a Commission on the Future of the Standards to plan the review and updating of the NCTM Standards. The April 1996 report of the Commission called for a revision of the Standards documents to be released in the year 2000. The new document should preserve the main messages of the original Standards, while bringing together the "classroom" parts of the three Standards documents into a single document. A major part of the revision process involves an organized strategy for working with other professional organizations. In the initial phases of the revision process, several prominent professional organizations were invited to form "Association Review Groups." These groups have been invited by the Commission and the Writing Group leaders to respond to specific questions about the format and substance of the NCTM Standards, in an effort to obtain the field's sense of what is needed in revision. The first questions posed to the Association Review Groups were:

1. Do the current statements of the Standards adequately communicate your view of the discipline?
2. Do the Standards convey a sense of consistency and growth in content themes as the student moves across the grade levels?
3. Do the Standards adequately reflect the needs of a student graduating in the 21st century and the needs of a student planning postsecondary study in a mathematics-related discipline?
4. What suggestions can you make for blending content, teaching, and assessment?

A second round of questions has focused on issues of algorithms and proof. Responses from the mathematics and mathematics education communities vary widely, and all criticisms and suggestions will be considered seriously in the revision process.

The Commission also has gathered input from NCTM members at focus groups held at regional and annual meetings. Several resource and advisory groups are being identified to support the writers and the process with specific expertise and input.

The revision is a highly publicized process within the mathematics education community. The Commission has indicated that, in this version, the grades should be divided into four grade bands: Pre-K-2, 3-5, 6-8, and 9-12 +. The finer grade-band divisions will allow for more specific focus on goals for students in these grades. The Writing Group faces interesting challenges in trying to preserve the main messages of the original NCTM Standards while attempting to look forward into the 21st century and seeking consensus across a field that is quite diverse in its views. The conflicts that are listed by Kirst and Bird (1996) relative to the development of content standards are especially useful for states and for national organizations to consider. Some highlights of their list include:

— Who must be involved in the process to feel it is inclusive? Students? Business? If you exclude groups, this will lead to charges of bias. If you include every group that is suggested, this will lead to a cumbersome and slow process.

— If you choose standards that achieve a broad consensus in the field, the "leading edge thinkers" will object. You will be accused of certifying "what is" rather than "what ought to be."

— If you choose a standard that achieves consensus in the field you will not be able to satisfy demands for "less is more"-consensus expands topics rather than reducing them. (Kirst & Bird, 1996, p. 31)

The NCTM Standards revision marks a new phase in the standards movement. Reflection on the revision process will be important to its effectiveness. The revision provides new opportunities for a professional organization to design ways of building consensus and looking forward for the improvement of mathematics education.

Perhaps of greatest significance in the NCTM story is the ground-breaking initiation of the standards movement. Not only did mathematics teachers have ready access to the NCTM Standards, but they were championed by national proponents such as Governor Roy Romer of Colorado and Senator Mark Hatfield of Oregon. The stage was set for national focus on standards.

NRC and the National Standards for Science Education

The *National Science Education Standards* were written in response to a nationally recognized need for goals and standards that could improve the quality of science education for all students. Support for national standards by state governments originated in 1989, when the nation's governors and President Bush established six national education goals, which were adopted by Congress and later expanded to a total of eight goals. In 1994, Congress enacted the *Goals 2000: Educate America Act* and formed the National Education Goals Panel (NEGP) to support and monitor progress toward the goals.

Several important events preceded the development of the science standards. In the 1980s, several organizations developed innovative instructional materials. Among these were the American Chemical Society, the Biological Sciences Curriculum Study (BSCS), the Education Development Center, the Lawrence Hall of Science, the National Science Resources Center, and the Technical Education Resources Center. In 1989, the American Association for the Advancement of Science (AAAS), through its Project 2061, published *Science for All Americans* (AAAS, 1989), defining scientific literacy for all high school graduates. Three years later, the National Science Teachers Association (NSTA), through its Scope, Sequence, and Coordination Project, published *The Content Core* (1992).

In 1991, the National Research Council (NRC) was formally asked by the president of NSTA to assume a leading role in developing national standards for science education. The NRC was encouraged by leaders of several other science and science education associations, the U.S. Department of Education, the National Science Foundation (NSF), and the NEGP The effort, funded by the U.S. Department of Education, NSF, and the National Aeronautics and Space Administration (NASA), was led by the National Committee on Science Education Standards and Assessment (NCSESA), advised by the Chair's Advisory Committee of representatives of the major science education organizations, and carried out by three working groups (content, teaching, and assessment) composed of science teachers, educators, scientists, and others involved in science education. Early drafts of the NRC Standards were reviewed by numerous focus groups and additional groups of experts, plus large numbers of educators across the country. More than 40,000 copies of a complete draft were distributed in December 1994 to approximately 18,000 individuals and 250 groups for review. The comments and recommendations received from these reviewers were used to prepare the final document.

Formally released in December 1995, the *National Science Education Standards* (NRC, 1996a) define the science content that all students should know and be able to do and provide guidelines for assessing the degree to which students have learned that content. The NRC Standards detail the teaching strategies, professional development, and support necessary to deliver high-quality science education to all students. The NRC Standards also describe policies needed to bring coordination, consistency, and coherence to science education programs.

In early 1996, the NRC consolidated its education activities into the Center for Science, Mathematics, and Engineering Education (the Center). The Center took on support for the new *National Science Education Standards* as an important priority. Because the NRC is unlike the National Council of Teachers of Mathematics (NCTM), an organization whose large membership is distributed throughout the United States and whose capabilities include a network of state affiliates who could engage in support for the mathematics standards, the Center needed its own unique strategy for supporting the science standards. That strategy, which takes advantage of the Center's position within the NRC as well as lessons learned from the NCTM experience with national standards, is elaborated in a general way in the Strategic Framework discussed earlier in this report. Within the Strategic Framework, the Center's focus has been on building awareness of the NRC Standards and support for their use throughout the country.

DISSEMINATION

Dissemination of the NRC Standards has taken many forms. The document was immediately available on the World Wide Web.[9] After the January 1996 publication, the NRC sent copies to all members of Congress, governors, state science and technology policy advisors, state science supervisors, NSF-funded systemic initiatives, and directors of Annenberg Challenge Sites. Following the Education Summit hosted by national business leaders in March 1996 that endorsed the need for common, clear, state and/or community-based standards, the Center provided copies of the NRC Standards to participating governors and chief executive officers along with a letter that linked the Education Summit's recommendations with the NRC Standards.

The NRC Standards have been distributed to members of the National Academy of Sciences (NAS), the Council of Scientific Society Presidents, and leadership of all professional organizations for science education, including the AAAS, American Association of Physics Teachers, American Chemical Society, Council of State Science Supervisors, National Association of Biology Teachers, National Association of Geology Teachers, and NSTA. This effort had the specific goal of informing the scientific and educational communities of the NRC Standards.

As of June 1997, over 131,000 copies of the NRC Standards had been distributed. To further dissemination efforts, the Center recently produced a brochure, *Introducing the National Science Education Standards* (NRC, 1997a), that describes what is in the NRC Standards and addresses typical questions about the Standards. In the months since the brochure's publication, nearly 10,000 copies have been distributed.

Dissemination of the NRC Standards document has been complemented by presentations about the Standards. Over 400 presentations were made to approximately 33,000 people by approximately 100 presenters before the actual release of the Standards. Hundreds more presentations have been made since. In the fall of 1995, before the release, a series of ten regional workshops was hosted by the Center for science education leaders throughout the country. The workshops initiated a Speakers' Bureau to support participants in their efforts to disseminate the NRC Standards in their own communities. The Center assembled a presentation guide from the material shared in those workshops and distributed the guide to the 375 people who attended.

The Center has worked closely with many other groups to disseminate the NRC Standards. With NRC assistance, the NSTA launched the "Building a Presence in Every School" project. The goal of this project is to place a copy of the NRC Standards in every school in the country, supported by a resource teacher within the school and a state-wide network. This program was initiated in Texas, with support from the Exxon Education Foundation. The NSTA continues to add states and sponsors to this highly ambitious effort. Other special audiences targeted for dissemination initiatives include commercial publishers of science instructional materials and parents. A convocation for publishers was held at the NAS in June 1996 to brief them on the NRC Standards and discuss ways their materials could support standards-based teaching and learning. The Center is currently producing a publication

[9] Available at www.nap.edu/readingroom/books/nses/

aimed at parents and the general public that sets the stage for their involvement in standards-based education by familiarizing them with rationale for standards and introducing them to the NRC Standards.

INTERPRETATION

Interpretation efforts focused on curriculum and instructional materials began early and are continuing into the implementation phase. A November 1995 conference, co-sponsored by the Center and the BSCS and funded by NSF, brought together curriculum developers, state and district science educators, and teacher educators and professional developers to study the NRC Standards and their implications for curriculum development. That conference resulted in a book, *National Standards and the Science Curriculum: Challenges, Opportunities, and Recommendations* (Bybee, 1996).

Understanding the role of assessment in standards-based education is an important interpretation issue as well. This was a focus of a conference, "Science Education Standards: The Assessment of Science Meets the Science of Assessment," sponsored by the NRC's Board on Testing and Assessment in February 1997.

In addition, the NRC has had a particular interest in teacher development. At the request of NSF, the NRC developed a letter report, *Science Teacher Preparation in an Era of Standards-Based Reform* (1997b), that provides a vision for teacher education and professional development. The role of scientists and engineers in standards-based reform also has been a focus of the NRC. The Resources for Involving Scientists in Education (RISE) Project is completing a Web site to inform scientists and engineers who are interested in contributing to standards-based reform. Information on the Web site will include examples of how scientists have worked in various projects with teachers, schools, and districts and descriptions of the various roles scientists and engineers can play-all in an effort to help them and those with whom they work understand better their potential contributions to standards-based reform. Exploring the roles of business and industry in standards-based reform was the focus of a December 1996 forum at the NAS, entitled "How Industry Can Use the Standards to Promote School Reform," that was hosted jointly by the NAS Academy Industry Program and the Center. Past meetings have included approximately 200 business leaders and have centered on involving business and industry in the reform of science education.

A publication nearing completion examines the critical issue of equity as presented in the NRC Standards. Aimed at parents and the general public, the tentatively titled *Science for All Students* will highlight various ways that the NRC Standards address equity and what an explicit emphasis on equity looks like in educational settings.

In 1996, the NRC launched a project to engage the informal education community including museums, botanical gardens, zoos, and science and technology centers-in support of standards-based education. The central goals for the project include (1) the enhancement of existing community resources found in science museums, botanical gardens, and in other youth-serving programs through study and dialogue about the NRC Standards; and (2) the development of local action plans that build cooperation among key community constituencies through use of the NRC Standards.

Borrowing a concept from the NCTM for supporting documents to accompany the Standards, the NRC is initiating a major effort to create a series of addenda that illuminate important standards, such as those addressing science as inquiry, science and technology, and the history and nature of science. These publications will provide teachers and professional developers with an understanding of the knowledge base in these areas, images of standards-based curriculum and instruction, and examples of educational resources that will help in implementing the NRC Standards.

IMPLEMENTATION

Most of the issues addressed by the Center through interpretation activities have been carried into implementation. Here the NRC has provided leadership through the development of products and the convening of groups to support state and local initiatives. To further the work in curriculum and instructional materials, for example, a conference on "Using the *National Science Education Standards* to Guide the Evaluation, Selection, and Adaptation of Instructional Materials" was held at the NAS in November 1996. Three hundred and fifty federal, state, and local science educators attended this meeting. A set of guidelines for aligning instructional materials with the NRC Standards is currently under development. A new project, funded by the Robert W. Woodruff Foundation, will develop criteria for selection of materials and will design and pilot a process to do so with district-level teams throughout the country as they critique, select, and adapt textbooks and instructional materials for their respective districts and schools.

In February 1996, the NRC and the Council of Chief State School Officers convened a symposium to explore the implementation of the NRC Standards with respect to teacher preparation and credentialing. It was designed for leaders in science education, university science deans and scientists, and state education officials responsible for teacher certification. Participants attended as part of a state team; the teams examined the NRC Standards and created action plans to further their own efforts. Proceedings of the symposium, including the state action plans, were published in *Improving Teacher Preparation and Credentialing Consistent with the National Science Education Standards* (NRC, 1996b).

The NRC is currently planning collaborative efforts with associations of science leaders from states (Council of State Science Supervisors [CSSS]) and districts (National Science Education Leadership Association [NSELA]). These initiatives will explore and document the various processes that different states and districts are using to move from national standards to state frameworks and, eventually, to influence changes in textbooks and instructional materials, curriculum, assessment, and teaching. In the future, the Center plans to host a summer institute for state leaders in mathematics as well as science that will provide state teams with the opportunity to apply new understandings about national standards to their state reform initiatives. Staff of the Center will work with NSELA leadership to formulate specific directions for collaborative work.

EVALUATION

The evaluation of the NRC Standards actually began as part of the process to establish a national consensus before the Standards were revised to their final form. Forty thousand copies of the penultimate draft were distributed for national review by individuals and groups that had expressed an interest in being part of the process. Approximately 4,000 responses were received from individuals and special focus groups; respondents included teachers (K-12 levels), science educators (district coordinators, science supervisors, curriculum developers, teacher educators), scientists (college, university, industry), policy makers (school boards, state government officials), and other role groups (business, parents)(NRC, 1995b).

Among these self-selected respondents, there was significant agreement on the content in the *National Science Education Standards.* The survey asked for agreement with characteristics of the content standards, including the intent, consistency, developmental appropriateness, vision of good science, and clarity. Across all respondent groups, there was at least 59 percent agreement or strong agreement. In most cases, the level of agreement was much higher.

Another series of questions in the national review asked about the various areas in the NRC Standards: teaching, professional development, assessment, content, program, and system. For all areas except the system standards, more than half of the respondents judged that the Standards were complete and accurate, that they would help policy makers and practitioners make decisions, and that they presented an acceptable vision. The teaching and content standards received the most supportive ratings.

Respondents were asked to choose one area for which the NRC Standards were likely to have the greatest influence. Program development and evaluation, teaching practice, policy formulation, and content selection received the most votes, in that order. These are important themes in the improvement of science education and ones that the NRC had intended the Standards to influence.

In January 1997, the NSTA completed a survey of 5,000 randomly selected NSTA members for their reactions to the NRC Standards (NSTA, 1997). Of the 1,900 members who responded, 87 percent were teachers. (There were no data to indicate whether those responding were representative of those surveyed.) When asked if they thought that the NRC Standards could improve the way science is taught in their classrooms, 80 percent of the teachers who answered the question responded "yes." Further, 75 percent of teachers responding thought the NRC Standards would improve the way science is taught in their schools. Very importantly, the survey asked what the teachers perceived as barriers to implementing standards in actual practice. The three top barriers cited by teachers were adequate time for planning and working with other teachers; financial support for relevant professional development; and instructional materials, resources, and facilities.

Results such as these are not unexpected. Like the NRC survey results, they indicate that educators are aware of the NRC Standards and the implications for their practice. Further, they underscore that science teachers understand that critical requirements for the success of standards-based reform include time, professional development, and instructional materials. These data have influenced the work of the NRC, as described in the discussion of strategies for interpretation and implementation above. Implications for state policy are discussed in the Recommendations section of this report.

The Efficacy and Influence project of the Center, mentioned earlier in the discussion of evaluation of the NCTM Standards, will serve as a guide for ongoing monitoring of science standards implementation.

REVISION

Although the NRC Standards were released quite recently, it is never too early to begin planning for revision. From the beginning, the various advisory committees encouraged the NRC to view the Standards as a living document, one that would undergo revision at appropriate intervals. The formal process of revision for the NRC Standards will likely begin in the year 2000, for release in 2002. It will include, as before, broad participation by those involved with and interested in science education and will incorporate the lessons learned from the mathematics community's current revision of the NCTM Standards.

Current Context for Mathematics and Science Education

In the late 1980s, "state and district policy makers (along with many professional subject matter associations and private foundations) turned their attention from the number of academic courses to the quality of the core academic content being taught in public schools" (Massell et al., 1997, p. 1). The standards movement-as launched by the work of the National Council of Teachers of Mathematics (NCTM) and continued in science by the National Research Council (NRC)-is an impetus and tool for this redirection of attention. It is a vehicle for moving toward Goal 5 of the National Education Goals-"By the year 2000, United States students will be first in the world in mathematics and science achievement." Now, in the late 1990s, attention is focused again on the quality of core academic content. President Clinton has called for a national voluntary test in eighth grade mathematics and has directed the National Science Foundation and the U.S. Department of Education to prepare an action strategy for the improvement of K-8 mathematics education. Mathematics and science education continue to benefit from high levels of visibility and attention in the public and policy arenas.

Some of the current attention to mathematics and science education is the result of international comparisons. The release of the Third International Mathematics and Science Study (TIMSS) reported that U.S. eighth grade students were slightly below average in mathematics and average in science achievement in comparison with their counterparts in more than 40 other countries around the world (National Center for Educational Statistics [NCES], 1996); fourth graders were average in mathematics and above average in science (NCES, 1997). TIMSS also reported on factors that may influence mathematics and science performance, including the nature of educational systems, the role of curriculum, time spent in school, and the breadth and depth of topics covered in school mathematics and science programs.

National and international benchmarking, which can draw from the goals of standards, is a focal point for public policy discussions of education at the state level. Results from TIMSS and from the 1996 National Assessment of Educational Progress (O'Sullivan, Reese, & Mazzeo, 1997; Reese et al., 1997) have stimulated discussions of how well students are doing in mathematics and science in comparison to those in other countries and states. A study of tests taken by high school students around the world, conducted by the American Federation of Teachers and the National Center for Improving Science Education (AFT & NCISE, 1997), has furthered the discussion of whether our expectations for students are sufficiently high.

At the same time, barriers and challenges to reform of science and mathematics education have persisted. Achieving public consensus has at times been problematic (Massell et al., 1997). Throughout the reform literature there is discussion of the need for teacher professional development to support the proposed changes of the standards documents (NCTM, 1991; Zucker, 1997). Textbooks and instructional materials are also needed as support for standards-based reform (Tyson, 1997). Questions of how teacher and student motivation and beliefs interact with reform and issues of administrative support merit further examinations as potential challenges to reform (Tyson, 1997).

There is current debate in the field about the directions and goals of mathematics education reform. This debate is due, in part, to different interpretations of the NCTM Standards-e.g., whether the Standards pay attention to basic skills. The debate might also be viewed as an effort to promote a more balanced perspective about what is important in mathematics teaching and learning. Various organizations have been established, such as Mathematically Correct, that are calling for alternative goals in mathematics education to those promoted in the NCTM Standards documents. Research mathematicians have been commenting extensively on their views about K-12 mathematics education (Andrews, 1997; Bass, 1997). The NCTM Standards revision process, through its Association Review Groups, provides an organized means of gathering various points of view, which will be considered in the revision process. The differences in views and values that are emerging in these mathematics debates are likely to remain visible at the state and local levels in the processes of reconsidering mathematics and science education reform.

In a general way, events that are calling attention to mathematics and science achievement have special promise for directing renewed attention to mathematics and science standards, in particular the relationships between national and state standards. The March 1996 Education Summit of the nation's governors and business leaders focused attention on the topic of state standards. The Council of Chief State School Officers (CCSSO) has conducted a review of state standards describing characteristics of state standards and frameworks (CCSSO, 1997a). On July 1, 1997, the National Education Goals Panel's ACHIEVE panel began its work on assessing the quality of voluntarily submitted state-level standards. Specific activities in mathematics and science education, both ongoing and new, also contribute to this moment of opportunity. The National Science Foundation's systemic initiative efforts at the state, city, and regional level-as well as similar efforts supported by states and local communities-are infusing resources into the system and involving large numbers of mathematics and science teachers, together with the business community and the public, in focused work on high standards for the learning and teaching of all students (Zucker, 1997).

The stage is set for continued work on standards-based education throughout the country. Significant portions of the mathematics and science education communities have focused their energies on standards; national and international studies of student learning point to progress, but identify areas that require substantial improvement as well; and national, state, and local resources are being directed on reform of all components of the system. The National Education Goals Panel has provided the NRC and NCTM with a rare opportunity: to pause and reflect on the past, and suggest specific ways to move forward the states' agendas of high standards for ***all*** students. Although both the NRC and NCTM can provide support for these agendas, the steps necessary to ensure widespread implementation of standards-based education must now be taken by state governments. The recommendations in the following section are intended to suggest productive directions for states.

Recommendations for State Policy

In the sections that follow, we propose recommendations in five areas: state infrastructure, textbooks and other instructional materials, curriculum, teaching, and assessment.[10] Many of these areas are highly visible to the public and so are of particular concern as reform initiatives continue. These are also areas in which the activities and interests of the states, the National Council of Teachers of Mathematics (NCTM), and the National Research Council (NRC) intersect. As the work of states in standards-based education continues, there are many ways in which they can draw on the past experiences and current initiatives of the NCTM and NRC, be supported in specific areas of work, and influence ongoing NCTM and NRC activity. The recommendations for state policy that follow are discussed in terms of these overlaps and the potential for mutual support now and in the future. The overarching recommendations are:

1. ***State infrastructure***
   Strengthen the state infrastructure for improvement in mathematics and science education with coherent, focused standards and with the policies, structures, and resources to support their achievement.
2. ***Textbooks and other instructional materials***
   Develop policies and strategies that promote the use of standards-based textbooks and other instructional materials and that build state and local capacity for selecting and using the materials appropriately.
3. ***Curriculum***
   Structure policies and support to focus districts and schools on designing science and mathematics curricula that are high-quality, well articulated, and standards-based.
4. ***Teaching***
   Create policies and practices to ensure that well qualified, highly competent teachers, whose practice is grounded in the mathematics and science standards, are in every elementary school, mathematics, and science classroom in the state.
5. ***Assessment***
   Establish testing and assessment programs consistent with the goal of high expectations for all students to learn standards-based mathematics and science.

[10] The recommendations that follow use the following definitions: Content standards specify the content knowledge and skills all students will know and be able to do upon completing particular grades or courses in K-12 education; the content standards state clearly the knowledge and skills to be learned, and at what developmental level content is to be presented (CCSSO, 1996a). Curriculum framework is a document published by a state education agency or state board of education [or school district] that generally includes desired subject content or standards for a core academic subject in K-12 education. It often serves as a bridge between national professional standards and local curriculum and instructional strategies. It may refer educators to other materials and resources to support local efforts (CCSSO, 1996a). Curriculum is the way content is designed and used with students. It includes the structure, organization, balance, and presentation of the content in the classroom (NRC, 1996a). Instructional materials are the physical components of the curriculum, including textbooks, software, kits, calculators, and teachers' guides (NRC, 1996a).

These recommendations are interrelated. States require strong leadership for coordination in all aspects of standards-based reform. Instructional materials, especially textbooks, are the primary tools used by many teachers and seen by most parents as fundamental resources for student learning. They contribute to the curriculum, broadly defined, through their organization and delivery of content. Teachers are seen by most reformers as the central agent in promoting high-quality mathematics and science education for *all* students. Effective assessment can be simultaneously a tool for improving curriculum and teaching and for measuring progress toward the goal of achieving rigorous standards for all students. Together, the five overarching recommendations listed above form a whole that can best be coordinated around standards, with each piece requiring attention and action separately. The recommendations have potential value for all disciplines and could gain more support if applied across the entire system, not just in science and mathematics.

Making a set of recommendations for state policy may imply that states are all alike, and this is not true indeed. From state to state, the mechanisms of governance are different, as are the responsibilities taken on at the state level. States have many vehicles for promoting improvement of education, including regulation, support, and persuasive power. States combine these in unique ways, depending on their structures, traditions, and resources. As a consequence, it has been a challenge of this report to make recommendations that are not so global as to be unattainable, but that are specific enough to be useful to most states in spite of their differences. In addition to being as specific as possible, this report includes a number of examples of how individual states and others are approaching some of the recommendations.[11]

In these ways, this report seeks to provide some practical guidance for state policy as states increase their efforts toward standards-based reform in mathematics and science.

RECOMMENDATION 1. STATE INFRASTRUCTURE

Strengthen the state infrastructure for improvement in mathematics and science education with coherent, focused standards and with the policies, structures, and resources to support their achievement.

International studies and the efforts of states to bring about systemic reform have underlined the need for a strong state infrastructure focused on improvement (Elmore, 1996; O'Day, Goertz, & Floden, 1995). This recommendation addresses the importance of focusing all elements in the system on the achievement of high-quality state standards. Policies guiding education, funding programs, and state procedures all must be coordinated and directed toward this common goal. The theme for state capacity building and indeed all of the recommendations in this report is, as stated succinctly by the National Commission on Teaching and America's Future, *"get serious about standards [emphasis added]" (1996).*

In order to get serious about standards, states need to go beyond their statutory duties of creating their own standards, curriculum frameworks, assessment systems, etc. and include mechanisms for ongoing learning about the standards in every one of their activities. Understanding of the standards is needed by every state official as well as the many stakeholders who participate on state committees and development efforts.[12] Conscious efforts to provide professional development build the capacity to fulfill the current state role as well as plan effectively for the

[11] Throughout this section we have provided examples of how some states are implementing all or part of a recommendation. These were chosen not because they are exemplary per se, but because they represent interesting ways to address the issues that are raised. We do not have extensive data about the effectiveness of these strategies.

[12] Note that useful materials promoting awareness and stimulating discussion of mathematics and science standards have been developed by the Annenberg/CPB Math and Science Project.

future. Getting serious about standards requires states to:

1-A Develop high standards for all students, through consensus, including a process for periodic review.

Most states have a document, or documents, that contain state content standards for science and mathematics education. These documents tend to draw heavily on national standards (CCSSO, 1997a). They vary considerably in specificity and scope (CCSSO, 1997a), in quality (Diegmueller, 1996; Zucker, 1997) and in their "ambitiousness" (Tirozzi, 1997). They also differ in the process used in their development. State standards that were well developed with careful attention to involvement of educators throughout the state, as well as important stakeholders like parents, business representatives, scientists and mathematicians, and community members, appear to have benefited from critical public support (Massell et al., 1997; Zucker, Shields, Adelman, & Powell, 1995). In such a consensus process, participants become a knowledgeable force of advocates, thus building the capacity of the state to improve the system for science and mathematics education.

For example, North Carolina uses a process external to the state agency to build consensus around state documents. A qualified, independent organization statistically samples both educators and the lay public regarding proposed documents, soliciting input from all groups. The organization then uses feedback from this survey to validate or make recommendations for improvement of documents in a report to the State Board of Education. This process, as well as strategies such as well publicized focus groups and expert advisory committees, provides many opportunities for input and ensures that no particular special interest group has undue influence on the development of important state documents.

In the development of standards, states may find the experiences of NCTM and NRC helpful, in addition to their links to the professional communities. National standards can be a reference point against which states can evaluate the degree of rigor in their own standards, including whether they have incorporated and, if so, adhered to such principles as "less is more," that is, depth of understanding is more important than breadth of coverage. The efforts of NCTM and NRC described earlier might help suggest ways to bring the forces in the state together in the dissemination, interpretation, and implementation of their own standards.

1-B Build a coherent system for mathematics and science education within the state in which every component and level of education is aligned and has a common goal: that all students will meet these high standards.

One of the benefits of having a common set of standards, built through a consensus process, is that they can focus and guide action within a state. This was the intention of both NCTM and NRC, whose national standards include attention to all components of reform including content, teaching, and assessment. They go beyond statements of what students should know and be able to do; they describe the teaching, assessment, programs, professional development, and the system support needed for students to learn that content. Further, the national mathematics and science standards address all levels of the education system, seeking "vertical integration" of what students learn in the early grades with what they learn in middle and high school and with how their teachers are prepared. Both sets of national standards suggest what needs to be done in classrooms, schools, districts, states, and at the national level.

States must similarly and continuously seek a "systemic" approach to science and mathematics reform, in which parts of the system work in concert with each other. Changes in one part influence adjustments in others; the common thread is the achievement of a shared set of standards (Smith & O'Day, 1991). Curriculum frameworks, funds for instructional materials, state assessments, preservice and inservice professional development programs, funding and other support for Title I and special education-all can be designed or redesigned and interrelated, using the national standards as a foundation.

In Texas, for example, the Statewide Systemic Initiative (SSI) worked to build coherence among programs and leverage resources by convening local and regional teams of Title I educators and administrators with other local educators and mathematics reform specialists. The SSI not only supported conversation and communication among these groups, but also funded team projects in which Title I mathematics programs were connected to standards-based, school-wide mathematics improvement efforts.

Most states have devoted a great deal of effort over the past several years to "systemic change," with varying levels of success. In some cases, federally funded programs run parallel to the state's own initiatives; this may or may not influence local reform. For example, in some states, the National Science Foundation (NSF) funded state systemic initiatives are independent of and not well integrated with efforts of the state department of education. Efforts to reform professional development in a state might be significant, but the Eisenhower-funded programs might perpetuate traditional, but less effective, approaches to science and mathematics professional development.

Similarly, although standards may be written for ***all*** students, Title I and special education programs within a state may not be incorporating standards ideas. However, current Title I legislation requires that districts pay attention to state standards and that states ensure that they do. States need to identify and eliminate these "discrepancies" between different programs and initiatives and replace them with common focus and vision if the states are to achieve the goal of meaningful learning for all students.

1-C Establish a long-range plan for improvement that involves the broader community as well as mathematics and science educators and provides sufficient support for local educators as they work to implement the standards.

Standards-based education requires an ongoing process in which the system is not fixed "once and for all," but rather in which the quality and coherence of the system are enhanced via a common set of standards for mathematics and for science. Through the evaluation and revision process, the system's capacity to improve will increase.

Students take 13 years to go through the K-12 education system, and we cannot expect to both have and fully understand the impact of standards until at least one cohort of students has experienced a new and improved educational experience. The kinds of support needed are well documented in the literature (Fullan, 1991; Loucks-Horsley et al., 1990), and are becoming better understood in evaluations of current efforts at state reform (Zucker, 1997).

Standards-based education in mathematics and science is in many ways an opportunity for scientific inquiry. Studies, such as those of previous reform efforts (National Advisory Committee on Mathematical Education, [NACOME], 1975) and current international comparisons (National Center for Educational Statistics [NCES], 1996, 1997), indicate a need for initiatives that are more coherent, systemic, sustained, and based on a commonly held set of high standards for student learning. Although reports of current "systemic" initiatives indicate that steady progress is being made in implementing key components of reform (Massell et al., 1997; Zucker, 1997), it is still unknown as to whether, under what conditions, and in what configurations such initiatives are successful in increasing the science and mathematics learning of students. The long-range plan suggested by standards is based on the best knowledge available to date, but such a plan must have feedback and evaluation mechanisms at many points and at many levels to inquire into its influence and impact, and to inform its revision and midcourse adjustment. Ongoing dialogues between state reform leaders and constituents provide one form of data. Careful measures of implementation of various components of the system, such as professional development and new assessment practices, provide another kind of data. Finally, data on student learning and the conditions under which they learn are needed to address such far-reaching questions as the following: Under what conditions, if any, can all students meet the standards? What are the costs of their doing so? What are the consequences of all students meeting the standards? Any long-range plan must take into account the tentative nature of the data currently available on which to base planning decisions, build in mechanisms to collect its own data, and approach the design and implementation of the initiative as an inquiry into standards-based reform.

The issue of expanding the community beyond those involved in science and mathematics education is critical. Earlier we noted the importance of including the broader community in the development of standards; ongoing involvement and support are needed as well. Working closely with business and other groups such as the PTA, states need to build the awareness and commitment of the public to the directions of standards-based education. Research suggests, however, that states are not doing well in this regard. "Lack of public support and understanding of standards-based reforms remained major obstacles to the stability of standards," note Massell and associates (1997, p. 6). Better strategies are needed to garner the support of various publics for standards-based reforms.

In Washington State, raising public support for standards is the primary purpose of Partnership for Learning, a non-profit organization sponsored by Washington business and community leaders. The Partnership works to increase public awareness about the state's effort to raise academic standards in the public schools. Resources made available by the Partnership include brochures, a parent's guide to academic achievement, public opinion data, a newsletter, and a web site with links to other resources around the country related to standards and assessments.

Some states have maintained coalitions in mathematics and science that were initiated by the Mathematical Sciences Education Board (MSEB) in 1990, with start-up support from the Exxon Education Foundation. These have established a "self-sustaining" leadership structure. A parent organization, the National Alliance of State Science and Mathematics Coalitions (NASSMC), now supports efforts in individual states to build broad capacity for standards-based reform, bringing together the varied resources of education, science and mathematics, and the business community. These efforts and others that work to expand the community must be folded into the state infrastructure to enhance the capacity of the system.

It would be irresponsible to recommend the broad and long-term changes required to implement high standards for all students without acknowledging the time and resources required at every level of the system-classroom to state house. Where resources are limited, as they are in education, there is competition for those that exist. Every content area can make a compelling case for their share and more. Certainly demands on teachers are keen, and seem to increase daily; elementary teachers are especially pressured to invest their time and energies in reform of each of the disciplines that they teach.

State policy makers need to examine carefully the issue of resources for educational reform. There are no definitive estimates of what it will cost to achieve high standards for all students. However, there is reason to believe that substantial progress towards meeting that goal could be made by reallocating current resources. As noted above, our educational systems lack coherence; major programs such as Title I and the Eisenhower funds are not always well coordinated. The result can be costly duplication of effort. The report of the National Commission on Teaching and America's Future (NCTAF, 1996) makes a compelling case for reallocating educational dollars. The report urges rethinking of school structures and roles to increase the number of instructional staff (and thus decrease teacher/student ratios), redirecting professional development funds to eliminate ineffective one-shot workshops, and supporting more useful forms of professional development to help teachers learn how to use new curriculum and assessments. It urges investment in "strategic improvements" such as teacher preparation, recruitment, licensing, and induction to eliminate the costs of replacing 30 percent of new hires in their first few years of teaching and "band-aid" approaches to staff development for those who have not learned to teach effectively. The cost analyses contained in the NCTAF report constitute a useful place to begin examining how resources are currently being used in and how they might be used differently to support standards-based reforms. Similar estimates could be made for how resources for curriculum and assessment are being used and how they might be reallocated.

1-D Ensure that state-level leadership positions in mathematics and science education exist and are filled by staff with expertise in the disciplines and in supporting change.

As of 1997, only 65 percent of the states have positions at the state level in mathematics education; 80 percent have similar positions in science education. Some of these positions are funded through external sources such as Eisenhower/Title II or NSF Statewide Systemic Initiatives; such positions may not be permanent. In several states, after the retirement or resignation of an individual holding this position, there may be a considerable time lag in hiring a replacement or the position may be eliminated altogether due to budget constraints. Some of these positions include additional general responsibilities, such as technology, assessment, or professional development; others combine mathematics and science. Individuals in these positions may have a broad range of responsibilities and serve in a variety of roles: working on state policy, coordinating mathematics and science programs, overseeing the development of state curriculum frameworks, organizing for the adoption of instructional materials, developing or influencing state assessments, and giving guidance to state superintendents. In a few cases, the main responsibility of state-level mathematics or science consultants is to consult with schools by invitation only; they are not involved in state policy.

Whatever the configuration of their roles, what these individuals know and can do is critical to their state's success in science and mathematics reform. Just as the current reforms call for teachers who deeply know the mathematics and science they need to teach, so too the current reforms require similar expertise in positions of leadership. Decisions about standards and curriculum frameworks, curriculum and instructional materials, teaching and professional development, and assessment design, as well as plans for implementation, hinge to a large extent on the nature of the disciplines, how they are learned, and how they are best taught. The issues differ by discipline; for example, those making decisions about mathematics need to understand the "gatekeeper" role played by algebra courses. Science decision makers need to understand the implications of the lack of science competence of elementary teachers and the importance of carefully organized systems that provide teachers with the materials they need to teach science. State leaders have to make the final decisions about what becomes state policy and procedure, what is published in state documents, and what is funded through state initiatives. They need to make important discipline-related links to programs such as Title I and Title II (the Eisenhower Professional Development Program). Without expertise in science and mathematics curricula, teaching, and programs resident in state departments of education, the decisions made may be to the detriment of the reform movement.

Expertise in the disciplines is necessary but not sufficient for state-level staff, who are increasingly moving into roles of technical assistance and away from the more traditional roles of monitoring compliance with state laws and procedures. This is important for state capacity building, but it does not happen simply by changing job descriptions; many staff do not currently have the capabilities to make this change. New knowledge and skills required include design of professional development, facilitation, consultation, organizational development, public relations, and change management. Specific professional development in these areas is required. Further, just as teachers must develop skills and dispositions for lifelong learning (NRC, 1996a), so, too, staff in state positions need to have the capacity to respond to new demands in appropriate, timely, and creative ways. Their knowledge, connections, and interactions with the NCTM and NRC capacity-building efforts, such as work with the Council of State Science Supervisors (CSSS) and the Association of State Supervisors of Mathematics (ASSM), can increase their understanding of issues in their content areas, and inform their policy decisions.

1-E Provide guidance and policy support to districts and schools in restructuring the use of school time to create opportunities for teachers to work together for improvement of mathematics and science education in their system.

The issue of restructuring time for teachers and administrators to work together for improvement is one that is critical to the success of standards-based initiatives. International studies indicate that teachers in countries scoring higher than the U.S. on international comparisons have far fewer student contact hours than American teachers (NCES, 1996; Raizen & Britton, 1996). Hours spent without student contact are typically devoted to teachers working together on teaching materials, lesson plans, and other areas of curriculum. The literature on school improvement repeatedly validates the importance of school staff having opportunities to talk about teaching practice; observe each other's teaching; and plan, design, research, evaluate, and prepare teaching materials together (Little, 1993; Rosenholtz, 1989).

Widespread experimentation is occurring in schools and districts to restructure school schedules to provide time for staff collaboration, provide release time for teachers or purchase time outside of the school day and/or year, and make better use of available time (Watts & Castle, 1993). Some states are creating policies to address this issue.

For example, in the early 1990s, the Connecticut Academy for Education in Mathematics, Science and Technology (1996) supported a task force that developed a report entitled, *The Case for More Time and Better Use of Time in Connecticut Schools.* Recognizing that the use of time was critical to any efforts to improve mathematics and science in schools, the monograph summarized issues and recommended ways to improve the use of time for both students and teachers, by increasing actual time and using existing time in innovative ways. A year after the release of the report, a Connecticut Academy survey discovered that many schools in the state were implementing various recommendations of the task force, including block or flexible scheduling, interdisciplinary study, and programs scheduled outside of the regular school day. Many schools were creating more teacher time through reducing nonacademic duties and lengthening both the teacher's and student's school day and school year.

State policies can assist local educators by providing more professional development time, supporting creative uses of in-school time (which may involve granting waivers of some state laws), and providing assistance to schools in designing and implementing alternative school schedules.

RECOMMENDATION 2. TEXTBOOKS AND OTHER INSTRUCTIONAL MATERIALS

Develop policies and strategies that promote the use of standards-based textbooks and other instructional materials and that build state and local capacity for selecting and using the materials appropriately.

Textbooks and other instructional materials are a staple in the classroom. As teaching tools, they embody the content and values to be learned by students, and so can be a significant force in helping students achieve high standards in mathematics and science. Yet, in many states, textbooks and instructional materials are a "weak link" in their improvement initiatives; educators recognize their potential value, but find the availability of high-quality materials limited (Zucker, 1997). SRI's study of 25 states with NSF funding for statewide systemic initiatives indicates that:

To improve student achievement, high quality textbooks (or other instructional materials, such as kit-based elementary science programs) need to be identified (or developed if necessary) and decision makers need to be well informed about them (Zucker, 1997, p. 5).

Teachers use textbooks as their main curriculum guide and source of lesson plans, especially at the elementary grades (Woodward & Elliott, 1990). Research on textbooks consistently shows that they "flip from topic to topic, covering very few in the depth a beginner would need to understand, remember, and integrate the knowledge" (Tyson, 1997, p. 2).

Reports of international studies, such as *A Splintered Vision* (Schmidt, McKnight, & Raizen, 1997), *Pursuing Excellence* (NCES, 1996), *Characterizing Pedagogical Flow* (Schmidt et al., 1996), and *Changing the Subject* (Black & Atkin, 1996), characterize the U.S. curriculum as one that is "a mile wide and an inch deep." The findings support the need for textbooks and other instructional materials that have fewer topics in any given year and put more emphasis on developing understanding of basic mathematical and scientific concepts and processes.

States have a great deal of influence over the nature of textbooks. This is especially true in the 20 states that "adopt" a list of state-approved textbooks and bear the cost of textbooks for all students in the state (Tyson, 1997). The influence of states contributes to the "mile-wide and inch-deep" nature of textbooks. Publishers, responding to the demand of the market, include everything that adoption states require (in particular, the high-population states of California, Texas, and Florida that have restrictive state adoption procedures). The result is broad coverage of mathematics and science topics, including a vast amount of review, which then becomes the focus of instruction.

This report views the influence of the states on the market for instructional materials, especially textbooks, as potentially positive. For students to achieve high standards, the materials from which they learn must be designed to promote understanding of key areas of mathematics and science. Thus, states need to demand materials that are more compatible with the standards they want their students to achieve.

There are specific actions and policy shifts that can be initiated at the state level to help improve selection processes and capacity.

2-A Implement state policies that support the development of selection criteria for instructional materials based on standards and consistent with curriculum frameworks.

In some states, such as those with state adoption panels, development of selection criteria occurs at the state level. In other states, selection criteria are developed at the local level. In either case, decision makers should promote the development of selection criteria that are aligned with standards and curriculum frameworks. It is important that the set of district-and state approved criteria for selection of instructional materials go beyond textbooks to include innovative print materials, kits, calculators, software, manipulatives, and other tools that enhance the opportunities for students to learn mathematics and science.

"Alignment with standards" has already taken on many meanings. For example, some publishers have claimed alignment of their science textbooks with the NRC Standards by making a quick match with the list of content standards. It is essential for those selecting materials to ask the harder question: Will students gain fundamental understandings from this material? A careful analysis is required that examines how activities and information in the instructional materials connect to help students build such understandings.

State-level educators need to think carefully about what it means to be "standards-based" as they develop their selection criteria and/or assist districts to develop their own. Every state has well-qualified professionals ranging from classroom teachers to curriculum specialists to university faculty who have thought about the NCTM and NRC Standards. Many have experience with the large-scale curriculum development efforts funded by NSF that attended to standards in their development. This expertise should be used as states design strategies and build capacity for materials selection. Part of this capacity building is encouraging district selection committees not to "undo" states' good selection criteria, by applying outdated or restrictive criteria.

As an example of state activity, Ohio's Statewide Systemic Initiative, *Discovery,* and the Eisenhower National Clearinghouse collaborated to review current middle grades science curricula, assessing the areas in which they align with the NRC Standards. Several sets of materials were reviewed, each by an educator familiar with the NRC Standards, using the *Discovery developed Middle Level Standards Based Inventory (grades 5-9).* Checked by independent reviewers and the material's developer or publisher, these summaries assist teachers, administrators, and parents in quickly accessing information about the NRC Standards and science curriculum materials.

2-B Commission evaluations of textbooks and other instructional materials by qualified professionals, and disseminate results to local adoption committees.

Efforts to describe and, in some cases, evaluate instructional materials and their alignment with standards are beginning to occur in some state agencies and other state, regional, and national organizations. But robust reviews are still rare, and many selection committees do not have access to them. State departments of education can fund and then disseminate reviews that will help state and local adoption committees make informed selections. Such reviews might be done by independent evaluators, with funding from agencies such as NSF or private foundations.

2-C Implement professional development programs that help school personnel effectively select textbooks and other instructional materials and integrate them into the science and mathematics curriculum and instructional practice.

Administrators and teachers are "the market" for textbooks and other instructional materials. Commercial publishers continually point out that their market analyses indicate uneven demand for "standards-based materials." Administrators and teachers influence the nature of the materials available to them; they are important members of material selection committees and they need to be prepared for these positions.

According to Tyson (1997), "training" evaluators of instructional materials is critical. She recommends developing selector training models that are "standards-driven, intellectually defensible, and informed by research. A deeper and more qualitative adoption process is the single most powerful way to improve textbooks" (p. 23).

As teachers and administrators become more analytical consumers of instructional materials, teachers will learn how to use them. Textbooks used wisely can complement a well-designed curriculum. Often, however, textbooks *are* the curriculum, and teachers use them in a lockstep fashion (Woodward & Elliott, 1990). This is sometimes due to teachers' belief systems or the culture of the school in which they teach. As observed in the Third International Mathematics and Science Study (TIMSS), experienced teachers are more likely to make judgments about which topics to develop and which to omit, in keeping with a curriculum design, while teachers with less preparation in science and mathematics, in difficult assignments and highly accountable situations, will proceed systematically from the front to the back of the textbook, covering each topic. They teach more and the students learn less (Schmidt et al., 1997).

A number of efforts are under way to assist school personnel with assessing and selecting instructional material aligned with standards. The NRC, for example, has held a series of conferences for curriculum developers, commercial publishers, materials adoption committees, and science educators from various levels to explore issues related to materials development, analysis, selection, and adaptation. A set of guidelines for the evaluation, selection, and adaptation of instructional materials aligned with the science standards is soon to be completed. A new NRC project, funded by the Robert W. Woodruff Foundation, will further develop these guidelines into a set of criteria for material evaluation, and design and pilot a process for doing so by teams of local educators and scientists. NCTM, as well as MSEB, is seriously considering ways to help teachers understand the nature of the materials from which they choose to teach.

RECOMMENDATION 3. CURRICULUM

Structure policies and support to focus districts and schools on designing science and mathematics curricula that are high quality, well-articulated, and standards-based.

Students need well designed, comprehensive, and coordinated experiences to help them learn important mathematics and science concepts. Although the term "curriculum" has different meanings for different people, in this report we view curriculum as the way content is designed and used with students. A textbook is *not* the curriculum.

The results of TIMSS (NCES, 1996; Schmidt et al., 1996) and other international studies (Black & Atkin, 1996) indicate the need for a more coherent curriculum for U.S. students. Changes that will bring greater coherence to the school mathematics and science curriculum include the following: vertical integration of experiences across grade levels and between elementary, middle, and high schools; coordination of mathematics and science learning, when appropriate; equitable opportunities for all students; and a well-thought-out curriculum framework that will influence selection and implementation of instructional materials. All of these changes should focus on achievement of a common set of standards. States can support these changes in several ways:

3-A Provide technical, financial, and material support to local districts for the design and implementation of programs in which all students have opportunities to meet standards for mathematics and science.

Interpretation and implementation of standards call for a thoroughly conceptualized and carefully-orchestrated plan. It is not enough to create standards; support for understanding the content, changing practice, and making assessments part of learning is critical. The resources necessary to implement a standards-based curriculum may be more than those required of a more traditional program. States can provide districts with information about best practices in other districts and states so that they can, for example, develop strategies for reallocating existing funds; phase in a new program unit by unit, or grade by grade; equip materials support centers in cooperation with other districts; and create partnerships with business and industry to design, implement, and subsidize standards-based programs (National Science Resources Center [NSRC], 1997).

Many states have developed curriculum frameworks that take standards one step closer to the classroom, informing teachers and administrators about the meaning of standards, and suggesting how to design and organize instructional materials and learning experiences so their students will achieve the knowledge and skills described in the standards. Some states assist or encourage districts to align specific instructional units and courses of study with standards. This encourages vertical (K-12) and horizontal (within grade level) integration of the school program for mathematics and science. Working together, teachers and administrators can trace a standard through their curriculum and ask the question: When and how will students have the opportunity to develop this understanding or ability? This process can ensure that important concepts are introduced and further developed through the grades, although the courses of study may look substantially different from district to district.

As an example, Michigan's state curriculum framework provides districts with specific guidance in designing their curriculum so that it is aligned with the state benchmarks and objectives. Their science framework gives several examples of how districts can construct their own elementary, middle, and high school curriculum frameworks using commercially available programs, individual units developed by the Michigan Department of Education, chapters from textbooks that have incorporated hands-on activities, teacher-developed investigations, and special projects of various kinds.

Any effort to improve the curriculum through design of a framework and selection of new instructional materials should also include a plan for the implementation of the new program--a plan that addresses the long-term nature of the change process; the need to identify and coordinate the actions of a variety of players and system components; and the attention required by individual teachers and administrators, school-based teams or departments, whole schools, and districts (Fullan, 1991; Hall & Hord, 1987). Further, implementation of changes needs to be based soundly on accurate data about the needs of teachers and student learning. As noted in the discussion of long-term state policy planning, local plans must have data-driven milestones to monitor progress and trigger mid-course corrections.

3-B Base high school graduation requirements, university placement tests, and university admission requirements on standards.

There are many obstacles to comprehensive change based on standards. For example, students whose K-12 curriculum emphasizes depth of study over breadth of coverage may not do well on traditional entrance or placement exams for university study. If their coursework does not resemble the courses a university requires for admission, they will not be admitted.

Changing to a standards-based approach to mathematics and science education brings with it criteria for success other than completion of courses and number of years of study. States need to consider new criteria based on standards and ways to demonstrate success, such as performance assessments or portfolios, for graduating from high school. Further, they need to explore with colleges and universities alternatives to current admission requirements and placement tests, in order to dispel the disincentives that currently exist for educators to use standards as their goal for achievement. Standards-based university admissions policies are beginning to emerge. For example, the North Carolina School for Science and Mathematics produces highly qualified seniors who do not take traditional high school courses, but instead participate in rigorous, applications-based, hands-on courses in mathematics and science. The school worked with top universities across the nation to accept their students based on portfolios of their work reflecting standards.

Students kept chemistry and physics lab manuals and records of their mathematics work to demonstrate what they had completed in high school. Using these sources, students consistently placed out of college courses, often receiving college credit for their work.

3-C Put in place in every school classroom new technologies that support standards-based teaching and learning of mathematics and science.

Technology includes computers, calculators, and other learning tools that can help students achieve high standards in mathematics and science. Further, technological tools can help teachers enhance their strategies for instruction. Research indicates that technology can help learners understand mathematics and science concepts more deeply and effectively (Heid, 1988; Hembree & Dessart, 1986), and that there are promising ways that technology can serve teachers' needs. Initiatives in every state are currently under way to address the enormous challenge of resources needed for technology. The issues of procuring equipment, wiring schools, preparing teachers, ensuring equitable access, and addressing the frequent obsolescence of both hardware and software need to be addressed as part of a plan to move schools into the 21st century.

RECOMMENDATION 4. TEACHING

Create policies and practices to ensure that well-qualified, highly competent teachers, whose practice is grounded in the mathematics and science standards, are in every elementary school, mathematics, and science classroom in the state.

The development of standards at national, state, and local levels has heightened awareness once more of the critical role of the teacher in student learning. But it is also the case that many of today's teachers are not adequately prepared or supported to perform in ways required by the standards. Further, the projection that, in the next decade, the U.S. will need to hire more than two million teachers due to increases in enrollment and replacement of teachers who retire or leave in the early years of teaching (NCTAF, 1996) demands immediate attention to preparation programs and licensing procedures.

There are some promising efforts under way to improve the quality of teachers and teaching that incorporate national standards. These efforts, or initiatives similar to these, can become part of a state's strategy. The report *What Matters Most: Teaching for America's Future* (NCTAF, 1996) is an especially useful resource for states and others who are interested in this area. Our first three recommendations centered on teaching reflect one of its statements: "...the three-legged stool of quality assurance-teacher education program accreditation, initial teacher licensing, and advanced professional certification-is becoming more sturdy as a continuum of standards has been developed to guide teacher learning across the career" (p. 29). Related to these three stages in teachers' careers, which are addressed as well in several NRC reports (NRC, 1995a, 1996b, 1997b), we recommend that states takes steps to move in the following directions:

4-A Accredit only teacher preparation programs that reflect the recommendations of mathematics and science standards.

4-B Incorporate as a requirement for licensing that teachers demonstrate teaching practices that are based on standards and are appropriate to the particular learning situation.

4-C Support the continuing professional development of accomplished teachers through mechanisms such as the National Board for Professional Teaching Standards.

The national standards have a bearing on each of these recommendations. In mathematics, the *Professional Standards for Teaching Mathematics* (NCTM, 1991) provide discussion about modeling good mathematics teaching, knowledge of mathematics, and developing as a teacher of mathematics. The NRC Standards include a section on "standards for professional development for teachers of science." The documents describe in detail what teachers need to know and be able to do, and the nature of teacher development programs that best develop teachers' knowledge and skills. Both sets of standards address the depth of content knowledge required for teaching at different levels of schooling-not in terms of courses, but in terms of knowledge and skills. Both also address how teachers can learn to teach their content, the characteristics of preparation programs that help them do so, and the clinical experiences needed to apply what they learn in actual classrooms and schools.

Three quality control mechanisms for improving teaching currently available to states draw heavily on the mathematics and science standards. Nationally, these include the National Council for Accreditation of Teacher Education (NCATE), which accredits teacher preparation programs; the Interstate New Teacher Assessment and Support Consortium (INTASC), which is developing performance-based licensure for teachers; and the National Board for Professional Teaching Standards (NBPTS), which is developing challenging performance assessments for certifying accomplished teachers (NBPTS, 1994). State and regional accreditation and licensure entities also exist. States can take advantage of these national efforts by either becoming partners with them or developing their own similar mechanisms tailored to specific state needs and/or standards.

The NRC and NCTM have both learned from and contributed to the work of NCATE, INTASC, and NBPTS, and the issues these efforts are addressing. For example, an NRC colloquium for state teams centered on teacher credentialing and licensure discussed the implications of the national science standards and resulted in action plans by each participating team (NRC, 1996b). NCTM is responsible for developing the guidelines and reviewing the NCATE folio mathematics and mathematics education components. (Folios are the self-studies of the teacher preparation programs being accredited.) NRC has issued two reports on the preparation of teachers of mathematics (NRC, 1995a) and of science (NRC, 1997b). These reports address a particular concern of the NRC that states and institutions of higher education are beginning to attend to: the critical need for undergraduate mathematics and science courses to be "standards-based" in both content and instruction. Until this occurs, teachers will not be adequately prepared to teach these disciplines.

States are actively addressing these issues of quality control in teaching. For example, representatives of major teacher education institutions in Texas have developed a set of voluntary standards entitled *Guidelines for the Mathematics Preparation of Elementary Teachers.* These guidelines support the state's recently adopted standards-based K-12 mathematics curriculum. After development of these standards, institutions across the state applied for funding from the Texas Statewide Systemic Initiative, the Higher Education Coordinating Board, and other funding sources to develop programs to implement the standards. Across the state of Texas, future elementary teachers will receive dramatically different mathematics preparation, focusing on deep understanding of important mathematical ideas. Parallel efforts in elementary science and in secondary mathematics and science are now under way.

As another example, through its Beginning Educator Support and Training (BEST) Program, Connecticut offers a variety of state-level innovations to improve the qualifications of beginning teachers and increase the likelihood that they will receive a solid foundation for sustained excellence in the classroom. During the first year of teaching, novices receive help from a school-based mentor or mentor team. Beginning teacher clinics, conducted by state-trained assessors through observation or videotape, help teachers prepare for the assessment of essential, basic teaching competencies. First and second-year teachers' abilities are assessed using the INTASC standards. Teachers develop portfolios of their work, including videotapes of specific lessons that reflect the teaching expected by new student standards, analysis of student work, and written descriptions of ways in which they adapt instruction to the needs of individual learners.

Ensuring the quality of preparation programs and teachers entering the profession is one thing; assisting those already in teaching positions to help their students achieve national standards is the role of ongoing professional development. Therefore, a final recommendation related to teaching centers on this area:

4-D Fund ongoing, high-quality professional development opportunities for teachers of science and mathematics based on standards for student learning and professional teaching.

Professional development is a common strategy used by states to support reform in science and mathematics education. For example, it is a high priority in 18 of the 25 states receiving NSF resources for statewide systemic initiatives. Although Zucker (1997) points out that "delivering high-quality professional development is something that we as a nation know how to do," it is not always done well, nor may the nature of current professional development efforts serve the agenda of standards-based reform (Little, 1993).

Research on professional development indicates that formats common to science and mathematics teacher professional development, such as training workshops and institutes, may not always be appropriate for the changes that are both broad-scale (i.e., across departments and schools) and deep (through curriculum, teaching, and assessment), as required by current reforms (Fullan & Hargreaves, 1991; Little, 1993). Rather than relying on the "expertdriven" model that takes teachers out of their schools to learn from outsiders, teachers need more opportunities that bring them together to learn in the context of their own programs, with their own students in mind (Ball, 1997; Ferrini-Mundy, 1997). Loucks-Horsley and her associates (in press) have described 15 different strategies for professional development, including professional networks, case discussions, mentoring for beginning teachers, and study groups, that can be combined in unique ways to meet the ongoing learning needs of teachers in their efforts to help students meet new and rigorous standards. Cohen and Hill (1997) have found in their research in California that professional development that is based on particular curricular materials is related strongly to student achievement.

Several states, including Colorado and Michigan, have developed standards for professional development in mathematics and science as guidelines for professional development planning by local educators and external "providers." In addition to encouraging new formats for professional development, these standards emphasize professional development as part of a teachers' daily work through opportunities for joint planning, curriculum and assessment work, research, and problem solving with colleagues. They also stress the importance of tying professional development to the curriculum teachers are teaching so they can put into practice what they are learning.

States are also sponsoring their own professional development programs. For example, a key component of the Arkansas Statewide Systemic Initiative is the teacher training and professional development programs that have been developed around the NCTM Standards, the NRC Standards, and the Arkansas Science and Mathematics Curriculum Frameworks. A professional development program of particular interest is the K-4 Crusade, a two-semester, standards-based course that is offered at 11 of the state's universities and is open to all K-4 teachers and administrators. Although it is not a mandatory program, the state's accreditation standards require that all teachers participate in 30 hours of professional development every year. The goal of the K-4 Crusade is to provide teachers with high-quality content, teaching strategies, critical-thinking skills, technology, and hands-on materials to strengthen their teaching practices. The belief behind the program is that high-quality professional development programs help teachers communicate curriculum materials to students more effectively and, consequently, may play a role in increasing a student's ability to learn.

California provides an example of a different approach to professional development for mathematics and science reform. In that state, professional networks are sponsored by several entities, including the state, the university system, and federal programs such as the NSF-funded statewide systemic initiative. The Subject Matter Projects, which offer summer institutes and follow-up support, occur in 11 curricular areas and focus on individual teacher development. The Mathematics Renaissance and California Science Implementation Network each work with hundreds of schools and their staffs in middle school mathematics and elementary school science, respectively. These networks have a broad infrastructure staffed by teacher leaders who work to build school as well as individual teacher capacity for teaching aligned with the state frameworks and national standards.

Both the NCTM and NRC have had and will continue to have initiatives aimed at helping teachers learn what they need to know to better teach their students, through development of reports, and opportunities for dialogue. NCTM in particular has a standing committee focused on professional development. In addition, each of the 14 other NCTM standing committees has been charged to design a professional development strategy for the Board's consideration.

RECOMMENDATION 5. ASSESSMENT

Establish testing and assessment programs consistent with the goal of high expectations for all students to learn standards-based mathematics and science.

Assessment is a major component of efforts to promote improved student learning in mathematics and science. There are a number of instances where assessment has been used as a driver for reformed teaching practice, for example, in the states of Connecticut and Texas. The national standards argue for aligned changes in all areas of program, practice, and policy; changes in assessment need to be coordinated with state standards and frameworks. State roles in assessment are, as in teaching, many-fold. First, for purposes of accountability, states create state assessment systems and require or encourage their use by local educators. States sometimes impose high-stakes assessments with consequences for schools and districts. Also, states can support the development or identification and use of new forms of assessment by teachers and administrators, primarily for instructional purposes. States also can encourage teacher professional development in the area of assessment. All of these roles are addressed in the following recommendations:

5-A Ensure that assessments of student learning are aligned with standards based curriculum and assessment principles.

From the beginning of the standards-based reform movement, state policy makers have worked to create assessments that are aligned with their new content standards and curriculum frameworks. As with the development of standards and frameworks, progress in assessment development has been steady and incremental, although the speed of change has varied among states (Massell et al., 1997). A recent report of the Council of Chief State School Officers (1996b) indicates that, for the 1994-95 school year, 33 states had science assessments and 46 had mathematics assessments. Most assessments combined different forms of test items, with many using open-ended and response tasks. (See Figure 4 for more detail.)

Gauging the alignment of new assessments with standards is a complex process (Webb, 1997). Interestingly, U.S. Department of Education Assistant Secretary for Elementary and Secondary Education Gerald Tirozzi noted that state standards as measured by states' own assessments may not be high enough (1997). According to Tirozzi, in several states, large percentages of students scored well on tests based on their state standards, while a far lower percentage did well on NAEP tests, which are perceived to be based on national standards. Although states generally are working on standards, existing state assessments may not yet be good indicators of the impact of these efforts.

As in other areas of the reform movement, many of the complexities of assessment have been revealed only as attempts to develop reliable, valid, and useful measures have progressed, and these measures have been implemented, either as pilots or full-scale. The SRI study of the 25 states funded by NSF for statewide systemic initiatives notes progress, but reports a mismatch in many states between the state goals established for student learning in standards and curriculum frameworks, and the content of state-mandated tests (Zucker, 1997). This is due, in part, to two difficulties in assessment development (Massell et al., 1997). The first difficulty stems from states' interests in having their assessments serve multiple purposes, in particular, both instructional improvement and accountability. This has resulted in technical problems as states have explored the promising uses of performance assessments, such as ensuring reliability and validity. In an attempt to deal with these technical issues, some states have pooled their fiscal and intellectual resources in collaboratives focused on designing and piloting performance assessments, such as the New Standards Project and the State Collaborative on Assessment and Student Standards (SCASS) initiative of the CCSSO (1997b).

One strategy to address political issues centered on assessment is to adopt a "mixed assessment model," which incorporates both multiple choice and performance items and targets basic as well as higher-order skills. Thus assessment has joined standards in this recent move towards "balance" in approach to reform, which seems to be leading to more public support and achievement of some, if not all, policy objectives (Massell et al., 1997).

Alignment of assessments with standards-based curriculum is a simple idea but, as noted, fraught with challenges. Our recommendation is that policy makers "stay the course" in working towards this goal, continuing to make progress, if slower than some have hoped.

5-B Develop at the state level, or encourage local districts to develop, strong accountability systems that go beyond single-measure tests.

An issue that every state and district must address is how to show progress in standards-based reforms while the plan is unfolding. Gains in student learning are unlikely to be demonstrated immediately, given that assessment systems aligned with standards are under development and changes may not have occurred or stabilized in teaching practices. States should establish intermediate milestones, such as specific changes in district policies and curriculum, numbers of students enrolled in reformulated courses, and changes in teaching practices, then monitor these indicators and hold themselves accountable over time. An explicit

FIGURE 4. Status of State Assessments, 1994-95 School Year

For science, 33 states had assessment programs. Nineteen of these used criterion-referenced tests; the same number used norm-referenced tests (the overlap means that some states used a combination of both). Of the 25 states that used non-traditional exercises, 5 used enhanced multiple choice items; 15 used extended response or short, open-ended response items; and 7 used individual performance tests. Twenty states have set performance standards or acceptable levels of school or student performance. For mathematics, 46 states had assessment programs. Thirty-one of these used criterion-referenced tests; the same number used norm-referenced tests (the overlap means that some states used a combination of both). Of the 35 states that used nontraditional exercises, 12 used enhanced multiple choice items; 31 used extended response or short, open-ended response items; and 8 used individual performance tests. Twenty-nine states have set performance standards or acceptable levels of school or student performance.

From: CCSSO (1996b). State student assessment programs data-base for the 1994-95 school year Washington, DC: Author.

plan with defined milestones to indicate progress can help sustain support by the public, policy makers, business, and professional educators.

Kentucky provides an example of a state that has devised a new approach to statewide assessment. The Kentucky Instructional Results and Information System (KIRIS) represents a comprehensive use of performance assessments as part of the state's accountability system. Over time the state has developed an accountability index that incorporates information from student performance tasks, multiple choice items, and mathematics portfolios.

As another state example, the Texas Academic Excellence Indicator System (AEIS) is a report card for schools and districts that provides a comprehensive set of indicators for school success. The accountability system provides appropriate rewards to schools and districts for high performance and equity, and sanctions for low performance and inequity, by reporting performance not only for a school or district, but also for various ethnic, gender, and socio-economic groups within the school or district. Schools must show comparable performance across all subgroups, with state-defined target performance rates raised each year to ensure growth toward equally high performance among all groups. AEIS indicators include, among others, student performance on the state assessment program and on other standardized measures, correlations between grades and performance, data on participation in advanced academic programs, and data on dropouts and attendance. This accountability system is based on the state's mandated standards-based curriculum as measured on the state assessment.

Although multiple measures are critical to understanding and documenting student learning, states and districts must guard against overtesting. Burdening students, teachers, and schools with undue data collection takes away from important instructional time and attendance.

5-C Collect and use information about learning conditions and the opportunities students have to learn.

With the standards movement largely directed at helping students reach ambitious learning goals, it is easy for assessment to be viewed primarily as measures of student learning. Yet teachers, principals, and local educators responsible for designing and delivering high quality science and mathematics education cannot make informed decisions without meaningful data about what actually goes on in classrooms: data on curriculum, instruction, and classroom conditions. As Martin, Blank, and Smithson (1996, p. 2) point out, "Clearly, a key ingredient to sound policy and program decisions is accurate and relevant information." A major component of the State Collaborative on Assessment and Student Standards (SCASS), a project of the CCSSO, addresses the issue that education systems are not well organized to systematically collect and report the kinds of data that are helpful for such decisions.

Both national and international studies have pointed out the importance of having such data-called students' *opportunity to learn*-in order to interpret student test scores (Porter, Kirst, Osthoff, Smithson, & Schneider, 1993; Schmidt et al., 1996; Stigler et al., in press). The connection between student learning and the teaching, curriculum, assessment, and support that are required for it to be successful is an important theme in both the NRC and NCTM Standards. It is also key to achieving the "science and mathematics for all" vision, for without opportunities for learning, *all* students cannot develop the concepts and skills described in the content standards for mathematics and science. A recent report of the NRC (1997c), which commented on the proposed national test in mathematics, makes this argument also: "It will be very difficult to interpret test results meaningfully, and to make constructive use of them, without a measure of what opportunities students have had to learn the mathematics that is being tested" (p. 3).

Many states have addressed the need to assess students' opportunity to learn. Some have done so through involvement with SCASS. In

New Jersey, state leadership has "openly embraced opportunity-to-learn standards as part of a strategic plan to improve education and address equity" (Massell et al., 1997, p. 48).

5-D Assist schools and the general community to understand and use the results of assessments and develop action plans based on results.

Reflection and understanding based on observation and evidence are at the core of science and mathematics. Assessment of student progress should be based on multiple sources of evidence. State reporting systems caution against reading too much into a single score and against using assessment results for purposes that do not match those for which the assessment was designed.

Public understanding and support are especially important in the area of assessment. Educators face a number of challenges in developing and maintaining public support for new assessments. In some cases, students who score well on traditional assessments have not done well on new ones, resulting in opposition to the new tests. Because test development is so technical, the strategy of involving people so as to gain their ownership and support is problematic. New laws in both Texas and California incorporate non-educator involvement in test development; it is unclear how this will influence future directions in these states and in other locations. Public relations efforts to help promote understanding of unfamiliar assessment strategies are needed (NRC, 1997c).

States have an important role in providing resources, supporting, and encouraging local educators to build systems at district, school, and classroom levels to gather appropriate information from assessment for use in design and improvement of standards-based education for their students. This role can be played in different ways, from the more direct requirement for school plans based on data, to the support of professional development for teachers and administrators to learn alternative approaches to classroom assessment. At the national level, an action strategy for improving middle grades mathematics education is being developed simultaneously with the national eighth grade mathematics exam. This may prove to be an example of how assessment and a strategy for improvement can be linked.

5-E Promote teacher assessment and student self-assessment in classrooms, based on standards.

Both the NRC and NCTM assessment standards make a strong case for assessment in the service of instruction. Some of the issues involved are addressed by two NRC publications, *Measuring What Counts: A Conceptual Guide for Mathematics Assessment* (1993a) and *Measuring Up: Prototypes for Mathematics Assessment* (1993b), developed with contributions from NCTM leaders. These sources establish crucial research-based connections between standards and assessment, and provide examples of new assessment exercises that can be appropriately embedded in instruction. Because new forms of assessment, measuring the new learning goals represented in the Standards, are substantially different from teachers' common practice, professional development is crucial. Not only must teachers change their practices, they must also help their students, parents, and the community understand the purposes, procedures, and benefits of such changes.

To the extent that assessments drive instruction, assessments that provide authentic pictures of student learning can be important sources of both pressure and information for educators as they work to implement standards.

Conclusion

The national standards in mathematics and science developed by the National Council of Teachers of Mathematics and the National Research Council comprise an important foundation for the changes that must occur if our students are to achieve to world-class levels and become the informed and literate citizens needed for the 21st century. States have made substantial and steady progress in their constitutionally mandated role of educating their students, launching reform initiatives in the important areas of curriculum, textbooks, teaching, and assessment, and building their infrastructures to support change. Support from the President, the nation's governors, and key business leaders has converged with the results of international studies that give substantial guidance for mathematics and science education reform.

The actions identified in this report represent a way to meld the experiences and strategies of those who wrote and support the national standards with activities of the states as they move forward in standards-based reform, to the ultimate benefit of all students in the United States.

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