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ABSTRACT

A 1992 conference on mathematics and science teaching focused on two specific topics: enhanced professional development for educators and better instructional materials for the classroom. Teachers, members of Congress, governors, teacher educators, professors, researchers, and policymakers shared what they believed was needed to be done to improve mathematics and science education in the United States. This booklet reports the views of the participants and the general consensus of the conference regarding changes needed in the education system. The concepts of systemic reform in education and the setting of national standards as exemplified by the National Council of Teachers of Mathematics are discussed in section 1. The second section discusses the necessity of providing all children with an opportunity to learn mathematics and science. The third section reports the participants' views emphasizing courses that teach mathematics and science for understanding. The fourth section discusses the necessity to prepare teachers of math and science to higher standards of skill and knowledge. Extensive professional development to help practicing teachers enhance their skills is suggested. The fifth section examines the need for the development of better instructional materials for the mathematics and science classroom. Finally, 20 recommendations in the following 4 themes are reported: (1) standards; (2) improving mathematics and science teaching; (3) instructional materials; and (4) systemic change. A list of presenters and demonstrators and a statement of principles on school reform in mathematics and science are provided. (MDH)

Improving Math and Science Teaching

To be "...first in the world in science and mathematics..."

A Report on the Secretary's Second Conference on Mathematics and Science

Office of Educational Research and Improvement

U.S. Department of Education

The U.S. Department of Education is sponsoring a series of conferences for policymakers on improving mathematics and science education. The first conference, held in December 1991, spotlighted state curricula and ways to improve teaching toward world class standards. It mixed some of the best ideas on curriculum improvement and grounded them in the experience of state decisionmakers. This report summarizes the second conference, held in October 1992, which focused on teaching and instructional resources. The third conference, which OERI is planning, will focus on mathematics and science assessment.

The first conference is summarized in a report, *Improving the Math and Science Curriculum: Choices for State Policymakers*. It is available for $2.25 from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 371954, Pittsburgh, PA 15250–7954. Ask for stock number 065–000–00547–6.

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Improving Math and Science Teaching

A Report on the Secretary's October 1992 Conference on Improving Mathematics and Science Teaching and Instructional Resources

Kay McKinney
Programs for the Improvement of Practice

Office of Educational Research and Improvement
U.S. Department of Education

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Acting Assistant Secretary

Programs for the Improvement of Practice
Eve M. Bither
Director

February 1993

Contents

This conference was held on October 8 and 9, 1992. Therefore, the titles and names of officials listed in this report reflect their status at that time.

Systemic Reform

Systemic reform begins with clear standards, with a solid consensus on what children should know and be able to do. Standards enable people to work on every part of the system at the same time because they share a common goal: better outcomes for students geared to clear standards. Standards allow students, teachers, administrators, teacher educators, textbook publishers, testmakers, and parents to work together for educational success.

In the absence of consensus about standards, systemic reform is impossible, because each part of the system will continue doing what it is already doing. The gap between the pieces will be even larger, as different parts of the system continue to push in different directions. Without consensus on standards, systemic reform is jargon without meaning.

Foreword

A little more than 3 years ago, the President and the nation's governors set six national education goals for our country to reach by the year 2000—now less than 7 years away. While all are ambitious, the fourth goal, which states that American students will be first in the world in mathematics and science achievement, is especially challenging. If we hope to achieve that goal, we must radically change what goes on in our classrooms—both what we teach and how we teach it.

To kindle the "can do" spirit and to help educators and policymakers find better ways to achieve this goal, the U.S. Department of Education held the second in a series of three conferences on improving mathematics and science education.

The conference was dedicated to showing how many—although not nearly enough—of America's classrooms are changing. We asked outstanding educators to show us how they are teaching mathematics and science for understanding. We used videos to showcase other exciting programs as well as instructional resources that support such teaching. We also invited members of Congress, governors, teachers, teacher educators, professors, researchers, and policymakers to share with us what they believe needs to be done to improve mathematics and science education in this country.

There was little disagreement about the direction in which we need to move. Many good ideas surfaced, but one that came up again and again was the importance of setting national standards that make it clear what we want our children to learn and what we want our teachers to teach. Establishing standards both raises expectations and lets everyone in the education system know what to aim for.

The consensus about the importance of standards is exciting because we believe that explicit standards can promote both equity and excellence. We believe that they can provide the basis

for improving the education of our nation's children. Standards will give educators, for the first time, the consensus that is needed to improve and align teacher certification, textbooks, assessments, teacher education, and staff development. Standards are the foundation on which we can build a new education system.

The conference also made it clear that if American students are to be first in the world in mathematics and science achievement by the year 2000—

- We must provide *all* children the opportunity to learn much more than just the basics of mathematics and science.
- We must teach mathematics and science for understanding.
- We must prepare teachers of mathematics and science to higher standards of skill and knowledge.
- We must generate better and different instructional materials.

To do this means that the education system, as we know it, must undergo a significant transformation. Change is never easy, but it is possible. Perhaps Senator Thad Cochran from Mississippi summed it up best when he said, "We should be challenged by the goals, and not overwhelmed or throw up our hands and say it can't be done."

It CAN be done. But more importantly, it MUST be done. I hope you will join us in beginning this transformation by making sure that your state participates in developing standards and your students have an opportunity to benefit from them. And I hope that you will take what we have learned from this conference and use it so that our children will indeed be first in the world in mathematics and science achievement by the year 2000.

Emerson J. Elliott
Acting Assistant Secretary
Office of Educational Research and Improvement

Setting the Stage for Change

Imagine the urgency of repairing a faltering airplane (on which you're a passenger) while it's in flight. This metaphor suggests the urgency of overhauling how we teach mathematics and science in this country. All passengers—children, parents, educators, business leaders, and citizens—will suffer the consequences if we fail, or reap the benefits if the repair work is a success.

That is the picture painted at a conference on improving the teaching of mathematics and science sponsored by the U.S. Department of Education in October 1992. While several steps need to be taken to strengthen the teaching of these subjects, the conference focused on two specific topics: enhanced professional development for educators and better instructional materials for the classroom.

However, if we hope to make a tangible difference in the mathematics and science achievement of American students, we must approach this enormous task by changing all parts of the education system, according to Eve M. Bither, counselor for mathematics and science education in the Office of Educational Research and Improvement (OERI).

Making piecemeal improvements in one area at a time is not the answer, according to those who attended the second Secretary's Conference on Improving Mathematics and Science Teaching coordinated by OERI. Although "systemic reform" may sound like just another bureaucratic phrase, it is much more than jargon. And, it is as necessary for our nation's educational health as lowering cholesterol is for our physical health. Systemic reform means transforming all parts of the education system at the same time to achieve high standards of student performance. As Maine Governor John R. McKernan, Jr. explained, "You've heard of communities that have a good elementary school, or middle school, or high school, but not all three. Very few communities are doing well in all three; that's why we need to work in a

systemic manner." Moreover, systemic reform drives change; when you don't have system reform, change is only temporary.

Systemic reform is a new concept for the field of education, which is accustomed to doing one thing at a time, according to Barbara Nielsen, South Carolina's State Superintendent of Education. "We can't do that anymore," she said, explaining that South Carolina formed a collaborative council composed of representatives from private and public elementary and secondary schools, higher education, technical groups, and the community. Not only does this involve all the players, it brings everybody together "so that we can get the big picture" about what is happening in education in South Carolina, she said. She illustrated how systemic reform works by explaining that in South Carolina professional development isn't limited to teachers; it includes support staff as well.

Luther Williams, Assistant Director for Education and Human Resources at the National Science Foundation (NSF), highlighted the need for systemic reform, saying NSF is striving to enhance teacher development while at the same time working to restructure teacher education at the college level.

> American education stands at a turning point. We're moving, for the first time, toward a consensus on what we want our children to learn.
>
> *Diane Ravitch*

Rethinking just about every aspect of education is a major undertaking, one that requires developing a common vision. Conference presenters stressed that setting national standards that define what it is we want our children—all children—to know and be able to do is the best, and possibly only, place to begin this vision. As McKernan said, standards drive all other aspects of systemic reform by giving us a measure we can work toward; they give us a foundation on which to build.

The mathematics standards set by the National Council of Teachers of Mathematics (NCTM) point the way toward what needs to be done. They establish clear goals and create a consensus about what all children should learn. And they lay the foundation for a renewed education system because they let parents and teachers know what children are expected to learn. Teachers should be trained to teach to the new standards. Assessments should be designed to measure what we teach. Instructional materials should reflect the curriculum educators have established to meet the new standards. And, the NCTM's efforts show that no federal mandate is needed to develop standards, according to Diane Ravitch, OERI's Assistant Secretary. "If standards are good, they win the support of teachers," she said.

State policymakers should take the lead role in launching systemic reform. They are in a position to establish a policy framework—or set of guidelines—that defines what must be done in their states. It is their responsibility to push for standards in their states and to link teacher certification, student achievement, instructional materials, and assessment to these standards. Policymakers who set certification standards, for example, can make sure that their certification requirements address the new standards.

"Developing such integrated policies that actually relate to one another, not just at the same time, but on parallel tracks, is far different from developing the kind of education policies we have had in the past," said Susan Fuhrman, director of the Consortium for Policy Research in Education at Rutgers University. Such policies envision a much more sophisticated approach to instruction and are much more challenging and complex, she said. The challenge we face, she continued, "is a political system used to grinding out discrete, unintegrated, often contradictory fragmented policies, policies that bring credit to the author and are distinguished from whatever was there previously. We

certainly don't want that to happen to these new reform efforts, where a true effort has been made to create policies that link together." She suggested we may need to think of new mechanisms that "can buffer the systemic reforms for the long haul—mechanisms that may have to take on the revision of existing policies."

All Children Must Be Given the Opportunity to Learn Mathematics and Science

Although providing children with the opportunity to learn seems to be nothing more than common sense, we shortchange many students, assuming they can't learn mathematics and science. While everyone readily accepts the idea that all children need to learn how to read, many presume these same children need to learn nothing more than the basics when it comes to mathematics and science. Nothing could be further from the truth. The workplace is undergoing remarkable changes that require our students to learn new and different mathematics and science. "Other industrialized nations understand the importance of technology. Never before in history has new knowledge been generated at such a dizzying speed," said Philip Smith, executive officer of the National Research Council. These new technologies demand that our children—our future work force—become adept at problem solving, critical thinking, and reasoning. As James D. Watkins, U.S. Energy Secretary, said, the basic core disciplines are more important than ever before.

U.S. Education Secretary Lamar Alexander stressed that "all children must have the opportunity to learn mathematics and science," not just those who want to become professional scientists or mathematicians, or those going to college. In fact, "teachers must be inculcated to know that all children can learn and achieve," said Dan Chernow, former California State Board of Education member and Vice President and Assistant General Manager of Pacific Theatres in California. This is especially important when it comes to mathematics and science.

However, our education system continues to offer minimum math to most, algebra to some, and calculus to only a few. When it comes to international assessments, our children are barely ahead of Third World countries. Why? Not because they are incapable of

learning what students in other countries have learned, but because we don't give them the chance to study mathematics and science every year.

A serious mismatch exists between what our students are capable of learning and what they are taught, according to Iris Carl, past president of the National Council of Teachers of Mathematics. They need to have the opportunity to learn more than addition and subtraction. They need, according to Syracuse University biology and science education professor Marvin Druger, to be taught problem-solving skills early in life, and to apply a scientific approach to solving real-life problems. He believes students need to learn how to attack problems logically, and then get plenty of practice, feedback, adjustment, reinforcement, and more practice.

> Who wants to walk into a classroom with me and point out which children are not capable of learning math or science?
>
> *Franklin Smith*
> *Superintendent of*
> *Public Instruction*
> *District of Columbia*
> *Public Schools*

Carl also stressed that the groundwork for mathematics and science competence must be laid early, as early as kindergarten and first grade. She believes we must get the elementary education community involved "if we are going to build a mathematical tower." McKernan concurred, indicating that all elementary teachers need to have a basic understanding of mathematics and science concepts, and introduce children early to the excitement of mathematics and science learning. Yet many colleges continue to graduate elementary teachers with only a few hours of mathematics and science. This in turn, robs youngsters of the opportunity to learn these critical subjects.

We Must Teach Mathematics and Science for Understanding

Offering all children mathematics and science courses isn't enough. We must teach them to *understand* these subjects, to grasp underlying concepts. Just as importantly, we must help them understand *why* these subjects are important. As Druger explained it, "Science provides an objective, systematic way of interpreting the world around us; it helps us appreciate things in life and can help us make informed decisions about important issues" about our environment and our own lives. James Rutherford of the American Association for the Advancement of Science agreed. "Some basic technology, math, and science should be taught to all children," he said, and suggested several examples why. If you don't realize that designs always require trade-offs between benefits and costs, you can be misled by simplistic, one-issue arguments for or against technical innovations. If you don't understand that unlikely chance events may occur quite often in large populations, you will underestimate risks or overinterpret coincidences. Or, he suggested, if you don't understand that everything is made of invisibly small particles, you can make little coherent sense of mixing, melting, boiling, burning, or recycling of substances. Druger believes that when it comes to teaching math and science, teachers should teach for the effect on students in 20 years, not on what they need to know at the end of the course.

Both the videos shown throughout the conference and the 24 sessions demonstrating effective teaching and instructional resources made it clear that this type of teaching demands skills very different from traditional teaching skills. Teaching for understanding means students don't just memorize information but actively seek it, building relationships among data. It means that teachers are facilitators, not just preachers of facts. It means moving away from simply absorbing facts, to constructing knowledge. Druger explained that children have to have

opportunities to develop ideas for themselves. They don't just need to know what to do, but why they're doing it. And that, said Jeremy Kilpatrick, mathematics professor at the University of Georgia, "is definitely harder to teach."

Teaching for understanding means realizing that children need to know certain concepts, but not dictating *how* they must learn them. It means understanding that there is more than one way to solve a problem, or to learn a scientific concept. Such teaching is not going on in the majority of our classrooms today.

> It's important to let kids fail and try again. They come up with wonderful solutions if we give them the chance. After all, that's what scientists do all the time.
>
> *Sally Crissman*
> *National Center*
> *for Improving*
> *Science Education*
> *Andover, MA*

As the conference made clear, to teach for understanding we must shift from a teacher-centered classroom to a student-centered one. For example, interactive mathematics and science programs have students work in groups to solve open-ended, long-term problems. Working this way forces students into self-assessment; it rewards them for saying "I don't understand that," and challenges them to keep after it until they do understand, according to Diane Resek, mathematics professor at San Francisco State University. The shift from a teacher-centered classroom to a student-centered one puts the emphasis on students and their groups, rather than on straight lectures and textbooks.

To teach for understanding, teachers should provide students with hands-on experiences, not just paper-and-pencil assignments. They should introduce problems related to real life, not those that are neatly formulated. Third graders, for example, traditionally receive a great deal of instruction on how to get

exact responses to math problems, when in real life, knowing how to estimate is equally, if not more, important.

We must encourage children to explore, to develop their natural curiosity. A fourth-grade class's fascination with aphids on the plants in the school yard, for example, turned into a learning experience when they wondered how many of the minuscule bugs there were. To find out, they made a grid of the flower patch with string and proceeded to count.

Teaching for understanding is a challenge for teachers—as well as for policymakers who must guard against mandating assessments that undermine teachers who teach for understanding. Open-ended questions, teacher observation, student portfolios, self-assessments, and group projects are appropriate assessment tools, according to Kilpatrick, who expressed concern that the assessment system is not changing fast enough. Chernow echoed these concerns, urging states to establish realistic goals that measure what we expect students to know. Or, in the words of Carl, "What we teach must be valued; what we test is what must be taught."

We Must Prepare Teachers of Mathematics and Science to Higher Standards of Skill and Knowledge

It is a paradox that teachers—not policymakers or researchers—are being called upon to make changes in the way mathematics and science are taught. In fact, little will change unless teachers change it, Gary Sykes, associate professor from Michigan State University, pointed out. Yet colleges of education continue to educate teachers in traditional ways, while policymakers demand that they teach in non-traditional ways. We end up expecting children to learn what we don't educate teachers to teach.

What and how teachers are taught is essential to what and how students learn, Sykes said. Teachers' beliefs about mathematics, for example, influence what they do in the classroom. A teacher who believes that mathematics is nothing more than a series of number facts will teach it that way. Thus, to effectively change classroom teaching, we must change the way we educate new teachers, and provide better and more extensive professional development for experienced ones.

A belief that all children can learn must be at the heart of any and all teacher education and professional development. This is not to say that all children learn in the same way, or at the same pace. What it does say is that we must educate teachers not to make assumptions that only an elite few are capable of learning anything more than the basics of mathematics and science.

Elementary teachers also should have a command of these subjects, and thoroughly understand the content. "Like any other subject, mathematics and science are better taught when they are understood," said Kilpatrick. Before they can teach for understanding, teachers need to learn what the "big ideas are," such as proportionality and energy, and their connection to the real world, according to Carole E. Greenes, associate dean and professor of mathematics at Boston University. The scientific

community must help define the "big ideas." Audrey Champagne, a professor at State University of New York, stresses they also must place reasonable boundaries on exactly what content should be learned and taught. "It is extremely important for undergraduate science departments to ground scientific theory in the natural world," she added.

James Kelly, president of the National Board for Professional Teaching Standards, said that teachers also need to know how to manage and monitor student learning; continually improve their practice; and work collaboratively with parents, other teachers, and administrators.

Good teachers also do much more than assign workbook exercises. They teach mathematics and science in investigative ways, continually assess what their students are learning, and know which remedial strategies to use, according to Greenes. Teachers also need to know how to teach their students to explore ideas and how to allow them the flexibility they need to develop problem-solving skills. In other words, they need to do much more than lecture and drill.

If we expect students to construct mathematical and scientific knowledge for themselves, then it is critical that teachers learn by the same path. Yet this is not happening in most of our universities. In fact, the lecture format often used by the liberal arts faculty to teach mathematics and science courses to education majors will not bring about the improved teaching we want from elementary and secondary teachers.

College pedagogy courses should duplicate or model what we want the teaching of mathematics and science to look like in our classrooms. Sykes said that teachers must have an opportunity to learn in classrooms where the type of teaching we expect from them is taking place. This means the education and liberal arts faculties must begin to work together, team teaching in investigative ways to develop improved preservice programs for prospective mathematics and science teachers.

Besides educating future teachers, colleges and universities have a responsibility to encourage their best students to enter the teaching profession. Professors who recognize mathematics and science competence in students should urge them to become teachers. Champagne also indicated that scientists at research universities should encourage their best students to become teachers. Instead, these students are often encouraged to focus solely on doing research. That is not the case at one university, however. Antoine Michael Garibaldi, from Xavier University in New Orleans, noted that the university's president frequently asks his faculty members, "When was the last time you said to a student, 'You are good enough to be a teacher'?"

We must also help practicing teachers enhance their skills by providing better and more extensive professional development. It is just as critical that they know how to teach mathematics and science for understanding as it is for new teachers. Some teachers may resist, claiming they have been teaching the "old" way for 20 years and it's been working. But the fact is it isn't working.

> We expect teachers to teach what they have never learned.
>
> *Gary Sykes*
> *Associate Professor*
> *Michigan State University*

Despite its importance, professional development doesn't have the political support it needs. "You might say it lacks political legs," Fuhrman said. School leaders and policymakers can demonstrate their support for professional development by giving their teachers time to participate in programs to enhance their teaching skills. Policymakers often view inservice training as a stepping stone for salary increments rather than as a way to retrain teachers, according to Chernow.

Universities can contribute to professional development by offering courses when working teachers are free to take them—in the late afternoon or evening. As Champagne pointed out, "It is

awfully hard to educate teachers in science when the only time science courses are available is in the morning." She also urged the scientific community to enhance professional development by recognizing that science teachers are an essential part of their community. She added that while the leadership of many national associations say they understand that the nation's well-being depends on the level of our scientific knowledge, they continue to see teachers as separate from themselves, she said.

We Must Generate Better Instructional Materials

While most everyone agrees we need to teach for understanding, many of today's instructional materials are not designed for this type of instru ·on. Instead, many teachers still teach math and science using pen-and-pencil or worksheet activities, rather than the new hands-on manipulatives— materials that help students grasp concepts. Francie Alexander, Deputy Assistant Secretary of OERI, described the "old way" of teaching as an overreliance on print, pencil, and paper, and the ubiquitous use of textbooks that treat science as a foreign language, and teach little more than vocabulary. In mathematics, the teaching-by-telling approach, as ϵ mplified by the verse, "Yours is not to reason why, just invert and multiply," is overused, according to Alexander.

In reality, good instructional material means more than books. It can mean sophisticated videos. Or worms, toothpicks, and tweezers—the tools one teacher uses to teach about the anatomic features of birds, leading students to explore, to draw conclusions, and to develop hypotheses about what and how birds eat.

> Learning from books is education too, but acting like a bird is more fun.
>
> *Student in Garie Rose's ·lementary science class (Broward County, FL) where children pretend they are birds and use tweezers, clothespins, and other tools to pick food off the ground.*

How do we get the high quality instructional materials we need to teach science and math? Chernow urged having publishers gear materials towards curriculum frameworks that are based on world class standards. These standards should be the basis for all instructional materials.

Good instructional materials should be designed for students but

directed at the teacher, because it is the teacher, after all, who is in charge of the learning environment. Alexander contrasted this approach to the "teacher-proof" materials developed and used in the 1970s and 80s. She stressed that new materials should be connected to teacher enhancement and professional development and should address three important phases of a teacher's professional development: teachers as learners (mastering an understanding of mathematics and science); teachers as teachers (teaching for understanding); and teachers as leaders (using state-of-the-art instructional materials that further achievement of students).

To get these kinds of materials, educators must establish new partnerships with the publishing industry. The California Department of Education, for example, in cooperation with the private sector, developed a database of more than 150 activity-based interactive science lessons. Teachers and students use activity sheets, software, simulation, and video to author new lessons and reports. Today's technology makes these types of instructional materials readily available, and makes learning more fun for both teacher and student.

It is not enough to develop new materials. Carl stressed that we must allow—and encourage—teachers to move away from textbooks that haven't changed much and to use new hands-on materials. And Greenes suggested that curriculum specialists can foster the use of new materials by looking at manipulatives as well as textbooks when choosing materials for use in the classroom.

States should develop new policies for adopting instructional materials, policies that have teachers taking the lead in certifying materials. If the American Dental Association can give its seal of approval to toothpaste that meets its standards, why shouldn't the National Council of Teachers of Mathematics and other professional organizations give a seal of approval to learning materials that meet their standards?

Recommendations

The four themes that emerged from the conference serve as the basis for consensus building among those interested in improved mathematics and science teaching and instructional resources. While these themes in themselves stand as recommendations articulated by the participants, embodied in each are a variety of additional recommendations for policymakers, teachers, teacher educators, administrators, and publishers.

Standards

- Setting national standards is the key to improving mathematics and science instruction and materials. Setting standards raises expectations and lets everyone in the education system know what to aim for. The development of national science standards needs to be supported, encouraged, and embraced by everyone, just as the mathematics standards were. Standards will provide the consensus needed to improve teacher education, staff development, textbooks, and assessments.
- *All* children should receive the highest quality mathematics and science education possible.

Improving Mathematics and Science Teaching

- Teacher education must be reformed to ensure that teachers learn what they are supposed to teach. For example, if fourth graders are to learn science, then would-be teachers must study science.
- Higher education preservice should to be tied to the new national standards in mathematics, which currently exist, and to the science standards as they are developed.
- The new standards demand a new non-traditional model of teacher preparation, one that is hands-on, collaborative, inquiry-based, exploratory, technology-rich, school-based, and

university-connected. Both content and pedagogy, as well as materials and assessment, are integral parts of the whole. College pedagogy courses should duplicate or model this interactive way of teaching so that prospective teachers can learn the type of teaching expected of them.

- The scientific community must recognize that science and mathematics teachers are an essential part of their community. The best mathematics and science students should be encouraged to become teachers.
- In order to teach for understanding, preservice mathematics and science courses must be restructured so that they provide an indepth coverage of the core concepts connected to the real world rather than superficial treatment of a large number of topics.
- Preservice instruction in mathematics and science should be strengthened through courses that are team taught in an investigative manner by education and liberal arts faculty.
- Professional development for experienced teachers needs to be enhanced at the same time efforts are made to restructure teacher education at the college level. Lifelong development plans need to be considered to encourage professional development on a continuing basis after permanent certification.
- School leaders and policymakers can demonstrate their support for professional development by providing time for teachers to participate in programs that will enhance their ability to teach mathematics and science more effectively. Universities can contribute by offering courses when working teachers are able to enroll—late afternoon or evening.
- Schools should consider a longer school year for teachers, bringing them in line with other professionals. This would allow more time for teacher enhancement, including extended field experience, community work, and demonstration classes.

- School systems should strongly consider shifting toward specialist teaching in elementary mathematics and science, identifying 20 percent of the teachers and developing them into strong teachers in mathematics and science.

Instructional Materials

- National standards should be the basis for mathematics and science instructional materials. Traditionally, classrooms were teacher-centered and students were expected to learn through lectures—assisted by the technologies of textbook and chalkboard. The new standards in mathematics turn the old model on its head by insisting that the classroom be student-centered and that students learn by doing—supported by instructional materials that accommodate the learning needs of all students.
- The focal point of the new mathematics and science classroom should no longer be the textbook and teacher, but problems and experiments being discussed within and between groups of students. Classrooms should be activity-centered and include information technologies—such as computers, calculators, and televisions.
- Education technologies must be used to promote the new standards, not to reinforce the old curriculum through the use of computerized textbooks, drill sheets, and flash cards.
- Instructional materials used in the mathematics and science classroom should reflect the curriculum educators have established to meet the new standards.
- Publishers should gear mathematics and science materials toward curriculum frameworks that are based on national standards. New partnerships are needed between publishers and states to assure that these materials are developed.
- States should develop new policies for adopting instructional materials that have teachers take the lead in certifying materials.

Systemic Change

- To bring about the changes needed in mathematics and science instruction, the current education system must be changed in a systemic manner based on clear standards of what children should learn. State policymakers should take the lead in bringing about the change.
- Because of the interconnectedness of standards, curriculum, teacher preparation, the development of instructional materials, and assessment, systemic change must come to mean the coordinated reform of all these components—in all their dimensions—simultaneously.

Presenters and Demonstrators

The Department is indebted to the following individuals who made presentations, moderated panels, and lead demonstration sessions:

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Demonstrators

(Note: Demonstration titles are in **bold** and areas of emphasis in *italics*.)

Promoting Hands-On Education Through a Regional Student Weather Network

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Learning Through Hands-On Science

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When Elementary Students Do What Scientists Do

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300 Brickstone Square
Suite 900
Andover, MA 01810

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Problem-Based Learning Theory and Practice

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1500 West Sullivan Road
Aurora, IL 60506-1000

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Marsville: The Cosmic Village

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The Second Voyage of the Mimi

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Linking Educational Reform with the Effective Use of Technology

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Learning To Use Manipulatives in Teaching Mathematics

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Associate Professor
Community Service Center
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Gary Bitter
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Arizona State University
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Using Technology to Prepare Mathematics and Science Teachers

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Vanderbilt University
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Changing Practice: Teaching Mathematics for Understanding

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East Lansing, MI 48824
(We are saddened that Dr. Kirsner was killed in an automobile accident in December 1992. However, others at the Center can answer questions about this program.)

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Teaching for Number Sense Now!

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Initiating Systemic Change Through Science Instruction

Kathy Daiker
Center for Multisensory Learning
Lawrence Hall of Science
University of California
Berkeley, CA 94720

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The Mechanical Universe: A Conceptual Approach to Physics

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University of Dallas
1845 East Northgate Drive
Irving, TX 75062-4799

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Teaching Math and Science for Understanding

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SMART—Science and Mathematics Academies for Rural Teachers

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101 SW Main Street, Suite 500
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Problem Centered Mathematics Project

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Image Processing for Teaching: Exploration and Discovery in Science and Mathematics

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Lunar and Planetary Laboratory
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University of Arizona
Tucson, AZ 85721

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The Optimal Learning Environment: Science and the Interactive Classroom

D. Joseph Clark
Videodiscovery, Inc.
1700 Westlake Avenue, #600
Seattle, WA 98109

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Plugged In to Hands-On Science

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Education Industry Consultant
Shelco Creative Consulting
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Atlanta, GA 30319

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Statement of Principles on School Reform in Mathematics and Science

To help make the most efficient use of limited federal resources, the U.S. Department of Education and the National Science Foundation are collaborating on ways to improve mathematics and science education. The agencies signed a memorandum of understanding agreeing to regularly share information and to work together on projects that capitalize on the strengths and experience of both agencies. The following is the text of *Statement of Principles*, a brochure that outlines the principles the agencies agreed to work towards.

The U.S. Department of Education and the National Science Foundation agree that all children should receive a challenging education in mathematics and science based on world class standards beginning in kindergarten and continuing every year through grade 12. We therefore declare that we will act in concert to improve the teaching and learning of mathematics and science in the United States in order to advance the nation towards the fourth national education goal. In our collaboration, we will adhere to the following principles:

General

Communities, states, and the federal government must work in a collaborative partnership to improve mathematics and science education.

The educational enterprise is a system with many parts, all of which must change in concert to meet the requirements of the 21st century.

National Standards

National content standards for students (what children should know and be able to do) must be developed and utilized as the basis for all other improvement activities, including instructional practices, assessment, and teacher preparation.

National content, assessment, and teacher preparation standards will serve as the foundation for grants to states to reform curriculum frameworks and local curricula, and for reform of instructional methods,

textbooks, teacher education and certification, inservice programs, and student assessment.

Curricula

States should develop comprehensive standards-based K-12 curriculum frameworks, which establish a sequential program of learning in mathematics and science for all children.

The use of new technologies and their influence on increasing student achievement in mathematics and science should be supported through research and development activities at national centers, regional laboratories, and other pertinent institutions.

Textbook publishers and developers of instructional materials should ensure a change in their products to support the new national content standards through improved instructional practices such as problem-solving activities, creative student learning tasks, and cooperative learning.

Curricula should promote active learning, inquiry, problem solving, cooperative learning, and other instructional methods that motivate students.

Student Assessment

For purposes of accountability, states should develop new student assessments based on national content standards and state curriculum frameworks. These new assessments should test students' knowledge and understanding of mathematics and science in ways that are more complex and demanding than current tests.

Teacher Education and Certification

States should ensure that teacher education prepares new teachers to teach all children in accordance with the new national student content standards and the new state curriculum frameworks.

States should change teacher certification so that only highly and appropriately qualified and well-prepared persons, fully familiar with the content standards, requisite teaching practices, and improved assessment of knowledge are accepted into the profession of teaching.

States should adopt means of recertifying current teachers to ensure that all elementary and high school math and science teachers understand the national content standards and new instructional methods in mathematics and science.

Institutions of higher education, states, and local school districts should ensure that the preparation of new teachers is a joint responsibility of university faculty in arts and sciences and education in collaboration with school practitioners and departments of education.

Conclusion

In conclusion, we urge every parent, every school, school district, and state to insist:

- On higher content standards for all students studying mathematics and science from kindergarten through high school;
- On teacher preparation, inservice, and certification programs supporting the standards;
- On a challenging K–12 curriculum that not only informs our children but inspires their understanding and enjoyment of the wonders and power of science and mathematics;
- On the inclusion of all children, particularly those who have been historically under-represented, in a challenging curriculum every year;
- And on fair and appropriate assessment instruments to measure student, school, and state progress toward this most challenging national education goal.

For Further Information

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U.S. Department of Education
Office of Elementary and Secondary Education, 202–401–0657
Office of Educational Research and Improvement, 202–219–2164

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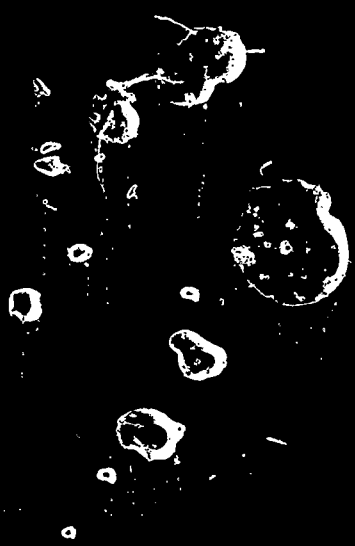

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