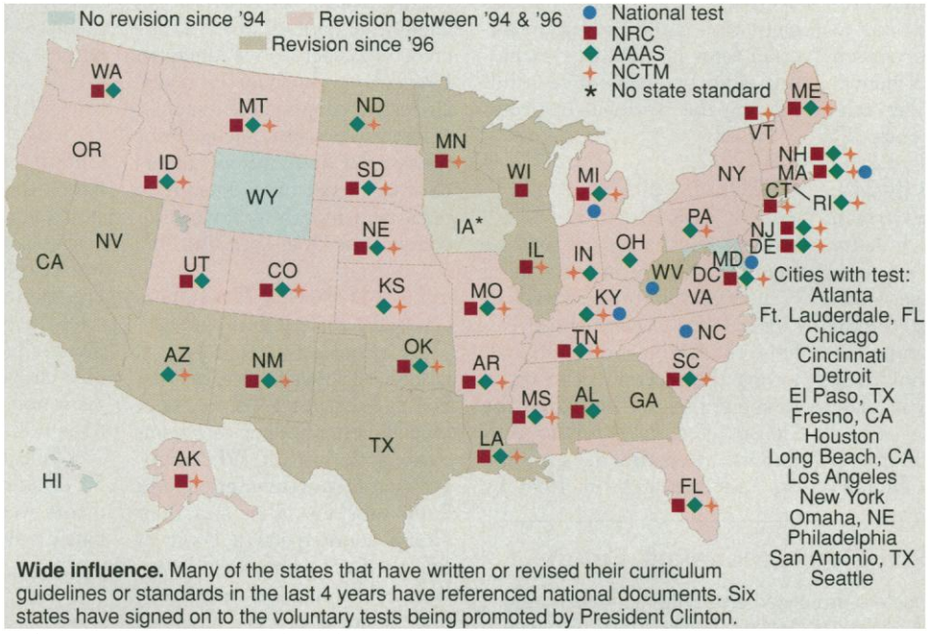
The Calculus of School Reform

Despite years of effort and hundreds of millions of dollars, there's scant evidence that the movement to reform U.S. mathematics and science education has significantly improved student learning. Why not?

Seven years ago, elementary school teacher Allyson Glass was a self-described math phobic. A former physical education teacher in her second year of teaching third grade, she relied entirely on a standard math textbook and spent only the prescribed time—about 1 hour a day—teaching the subject. But after a two-summer fellowship studying how to improve math and science teaching, she says she was "totally transformed." Even during history lessons, her students at Benjamin Franklin Elementary in Meriden, Connecticut, use math to study the geometric patterns in a quilt from colonial times. "The kids know they can't get away from a lesson without doing some math," she says. But they don't seem to mind—most of her students say it's their favorite subject.

What's happening in Glass's classroom is being repeated this fall in thousands of schools across the United States, as a movement to implement national educational standards in math and science takes hold. The movement dates back at least to 1989, when the National Council of Teachers of Mathematics (NCTM) issued guidelines on what students should know at various grade levels. In 1993, the American Association for the Advancement of Science (AAAS), which publishes *Science*, issued a set of benchmarks for science, math and technology education. Two years later, the National Research Council (NRC) followed suit with similar standards for science. Now, educators are revising teacher training, curricula, and assessment practices in an attempt to meet these or similar guidelines, which call for a new approach to teaching, with more hands-on learning leading to a deeper understanding of the subjects. The National Science Foundation (NSF) has also poured $25 million a year since 1990 into more than a dozen programs to develop standards-based curriculum materials in mathematics and science.

The push is coming from the top: President Clinton has made a cornerstone of his second Administration the goal that U.S. students will be first in the world in math and science by 2000. And it's a rare Clinton speech that omits mention of his proposal for a voluntary national test—of reading in the fourth grade and of mathematics in grade eight—that will allow parents and teachers to chart their children's progress.



Wide influence. Many of the states that have written or revised their curriculum guidelines or standards in the last 4 years have referenced national documents. Six states have signed on to the voluntary tests being promoted by President Clinton.

SOURCE: ROLF BLANK/CCSSO & STATE AGENCIES

Yet, for all this ferment, the effort to implement math and science standards has been a slow and, at times, frustrating experience. The results speak volumes about the difficulties of reforming an educational system run by thousands of independent school districts. Although scores on some tests have improved nationally, significant gains in student achievement remain, for the most part, elusive. One major hindrance is the vast number of teachers who took few math or science courses in college and, unlike Allyson Glass, have had no additional training in the new world of standards-based education. Progress is also slowed by textbook publishers reluctant to make real changes in their products and by the continued emphasis on standardized tests that measure only proficiency with basic facts.

The standards-setting movement has also stirred up political passions that underlie the bedrock conviction that local communities should control what their kids learn. Indeed, in some places, battles between proponents and opponents of math reform have left the movement in disarray (see sidebar on p. 1194). A debate is also heating up at the national level as powerful critics attack the notion of national standards as an unwanted incursion into local control. For example, Representative William Goodling (R–PA), chair of the House Committee on Education and the Work Force, has introduced two bills to block the nationwide tests for fourth and eighth graders that Clinton advocates. In a recent *Washington Post* editorial, Goodling wrote that such testing "could lead to a national curriculum ... which Americans don't want and don't need."

As a result, while anecdotal evidence of positive change abounds, no state—or even school district—can yet claim to have reached the promised land of standards-based learning. Yet many educators take some comfort from the fact that, difficult as it is, change is at least occurring throughout the vast and fragmented U.S. education enterprise. "Considering where American education was [in the late 1980s], there has been remarkable progress," says education professor David Cohen of the University of Michigan, Ann Arbor. "But, considering where American education was, it would be really good if there had been more progress."

Whose standards?

The NCTM, AAAS, and NRC guidelines are often billed as national standards, and educators say they have had widespread impact. "The NCTM standards have definitely been used as an important resource document in virtually every state," says Gordon Ambach, executive director of the Council of Chief State School Officers (CCSSO) in Washing-

The Special Needs of Science

While educators making efforts to set standards for science education face many of the same hurdles as those in mathematics, the diversity of the science community makes the job even tougher. Thanks in part to that diversity, there have been two separate efforts in the past 4 years to present a cohesive vision of what students should learn in science classes from kindergarten through grade 12. Combined with the relatively recent appearance of the two documents, these factors have caused science reform to lag behind math in many of the nation's schools.

In 1993, Project 2061, an education reform effort sponsored by the American Association for the Advancement of Science (which publishes *Science*), issued *Benchmarks for Science Literacy*, which recommended what students should learn at various grade levels. (That document followed *Science for All Americans*, which in 1989 described what scientifically literate adults should know.) In 1995, at the request of the National Science Teachers Association and other scientific and educational societies, the National Academy of Sciences issued the *National Science Education Standards*. While the documents are compatible, say most educators, there are enough differences to confound well-intentioned teachers.

Science reformers also labor under special conditions. Unlike in math, in which there was a consensus in the community on what to cover, the science standards generated pitched battles within fields about content, and between disciplines about their relative importance. In addition, the emphasis of hands-on and lab activities puts increased pressure on an already crowded school day, not to mention tight budgets.

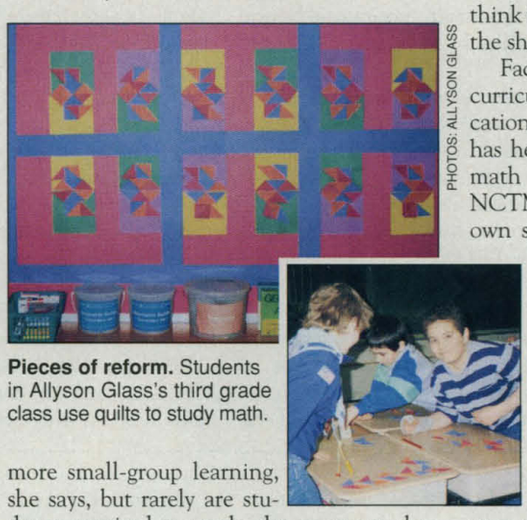
Although the hard-won compromises in the *Benchmarks* and the *Standards* are a welcome step in the right direction, some educators say they both have flaws. "They still are trying to teach everything and therefore not teaching anything in depth," says Senta Raizen of the National Center for Improving Science Education in Washington, D.C. "If we really take inquiry seriously, and it takes a month or two or three, what are we giving up?" she asks. George Nelson of Project 2061 says an upcoming book, *Designs for Science Literacy*, should help teachers decide what to take out of their lesson plans. That's a much harder question, everyone agrees, than deciding what to put in. **–G.V.**

ton, D.C. But many states have adopted their own variations. For example, the NRC science standards for grades five through eight list six ideas that lead to an understanding of structure and function in living systems. However, the Illinois science framework simply states that by the end of eighth grade, students should be able to "identify similarities and differences among animals that fly, walk, or swim" and "compare structures of plant cells to animal cells."

It's hard enough for even well-trained teachers to keep up with this bewildering diversity of standards. So it may be no surprise that most say they really don't understand what the standards ask them to do. Despite several public relations campaigns—including 500,000 brochures and a video featuring jazz trumpeter Wynton Marsalis and other entertainers—45% of fourth grade teachers nationwide told a 1996 Department of Education survey that they have "little or no knowledge" of the NCTM standards, while only 6% said they were "very knowledgeable" about them. The numbers are somewhat better for eighth-grade teachers—only 16% claim little or no knowledge of the standards, and 17% are very knowledgeable.

Even when teachers are well versed in the standards, they face a tough problem in applying them in the classroom. "You can't just sit down and look at the NCTM standards and say, 'This is what I'm going to do tomorrow, and I'll be implementing the standards,'" says John Wheeler, a mathematics consultant for the Iowa Department of Education. Education professor Marcia Linn of the University of California, Berkeley, agrees. "It's like reading the Bible or the Talmud," she says. "There's 102 million interpretations."

Researchers who have observed "standards-based" classrooms agree that much of what passes for standards-based teaching is a pale imitation of the real thing. Teachers are "making changes around the edges," says Lorraine McDonnell, a political scientist at the University of California, Santa Barbara. There may be more hands-on activities and more small-group learning, she says, but rarely are students required to apply the concepts they learn to real-world problems—one of the central recommendations of the standards.



PHOTOS: ALLYSON GLASS

Pieces of reform. Students in Allyson Glass's third grade class use quilts to study math.

Such sophisticated teaching is much harder, says McDonnell, and requires more teacher training and more time in the classroom. But training is often lacking. Although "how-to" workshops on implementing the standards are available in many states, the Department of Education survey found that 60% of U.S. students are taught by teachers who have never attended such a workshop, much less a comprehensive program like Allyson Glass's fellowship.

Standards-based textbooks could help guide teachers, but publishers have been slow to catch on. "A lot of textbook publishers claim they meet NCTM standards, but it's a little like a Rorschach test," says Senta Raizen of the National Center for Improving Science Education (NCISE) in Washington, D.C. "I don't think there is a textbook series you can buy off the shelf that really speaks to the standards."

Faced with that hurdle, Jo Ellen Roseman, curriculum director for Project 2061, an education reform project sponsored by AAAS, has helped to design a system for analyzing math and science textbooks. It tracks the NCTM and NRC standards as well as 2061's own set of standards, called *Science for All Americans* and *Benchmarks for Science Literacy*. Although she cautions that the project is not finished, preliminary results aren't wildly encouraging. "We've found some units that are outstanding," she says, "but very few." Even NSF-sponsored projects "don't necessarily come through with flying colors."

Most available materials, Roseman says, spend too little time on a given topic, introduce concepts earlier or later than the standards recommend, and rely on memorization rather than allowing students to draw their own conclusions. "Publishers are not yet convinced that the market is driving them to produce these kinds of materials," she adds. "But we're beginning to work with developers" to revise and improve their texts.

One frustration faced by educational reformers is the lack of good information on what students know and how the implementation of standards has influenced that knowledge. The

California Spars Over Math Reform

The world happens first in California, the saying goes. If so, then many of the changes in primary and secondary school mathematics being advocated by professional societies and national education organizations could have a tough time finding a permanent home in U.S. classrooms.

In the late 1980s and early 1990s, California was seen as a shining example of how to implement standards-based reform. And because the state buys 12% of the nation's textbooks, what was happening in California was expected to have widespread impact. But the efforts of reformers—a revised state curriculum framework, new textbooks, and a new statewide test—sparked a vigorous backlash from parents and politicians after their introduction in 1992. As a result, the next version, due out in 1998, promises to be quite different from the standards promoted by the National Council of Teachers of Mathematics (NCTM) in its 1989 document (see main text).

The reformers in California had hoped to create "mathematically powerful" students who could reason and apply mathematics to problems in their daily lives. The primary vehicle for change was the state's curriculum framework, which guides local school districts and the state's textbook adoption committee. The 1992 framework, quoting generously from the NCTM standards, called for teachers to question more and explain less, to group higher and lower ability students together, and to assign more projects and fewer workbook drills. By 1994 the radically new textbooks started appearing in classrooms.

The reaction was swift: Parent groups around the state organized to fight what they called "fuzzy math" and "new New Math." They said the new curriculum used untried teaching methods and replaced basic skill drills, such as multiplication tables and long division, with projects such as writing and illustrating a "Problem of the Week." "It transformed math problems into English essay writing" and sacrificed mathematical precision, says Bill Evers, a political scientist at Stanford University and a leader of a Palo Alto–based parent group on math reform called Honest Open Logical Debate (HOLD).

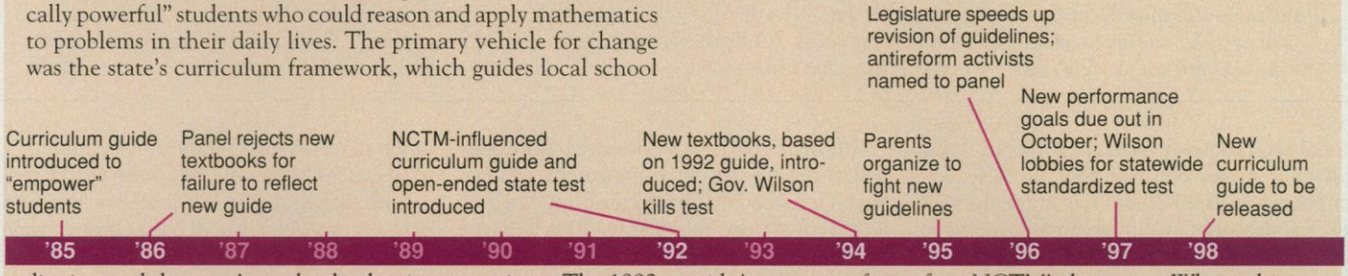
In an effort to wipe the slate clean, HOLD and other grassroots organizations persuaded state officials to move up by 1 year, to 1998, the next revision of its frameworks. The state test implemented with the 1992 standards, which included open-ended and essay questions, fared even worse: Governor Pete Wilson scrapped it in 1994. The controversy also robbed the reform movement of whatever political clout it once possessed. Antireform activists constitute the majority on the panels that are drafting both the new content and performance standards and the 1998 framework.

Supporters of the 1992 framework fear that the new version will abandon a cornerstone of reform: namely, that all students—not just those pegged as gifted—should be able to understand mathematical reasoning in addition to knowing the basic facts. "The attempts to be bold and visionary have been cast as the only thing we care about," says Shelley Ferguson, an elementary school teacher in San Diego who has been involved in the reform process. "They've been taken to the *n*th degree in an effort to trivialize what the reform should be about."

Both sides agree that the latest drafts of the standards, released in mid-August, are a far cry from NCTM's document. What is driving the new standards, say Evers and other committee members, is a state requirement to enumerate what students need to know in each grade. In drawing up their plan, the group relied heavily on standards from Virginia and from the Charlotte-Mecklenburg, North Carolina, school district, which follow that format.

Evers says the new draft contains standards as rigorous as those in high-performing Japan, and that it will prepare students to go on to algebra and geometry in eighth grade, 1 year earlier than had been the norm. But Ferguson disagrees. "It's back to a laundry list of topics to know," she laments. "Conceptual understanding and problem solving are pretty absent."

Whatever the outcome, reformers elsewhere say that the California math wars have taught them the importance of educating parents and policy-makers as well as teachers. "We can't neglect the effort to educate the public about public education," says Suzanne Wilson of Michigan State University in East Lansing, who has followed the California reforms for more than a decade. If they do, reformers could end up with a report card marked incomplete. –G.V.



meager evidence is decidedly mixed. On the plus side, mathematics scores on the National Assessment of Educational Progress (NAEP)—a national test given by the Department of Education—have risen since 1992. Progress on this test is especially heartening, say reformers, because it includes open-ended questions that measure the kinds of learning they are trying to encourage. And U.S. third and fourth graders scored above the international average in math on the highly publicized Third International Mathematics and Science Study (TIMSS), which compared students from 29 countries. Yet seventh and eighth graders scored below the international mean (*Science*, 22 November 1996, p. 1296; and 13 June, p. 1642). The TIMSS results were especially curious because the new standards have so far had a limited impact in the lower grades, at least judging by the proportion of teachers who say they are familiar with them.

At the local level, reformers say that traditional tests, which tend to measure how good students are at remembering facts quickly, are not a fair gauge of their efforts. "So much of what is in the standards," says Iowa's Wheeler, "is not adequately measured by traditional multiple-choice norm referenced tests like the Iowa Tests of Basic Skills," which hundreds of thousands of students across the country take each year. "So if you're not testing that kind of thing, you don't have any baseline data to go on." At the same time, the push for accountability has increased the use of such tests. And when scores have dipped, parents have taken to the streets—and school board offices—to protest standards-based reforms.

Accordingly, the standards not only call for a new curriculum and new teaching strategies, but also new tools to measure students' learning. The NAEP mathematics and sci-

ence tests are a step in the right direction, say reformers, with their open-ended problems that require students to explain their reasoning and give credit for correct reasoning as well as correct answers. In addition, the New Standards, a student assessment system that includes open-ended test questions and student portfolios, is gaining popularity.

If Clinton has his way, by 1999 every eighth grader in the country may have the chance to take a standards-based test. Such a test could help shepherd teachers toward a more consistent interpretation of the standards, note former NCTM President John Dossey and current President Gail Burrill, who are chair and vice chair of the committee charged with writing the mathematics exam to be given to eighth graders nationwide.

But some reformers wonder how much impact a voluntary test can have. It is not yet clear what rewards and punishments Clinton's proposed test would carry, but it may be a test without teeth. "I'm skeptical about it," says NCISE's Raizen. "Does it count? No. There are a lot of people who think this kind of test is going to drive reform, but I don't think so."

There's also the question of coverage. So far, only six states and 15 urban school districts have volunteered to join the testing program (see map). Still, the White House remains committed to preparing such a test through the Department of Education, and officials claim that a dozen more states are ready to join in.

Standard iterations

Even as educators around the country are struggling to implement the 1989 standards, NCTM leaders are working on a new and improved version for 2000. The revision provides a "chance to see where we are and what we've done," says Mary Lindquist, education professor at Columbus State University in Georgia, who heads the math council's Commission on the Future of the Standards. The main message will stay the same, but the revised document will "clarify" several areas—including basic skills and proofs—that critics fault in the current version. The new document, called *Standards 2000*, will also update recommendations for using calculators and computers in the classroom. The NCTM has received critiques and suggestions in sessions at its national and regional meetings and through its Web site (www.nctm.org), and it's sorting through thousands of responses before proposing revisions.

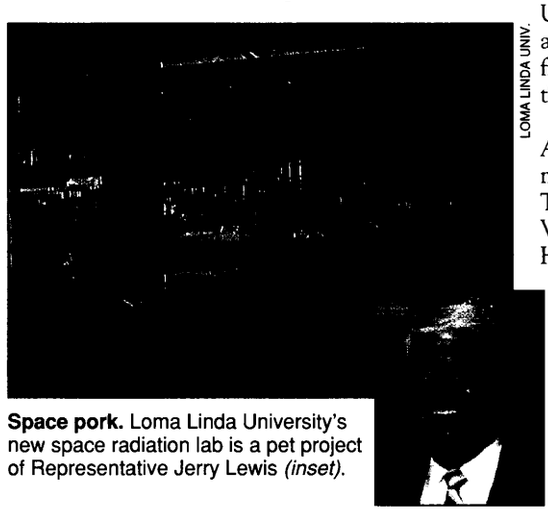
But Glass says she doesn't need a national survey to glimpse the future of standards-based reform. "The teachers who have taught by the standards and who have invested in them believe in them," she says. As a result, she adds, her students "become problem solvers. And I don't think that leaves a child."

–Gretchen Vogel

1998 BUDGET

Bipartisan Mood in Congress Opens Door for Pork

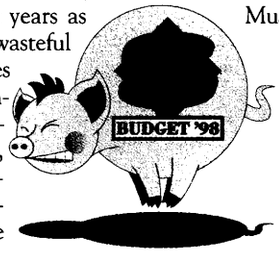
The bipartisan flavor that has become so popular in Congress these days has brought with it the distinct aroma of pork. After falling into temporary disfavor with congressional budget cutters, legislative earmarks—also known as porkbarrel projects—no longer seem to be a lightning rod for criticism. That's good news for the institutions that stand to gain millions of dollars in R&D funding set aside by lawmakers in 1998 spending bills that Congress hopes to wrap up as it returns to work next week. But others worry that Congress is encouraging bad science by circumventing peer review.



LOMA LINDA UNIV.

Space pork. Loma Linda University's new space radiation lab is a pet project of Representative Jerry Lewis *(inset)*.

Adding money not requested by the Administration and targeted for specific districts or states is an ancient practice. However, it came under attack in recent years as part of a broader assault on wasteful government spending. But times have changed. The antigovernment ardor has cooled, key opponents of pork have retired, and Republicans and Democrats have set aside their differences in a plan to eliminate the budget deficit by 2002.



NASA and the Environmental Protection Agency (EPA) appear to be the biggest recipients of proposed earmarks among R&D agencies. About $20 million of the $614 million that the House appropriated for EPA research in 1998 is for specific pork projects, for example. A typical earmark is the one offered by Representative Jerry Lewis (R–CA), who chairs the House panel with funding oversight of NASA and EPA. He's designated $2 million in NASA funding for a space radiation lab at Loma Linda University, a Seventh-Day Adventist school east of Los Angeles, which is in his district. Lewis has also arranged for the University of Redlands in California—also in his district—to get $1 million from a $6 million pot for EPA to study the rapidly disappearing Salton Sea.

In the same bill, Representative Alan Mollohan (D–WV) won $1.9 million for the National Technology Transfer Center in Wheeling, West Virginia, while $2 million is headed to Houston's Mickey Leland National Urban Air Toxics Research Center, compliments of Texas legislators. Next door, the Louisiana delegation, which includes Appropriations Committee Chair Bob Livingston (R), wangled $2 million for research at the University of New Orleans into urban waste management and $1.3 million for oil spill remediation research at McNeese State University in Lake Charles, Louisiana.

The Senate version of the bill has fewer earmarks, but they are individually more impressive. Senator Ted Stevens (R–AK), who chairs the Senate Appropriations Committee, succeeded in winning the largest NASA earmark of all—$2.5 million for a science learning center in the small town of Kenai, Alaska. And again, Democrats shared the spoils. Senator Daniel Inouye (D–HI), for example, inserted $2 million for work on a national space education curriculum by the Center for Space Education at the Bishop Museum in Honolulu.

At this point, the projects appear to be mostly add-ons rather than substitutes for the agency's scheduled research. The House version of EPA's overall budget is $104 million above this year's level and $41 million above the president's request, while at NASA, the House has included a little less than $10 million in specific earmarks to a $5.7 billion appropriation that is $50 million higher than the White House requested for science, aeronautics, and technology. The bills that include funding for the Energy and Defense departments also have a smattering of specific R&D earmarks, such as the Senate's offer of $3.9 million in DOE money for biological imaging at the University of California, Los Angeles.

Some appropriators have resisted the