Archived Information

Before It's Too Late

A Report to the Nation from The National Commission on Mathematics and Science Teaching for the 21st Century

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A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century

Letter of Transmittal

September 27, 2000

Richard W. Riley
Secretary of Education
U.S. Department of Education
Washington, DC 20202

Dear Secretary Riley:

On July 20, 1999—the 30th anniversary of the first landing on the moon—you announced the appointment of the 25-member National Commission on Mathematics and Science Teaching for the 21st Century. In your charge to the Commission and its eight ex officio members, you asked us to investigate and report on the quality of mathematics and science teaching in the nation, directing us to consider ways of improving recruitment, preparation, retention, and professional growth for mathematics and science teachers in K–12 classrooms nationwide. You reminded us that, three decades after a historic achievement, "we need to set the stage for advancement in mathematics and science for the next thirty years."

It has been my privilege to chair the Commission, and I am pleased to report to you, on behalf of its members, that we have completed our work. With this letter, we transmit to you our report, *Before It's Too Late*, which summarizes our findings. It presents to both the Department of Education and the American people a set of ambitious goals for improving mathematics and science teaching and specific action strategies for achieving each of them.

We trust that we have been faithful to your charge. As we have listened to the presentations of scholars, deliberated over the studies of outstanding researchers, and attended to the experience of dedicated administrators and teachers, we have learned much. Our assumptions have been called into question. Our individual views have been tempered by the perspectives of colleagues whose judgment we have come to respect, even in disagreement. As we have sought to understand today's problems in mathematics and science education, we have also worked to uphold a constant vision of high-quality teaching as the irreducible minimum for creating tomorrow's solutions.

We believe that the issues and concerns raised in our report can be understood, addressed by, and potentially unite policymakers, teachers, the business community, parents, students, and private citizens alike. The goals and action strategies we suggest may be seen by some as too great a reach, by some as not bold enough. We are convinced, however, that if they are ignored, our children and our nation will soon pay the high price that always accompanies apathy.

Each member of the Commission, through this letter, expresses appreciation for your leadership in having brought this diverse group together to examine an issue that has pivotal significance for our country as we embark on a new century and millennium. It is our collective and earnest hope that you will continue that leadership by encouraging widespread discussion of our views and suggestions, and by urging appropriate action based on our findings and recommendations.

Finally, we offer our profound thanks for having provided us with this opportunity to serve our country—and our children—as members of this Commission.

Respectfully,

John Glenn, Commission Chairman

John Glenn
Commission Chairman

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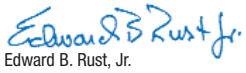

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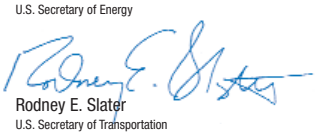


Rodney E. Slater
U.S. Secretary of Transportation

Commission Members

Foreword

John Glenn, Commission Chairman

This report makes only a few straightforward points, but it makes them urgently and insistently.

First, at the daybreak of this new century and millennium, the Commission is convinced that the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically.

From mathematics and the sciences will come the products, services, standard of living, and economic and military security that will sustain us at home and around the world. From them will come the technological creativity American companies need to compete effectively in the global marketplace. "Globalization" has occurred. Economic theories of a few years ago are now a reality. Goods, services, ideas, communication, businesses, industries, finance, investment, and jobs—*the good jobs*—are increasingly the competitive currency of the international marketplace.

Among the first things Americans watch every morning on TV is the global marketplace at work. The quotes not only from Wall Street itself, but also from the Nikkei, Hang Seng, and Hong Kong exchanges, followed in turn by those of Frankfurt, Zurich, and London—along with reports on the status of the yen, peso, and Euro—all reflect investment flows of hundreds of billions in assets around the world. Times have changed. In an integrated, global economy, whose key components are increasingly knit together in an interdependent system of relationships, will our children be able to compete?

Beyond the world of global finance, mathematics and science will also supply the core forms of knowledge that the next generation of innovators, producers, and workers in every country will need if they are to solve the unforeseen problems and dream the dreams that will define America's future.

Second, it is abundantly clear from the evidence already at hand that we are not doing the job that we should do—or can do—in teaching our children to understand and use ideas from these fields. Our children are falling behind; they are simply not "world-class learners" when it comes to mathematics and science.

The Third International Mathematics and Science Study (TIMSS) tested the students of 41 nations. Children in the United States were among the leaders in the fourth-grade assessment, but by high school graduation they were *almost last*. Here at home, the National Assessment of Educational Progress basically substantiates our students' poor performance.

In short, our children are losing the ability to respond not just to the challenges already presented by the 21st century but to its potential as well. We are failing to capture the interest of our youth for scientific and mathematical ideas. We are not instructing them to the level of

competence they will need to live their lives and work at their jobs productively. Perhaps worst of all, we are not challenging their imaginations deeply enough.

Third, after an extensive, in-depth review of what is happening in our classrooms, the Commission has concluded that the most powerful instrument for change, and therefore the place to begin, lies at the very core of education—*with teaching itself*.

The teaching pool in mathematics and science is inadequate to meet our current needs; many classes in these subjects are taught by unqualified and underqualified teachers. Our inability to attract and keep good teachers grows. As a result, newer, technologically oriented industries are having trouble finding enough qualified employees from among those teachers' students. Worse, creativity atrophies and innovation suffers.

We are of one mind in our belief that the way to interest children in mathematics and science is through teachers who are not only enthusiastic about their subjects, but who are also steeped in their disciplines and who have the professional training—*as teachers*—to teach those subjects well. Nor is this teacher training simply a matter of preparation; it depends just as much—or even more—on sustained, high-quality professional development.

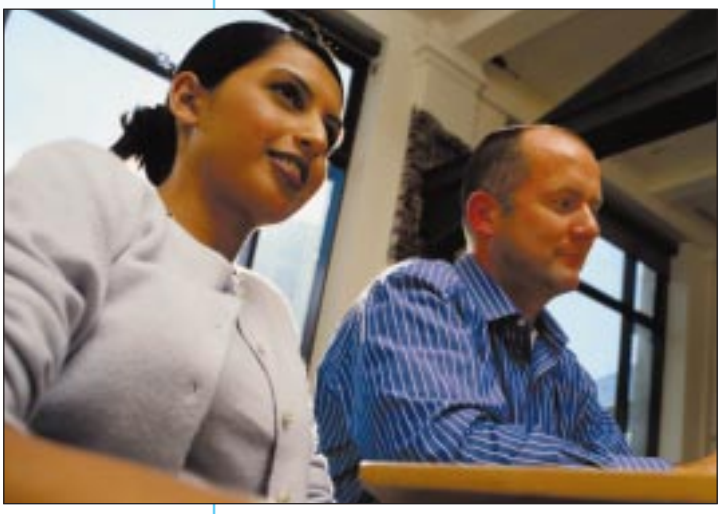
Fourth, we believe that committing ourselves to reach three specific goals can go far in bringing about the basic changes we need. These goals go directly to issues of quality, quantity, and an enabling work environment for teachers of mathematics and science. For each goal, we offer specific action strategies for achieving that particular goal, ideas on who should implement them, and how. Specifically, we offer suggestions on how to:

- *Establish an ongoing system to improve the quality of mathematics and science teaching in grades K–12;*
- *Increase significantly the number of mathematics and science teachers and improve the quality of their preparation; and*
- *Improve the working environment and make the teaching profession more attractive for K–12 mathematics and science teachers.*

The goals we set before the American people in this report will not be easily attained, nor will the action strategies we offer be readily implemented. Most other nations have a national education system that can change direction more rapidly than our K–12 system, which is operated by nearly 16,000 independent school boards. Even when the majority of board members are firmly dedicated to good education, it is still a difficult job to change direction when needed.

The task to which we call the American people is therefore not an easy one. Nor will our goals be met at bargain-basement rates. But we believe we have a well-focused view of the needs facing our country and its youth, and that we have identified the right starting points for preparing them to meet their future. We are just as strongly convinced that the downstream cost of not turning this problem around will be exponentially higher than the cost of beginning to solve it now.

But rising to great challenges is a part of our national character—not only in such arduous deeds as breaking the bonds of the planet itself, but in the daily work of equipping each new generation to meet new responsibilities. The last time we turned a century, our schools rose to the challenge of educating the nation's youth to meet the demands of an industrializing economy. We succeeded in the equally formidable task of integrating millions of immigrants from around the world into a dynamic culture without precedent in history.



Now history presents us with a yet more pressing demand. We are being called upon to capitalize on the changes wrought by two great revolutions: rapid economic globalization on the one hand and the expansion of information-based technologies on the other. In this light, we can take heart from American history's most profound lesson: Our ability, as a people, to uncover the liberating opportunities concealed within daunting tasks is what defines the American genius.

In the end, then, the message of this report is a simple one. The time has come to move from the information and analysis we have gathered to the resolution we need. We are summoned to answer a stark question. As our children move toward the day when *their* decisions will be the ones shaping a new America, will they be equipped with the mathematical and scientific tools needed to meet those challenges and capitalize on those opportunities?

These are our children, and the choice is ours. We know what we have to do; the time is now—*before it's too late*.

* * * * *

The Commission sincerely appreciates the confidence that Secretary Richard W. Riley placed in us, and hopes that our report is a worthy and useful product in guiding our nation's students to world-class performance.

Special thanks are due to our Executive Director, Linda P. Rosen, whose lifelong experience in mathematics education was vital to our work, and whose direction of the labors of the Commission through long hours on a day-in, day-out, yearlong basis was exemplary and crucial to our work.

Executive Summary

In an age now driven by the relentless necessity of scientific and technological advance, the current preparation that students in the United States receive in mathematics and science is, in a word, unacceptable.

Recent reports of the performance of our country's students from both the Third International Mathematics and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP) echo a dismal message of lackluster performance, now three decades old; it's time the nation heeded it—*before it's too late.*

Four important and enduring reasons underscore the need for our children to achieve competency in mathematics and science: (1) the rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science-related knowledge and abilities; (2) our citizens need both mathematics and science for their everyday decision-making; (3) mathematics and science are inextricably linked to the nation's security interests; and (4) the deeper, intrinsic value of mathematical and scientific knowledge shapes and defines our common life, history, and culture. Mathematics and science are primary sources of lifelong learning and the progress of our civilization.

Beyond the disturbing news that our young people are not performing well enough in mathematics and science to take firm command of their own futures, five major factors have begun to coalesce that make this a particularly opportune time to focus on strengthening mathematics and science education: (1) reform efforts have sharply focused the attention of the American people on education as a public issue; (2) the nation now has a surplus of resources to invest in education; (3) a coming demographic shift in the teaching force—two thirds of which will be retiring in the next decade—offers an unparalleled chance to plan for and make changes at the core of education itself; (4) our schools can now put to work what educators have learned in the past generation about curriculum, high standards, effective teaching, assessment, and how children learn; and (5) the rising generation of college graduates is once again showing an interest in teaching as a profession. The nation must capitalize on the convergence of these factors to improve mathematics and science teaching in the United States. We need to act now, *before it's too late.*

The primary message of this report holds that America's students must improve their performance in mathematics and science if they are to succeed in today's world and if the United States is to stay competitive in an integrated global economy. The Report's second message points in the direction of a solution: the most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching.

Evidence of the positive effect of better teaching is unequivocal; indeed, the most

consistent and powerful predictors of student achievement in mathematics and science are full teaching certification and a college major in the field being taught.

Better mathematics and science teaching is therefore grounded, first of all, in improving the quality of teacher preparation and in making continuing professional education available for all teachers. A closer look at the teaching that goes on in mathematics and science

classrooms today puts the performance of U.S. students on national and international assessments in sharper focus. The basic teaching style in too many mathematics and science classes today remains essentially what it was two generations ago. By contrast, teaching innovation and higher student performance are well documented in other countries, where students' improvements are anchored to an insistence on strong professional development for teachers.

What *could* be happening in U.S. mathematics and science classrooms is markedly different. The report names an extensive set of characteristics of "high-quality teaching." When they are focused through the lens of exemplary teacher preparation and an integrated *system* of professional development, an enormous potential for empowering teachers and improving instruction is apparent.

The pressing national need for *high-quality teaching* described in this report, therefore, demands a vigorous, national response that unifies the efforts of all stakeholders in mathematics and science education. To that end, three wide-ranging, intertwined goals focus the report's call for action at local, state, and federal levels. As an aid to implementation, each goal is accompanied by a coordinated set of well-funded action strategies that identify key stakeholders who should take the lead in implementing each strategy. The estimated annual cost to achieve these action strategies is over $5 billion. These funds and other resources will come from a diversified set of sources, including all levels of government, higher education, business and industry, professional education associations and teachers' unions, community groups, and the citizenry. The goals and action strategies set forth in the report are as follows:

Goal 1: *Establish an ongoing system to improve the quality of mathematics and science teaching in grades K–12.*
Seven interdependent action strategies are offered to implement this system: (1) each state must immediately undertake a full *needs assessment* to determine what teachers require, both in their schools and their professional lives, if they are to routinely deliver high-quality teaching; (2) *Summer Institutes* must be established to address the professional development

needs identified; (3) building- and district-level *Inquiry Groups* can provide venues for teachers to engage in common study to enrich their subject knowledge and teaching skills; (4) *Leadership Training* is needed to prepare facilitators for the Summer Institutes and Inquiry Groups; (5) a dedicated *Internet Portal* must be available to teachers so they can make use of and contribute to an ever-expanding knowledge base about mathematics and science teaching; (6) a nongovernmental *Coordinating Council* is needed to bring together the above initiatives and those that follow to assess accomplishments; and (7) all states and local districts should initiate *reward* and *incentive programs*, both to support exemplary professional development that results in higher student achievement and to increase the attractiveness of teaching as a profession.

Goal 2: *Increase significantly the number of mathematics and science teachers and improve the quality of their preparation.* Three action strategies are offered for this goal: (1) a direct strategy that identifies *exemplary models of teacher preparation* whose success can be widely replicated; (2) an overarching strategy of finding ways to *attract additional qualified candidates into teaching* from among high school and college students, recent college graduates, and people at mid-career; and (3) creating 15 competitively selected *Mathematics and Science Teaching Academies* to annually train 3,000 Academy Fellows, who will be nationally recruited for a one-year, intensive course on effective teaching methods in mathematics or science.

Goal 3: *Improve the working environment and make the teaching profession more attractive for K–12 mathematics and science teachers.* Four action strategies address this goal: (1) focused *induction* programs are required to help acclimate beginning mathematics and science teachers to the profession, create formal mentoring relationships, and introduce teachers to Inquiry Groups; (2) *district/business partnerships* are needed to provide support for a broad range of efforts that can help create professional working environments for teachers. These efforts can enhance teaching by providing materials, facilities, equipment, and mentor stipends; (3) *incentives*—whether in the form of cash awards, salary increases, support for further education, or community-wide recognition—are needed to encourage deserving mathematics and science teachers to remain in teaching and improve their skills; and (4) *salaries* of all teachers must be made more competitive, but especially for mathematics and science teachers, whose combined preparation and skills command high wages in the private sector.

The report concludes by challenging all Americans directly to take personal responsibility for expressing their views on mathematics and science education to policy- and decision-makers, and to take the initiative to implement the report's action strategies in their own communities.

The Problem

Our Students' Performance in Mathematics and Science is Unacceptable

Eleven Septembers ago, with the heady horizon of a new millennium within sight,

the nation's governors gathered in Charlottesville, Virginia, to set ambitious goals for our schools. Among the challenges the governors issued was this one:

"By the Year 2000, United States students will be first in the world in mathematics and science achievement." [1]

A goal like that might be tough, Americans thought, but it was reachable.

But our effort since has not matched our rhetoric. Results from the Third International Mathematics and Science Study (TIMSS) show U.S. students devastatingly far from this goal by the time they finish high school.

In an age now driven by the relentless necessity of scientific and technological advance, the preparation our students receive in mathematics and science is, in a word, unacceptable. Despite our good intentions, their learning is too often superficial. Students' grasp of science as a process of discovery, and of mathematics as the language of scientific reasoning, is often formulaic, fragile, or absent altogether. And perhaps most alarming of all, as recent assessments seem to show, the longer our children study these crucial disciplines, the less favorably they compare with their peers in other countries.

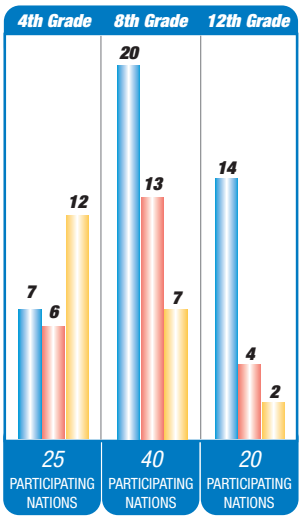
The Recycled Message of TIMSS and NAEP: Our Students Are Losing Ground

America has heard news like this before. In 1957, the sudden appearance of Sputnik galvanized a massive national effort to win the space race and improve mathematics and science education. We knew we had to "catch up with the Russians." With a burst of single-minded intensity, we more than caught up: in 12 years we achieved the moon. But we did not duplicate or sustain that intensity, a lesson we have heard three times over from international assessments of science and mathematics achievement conducted since the 1960s. The unmistakable message is that our students' performance relative to their peers in other countries—our competitors all—is disappointedly unchanged. Their students have consistently scored higher than U.S. students.[2] Indicators from those three assessments and those conducted here at home corroborate the point.

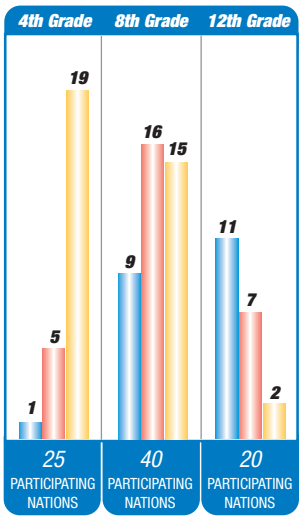
TIMSS Results: The Third International Mathematics and Science Study assessed the performance of students from 41 countries in 1995. U.S. fourth-graders scored above the international average in mathematics and science; eighth-graders scored slightly above the international average in science and slightly below the international average in mathematics. However, among 20 nations assessed in advanced mathematics and physics (students were not assessed from all

*TIMSS Results**

MATHEMATICS



SCIENCE



Nations with average scores HIGHER than the U.S.

Nations with average scores EQUIVALENT to the U.S.

Nations with average scores LOWER than the U.S.

**When participation of the United States is included, the total number of participating countries is 26, 41, 21 at the 4th grade, 8th grade, and the 12th grade respectively.*

countries for all grades), *none* scored significantly lower than the United States in advanced mathematics, and only *one* scored lower in physics.[3] In a phrase, our mathematics and science students are not "world class."

NAEP Results: The National Assessment of Educational Progress (NAEP, the "Nation's Report Card") periodically reports student achievement in science and mathematics using four categories: "Below Basic," "Basic," "Proficient," and "Advanced." On the 1996 NAEP, *less than one-third* of all U.S. students in grades 4, 8, and 12 performed at or above the "Proficient" achievement level in mathematics and science, where "Proficient" represents solid academic performance for each grade assessed. Perhaps even more alarming, *more than one-third* of U.S. students scored below the "Basic" level in these subjects, which means they lack mastery of the prerequisite knowledge and skills needed for "Proficient" at each grade. While U.S. students do, indeed, learn more each year they are in school, they are performing less well in twelfth grade than in the fourth and eighth grades, *compared to the standards of proficiency* for those grade levels. Despite some improvements in NAEP mathematics scores since the 1970s, our students' performance in science and mathematics has remained at disappointing levels for nearly 30 years.[4]

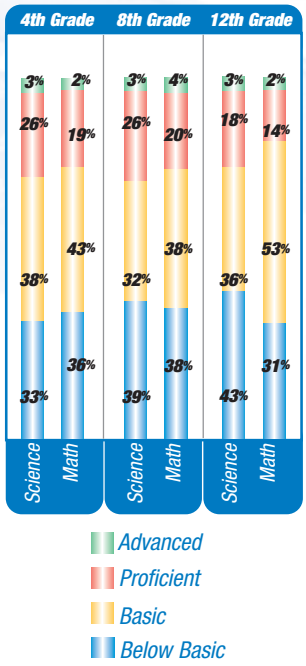
In sum, whether we look at comparisons of our young people to those of other nations or look simply at the progress our students are making at home,[5] the nation keeps getting the same dismal message about mathematics and science achievement: our students are losing ground. It's time we heeded it.

But heeding the bad news has to involve something other than wringing our hands and raising a polite rallying cry for improvement. The issues raised by TIMSS, NAEP, and state performance data are deeply entrenched. They cannot be papered over. Only a well-conceived strategy, grounded in data and sustained over time, can possibly overcome the status quo. The majority of states report assessment data for both mathematics and science; but proficiency levels in both subjects are often too incomplete to paint a useful portrait for determining accountability. This is especially true in science, where only 16 states report proficiency levels. Thus, a crucial first step in creating greater accountability is for state education agencies to supply to the public complete, user-friendly, reporting on student performance, *school-by-school*.[6] As it stands, only 12 state education agencies provide parent information on their Web site guides to student assessment; that is 38 states too few.

Why Does It Matter?

Four important and enduring reasons underscore the need for our children to achieve competency in mathematics and science: (1) the demands of our changing

NAEP Performance Results



Science Results Reported in "What Do Students Know?": Results for 4th, 8th & 12th Grade Students, National Center for Educational Statistics, www.nagb.ort/pubs/students/nation.html

NAEP 1996 Mathematics: Report Card for The Nation and the States, Washington D.C.: National Center for Educational Statistics, February 1997, p. 59

economy and workplace, (2) our democracy's continuing need for a highly educated citizenry, (3) the vital links of mathematics and science to the nation's national security interests, and (4) the deeper value of mathematical and scientific knowledge.

The demands of our changing economy and workplace

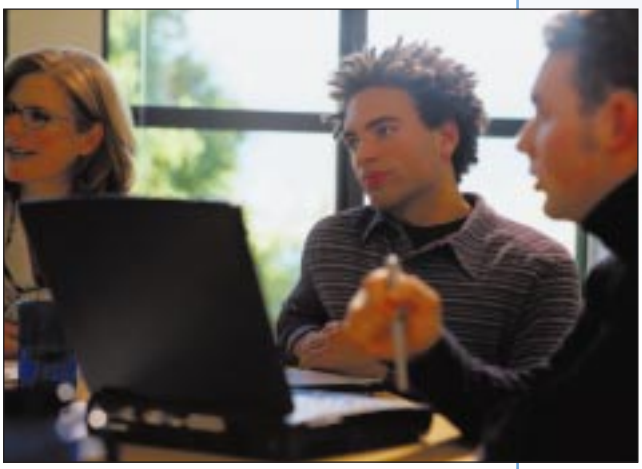
A Changing Economy: Science and mathematics exert the most visible influence on the economy through their most rapidly changing offspring—new technologies.

- New technologies are the relentless drivers behind the nation's standard of living. Since 1996, national productivity (i.e., output per worker hour) has increased, on average, by 2.6% per year, a rate that doubles the standard of living roughly every 25 years.[7] Such productivity gains are unsustainable without a workforce sufficiently educated in the sciences and mathematics.
- The technology-driven economy of the 21st century will add about 20 million jobs to the American economy by 2008—if we can only educate our young people to fill them.[8]
- Jobs in both the health sciences and computer industries requiring science and mathematics skills will increase by 5.6 million by 2008. The Department of Labor estimates that postsecondary institutions will have to produce nearly four times as many graduates in computer science as they do now to meet the demand.[9]
- Bureau of Labor Statistics projections for 1998-2008 revealed that more than two-thirds of the 30 occupational categories expected to have the fastest growth—most of them high-tech—already had hourly earnings above the national median; 11 of those job categories were in the top earnings quartile of $16.25/hour and up.[10]
- Finance, trade, industrial production, communications, and asset ownership are becoming increasingly integrated on a global basis. So are capabilities in science and technology. Singapore, for example, reputedly has the most technologically intensive workforce in the world. Israel now produces more technology-based startups than anywhere outside Silicon Valley; its high-tech exports account for a quarter of its global sales, and the country boasts 135 engineers per 10,000 citizens—twice the U.S. ratio. Drawing on a young, skilled, and well-educated workforce, Ireland now produces 60% of all PC business-application software sold in Europe. The common denominator of these advances abroad is education—a "raw material" far easier to acquire than lumber or iron ore.[11]
- Ironically, the U.S. higher education system itself contributes mightily to the rapid advances by equipping the

workforces of our competitors. The Department of Education has reported that, for 1995-96, nonresident aliens received 34.6% of all bachelor's and 44% of all master's degrees in engineering, mathematics, and information science. These students are out-competing young Americans for university spots and are returning to their native lands to expand technical capacity there.[12]

A Changing Workplace: New scientific discoveries not only add to basic knowledge, they also transform jobs, the lives of families, and the shape of public issues. The mathematical and scientific preparation of each new generation—beginning with the one now in school—has become the precondition not just to progress but to the future itself, as the links among economy, technologies, and education tighten in a rapidly changing workplace.

- "Knowledge work" is replacing low-end, low-wage jobs. In 1950, 80% of jobs were classified as "unskilled"; now, an estimated 85% of all jobs are classified as "skilled."[13] A telling example is found in machine tooling. The operators of today's computer-numerically-controlled (CNC) manufacturing technology now need sophisticated skills, commonly including computer programming and knowledge of calculus.[14]
- Many American companies now have to import the computing talent they need to stay competitive. Two years ago the Congress had to pass special legislation to permit the entry of computer workers, in rapidly escalating numbers, from abroad. The so-called "H-1B Visa Bills" progressively raised the ceiling to permit the entry of some 300,000 temporary, non-immigrant, skilled computer workers between 1998 and 2002.
- *Training Magazine* reports that approximately $62.5 billion was spent by businesses on training in 1999.[15] Much of these funds are spent on upgrading basic employee skills, many of which should have been acquired at school. In too many contexts, the nation is paying twice to equip its workforce.
- Among the scarier statistics recently reported by a Midwest think tank is this one: 60% of all new jobs in the early 21st century will require skills that are possessed by only 20% of the current workforce.[16]



Our democracy's need for an educated citizenry

It is not just the role that mathematics, science, and technology play in the changing economy and workplace that matters. Mathematics and science have become so pervasive in daily life that we tend to overlook them. Literacy in these areas affects the ability to understand weather and stock reports, develop a personal financial plan, or understand a doctor's advice. Taking advantage of mathematical and scientific information does not generally require an expert's grasp of those disciplines. But it does require a distinctive approach to analyzing information. We *all* have to be able to make accurate observations, develop conjectures, and test hypotheses—in short, we have to be familiar with a scientific approach.

Examples of science-related issues with far-reaching implications for public and private life that require the understanding of an informed citizenry are present everywhere:

- **In biology**: Cloning of organisms, the selective genetic manipulation of human reproduction, and the use of DNA as courtroom evidence;
- **In health**: The development of new drugs, chemical and biological terrorism, the effect of agricultural herbicides and pesticides on the food chain, whether to take nutritional supplements, or even calculating the nutritional value of a week's groceries;
- **In computer science**: Issues of data encryption, maintaining computer privacy, the conduct of e-commerce; and
- **In meteorology and earth science**: Global warming, the ozone layer, and hurricane and earthquake research.

The list is endless, but the point is a simple one. No citizen of America can participate intelligently in his or her community or, indeed, conduct many mundane tasks, without being familiar with how science affects his daily life and how mathematics shapes her world.

The vital links of mathematics and science to our national security interests

The warp of our nation's security interests and the woof of mathematics and science are closely woven. It was the pure science of nuclear physics that first gave rise to, then continued to support, the nation's nuclear deterrent throughout the last half century. Nuclear science—put to sea in nuclear submarines—has also formed the second pillar of our strategic defense system. Long-range bombers, the third pillar, became possible only with advances in aeronautical science.

Mathematics and science today supply the architecture that gives structure and strength to the development of new weapons, from long-range missiles to the B-2 ("Stealth") bomber. Science and mathematics continuously enhance our armed forces' ability to protect the nation, whether in the form of vaccinations against chemical and biological agents, or night-vision goggles for combat troops, or the Global Positioning Satellite system (GPS) that can pinpoint the location of virtually any object on the planet. An invisible web of sophisticated satellite communications technology connects our military forces in the global defense arena,

where U.S. troops must respond quickly and operate for indefinite periods. On the ground, the modern equipment and weaponry that our troops are now called on to use in battle require mathematical and scientific skills, particularly computer-based learning. Finally, the sophisticated mathematics of encryption supports and protects our diplomatic and military communications around the world, as well as those of American corporations.

The deeper value of mathematical and scientific knowledge

The wealth of knowledge that mathematics and science impart for understanding the world has such breadth that it is easy to overlook the dimension of depth. But teaching our children these subjects is important at a more profound level than that of their practical benefits. Above all, mathematics and science impart three qualities that define our human world and enable us to meet its challenges.

- First, mathematics and the sciences bring order, harmony, and balance to our lives. They have great explanatory power. They teach us that our world is not capricious but predictable, i.e., that it contains pattern and logic, which can be used in the service of humankind. The analytical tools of mathematics and the investigative skills of a scientific approach are also foundational skills for lifelong learning, in other words, for creating progress itself.

- Second, science and mathematics continually shape and reshape our history and culture, giving rise to new ideas and inventions. It was early astronomy that formed the knowledge base of ancient Near Eastern civilizations. The physics of Newton made the Industrial Revolution possible. In our own time, the pure science of information theory has yielded not only computers but also an incredibly useful global communications system.

- Third, as science and mathematics provide human beings with powerful tools for understanding and continually reshaping the physical world itself, they teach us again and again that Nature's secrets can be unlocked—in short, that the new is possible.

Not the Last Word

Despite the pervasiveness of mathematics and science in our lives, the sad reality is that our nation continues to renege on its *"By the Year 2000…"* promise. Our schools are not producing graduates with the kinds of skills our economy needs to remain on the competitive cutting edge. In consequence, we are bequeathing failure to our children. As they try to meet the challenge with the longest-range implications of all—securing their own and America's place in the world—they need to command the disciplines that they are only indifferently mastering today.

If this were all that could be said, then the future would be bleak indeed. But it is not. Some important factors have begun to coalesce, each adding to the others' momentum.

The Time to Act is Now

An ancient Chinese proverb says, "The best time to plant a tree is twenty years ago; the second best time is today."

We believe that wisdom applies to the task of strengthening and improving the quality of mathematics and science teaching and learning in America. Fortunately, an unusual confluence of factors has created an unprecedented—perhaps once-in-a-lifetime—opportunity for making progress. Five things seem to be happening at once.

- First, two decades of experience in education reform demonstrate that tinkering around the edges will not suffice. Happily, education reform now has the focused attention of the American people. Not long ago, when asked to name the top problems facing the nation, Americans ranked education well down on the list. Today, in poll after poll, it is number one. That kind of concern, focused through the lens of a well-crafted agenda, offers an opportunity to generate real energy. But that opportunity will not last forever.
- Second, America now has the abundance of resources it needs to address the issue of mathematics and science education powerfully. We are still in the midst of the longest economic expansion in our history. Thanks in part to a half-century of investment in science and technology, there may be a trillion-plus-dollar surplus at hand to invest in our people.
- Third, the U.S. teaching force is about to go through a massive reshuffling. Over the next decade, our schools will replace two-thirds of their teachers, whether by retirement, attrition, or job changes. This immense demographic shift in our schools presents us with an unparalleled chance to plan—to inject new energy into mathematics and science teaching in the form of new recruitment, training, and supportive structures that can strengthen teaching at all grade levels. This we *must* do, before we are forced to play yet another game of educational catch-up.
- Fourth, we have learned much in the past generation about what works in mathematics and science education—about rigorous curriculum, high standards,[17] effective teaching methods, challenging assessments, and how young people learn.[18] In several states, school districts, and schools, innovative approaches are being attempted. Many are promising. We need to build on these approaches and extend them with new research. We now have the chance to bring this knowledge together in a mathematics and science education effort that will serve as a powerful tool for change. Ignored research is worthless; unused tools can only rust.

- Finally, many more able college students are expressing an interest in teaching. The success of such programs as *Teach for America* and *AmeriCorps*, and the national resurgence in volunteerism, demonstrate that the long dormant idealism of a former generation has been reawakened. According to a recent poll, 10% of young Americans say they want to teach in our schools—double the number who said so in 1982.[19]

Now, The Glimpse of a Greater Challenge

At the beginning of the 20th century, schools in our country underwent profound changes as they adapted teaching and curricula to the demands of industrialization and the needs of a growing population. At the beginning of the 21st century we look to an even greater challenge. Our schools, and the teachers who imbue them with life, must find ways to produce higher levels of proficiency in mathematics and science in *all* their students. The American people must do this because our world and our times require it. If we do not plant this tree today, we will surely have to do so tomorrow, next month, or next year—at a higher price.

Toward a Solution

We Must Place Better Teaching at the Center of Mathematics and Science

The two core premises of this report are simply stated and they undergird every change we recommend:

(1) *Now, more than ever, America's students must improve their performance in mathematics and science.* That is the burden of the case presented thus far.

(2) The second premise points in the direction of a solution: *The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching.* In other words, better teaching is the lever for change.

To call for higher student achievement and high-quality teaching as the most direct route to change seems obvious on the surface, but recent educational reform recommendations have not been sufficiently guided by this clear linkage. Now, before it's too late, is the time to head this guidance.

The evidence for the effect of better teaching is unequivocal.[20] The most consistent and most powerful predictors of higher student achievement in mathematics and science are: (a) full certification of the teacher and (b) a college major in the field being taught.[21] Conversely, the strongest predictors of lower student achievement are new teachers who are uncertified, or who hold less than a minor in their teaching field.

The difference better teaching makes is often dramatic. The National Commission on Teaching and America's Future reported in 1996, for example, that licensing examination scores and teaching experience accounted for 43% of the gains in mathematics test scores in the early grades.[22]

The difference better teaching makes for students is paralleled by what can also happen for teachers. A focused *professional development* experience led by qualified teachers, mentors, and colleagues is the indispensable foundation for competence and high-quality teaching.

As school gets under way in the fall of 2000, many underprepared and out-of-field teachers will take charge of mathematics and science classrooms. They, as well as their better-prepared and more knowledgeable colleagues, must have access to ways to continually improve their teaching. Only a tailored system of professional development provides that access.

Thus, if we are to create the kind of mathematics and science education America needs, we have to start rebuilding at education's very foundation—*teaching itself*.[23] For this reason, the three goals in this report—and the action strategies that accompany them—point in a new direction.

But before turning to specific remedies, we need to know more about what is happening now in America's mathematics and science classrooms—and what should take its place.

WHO IS A MATH OR SCIENCE TEACHER?

All teachers, grades K–12, who provide instruction in mathematics or science for some part of the school day are math or science teachers. The elementary school generalist, the high school teacher specializing in physics, as well as the drama teacher who may be assigned to a single geometry class, are all persons whose teaching quality is of interest—and of consequence—to the nation.

WHAT IS PROFESSIONAL DEVELOPMENT?

When this report uses the term "professional development," it means a planned, collaborative, educational process of continuous improvement for teachers that helps them do five things: (1) deepen their knowledge of the subject(s) they are teaching; (2) sharpen their teaching skills in the classroom; (3) keep up with developments in their fields, and in education generally; (4) generate and contribute new knowledge to the profession; and (5) increase their ability to monitor students' work, so they can provide constructive feedback to students and appropriately redirect their own teaching.

The Need for Professional Development

To say that improving the quality of teaching yields better student performance in science and mathematics makes sense, and some states have taken this wisdom to heart.[24] But in many more places, nearly the reverse is true. There, the knowledge base and arsenal of teachers' skills must be replenished:

- More than one in four high school mathematics teachers and nearly one in five high school science teachers lack even a minor in their main teaching field.[25]
- More than 12% of all new hires enter the classroom without any formal training; another 14% start work without meeting the teaching standards of their states.[26]
- About 56% of high school students taking physical science are taught by out-of-field teachers, as are 27% of those taking mathematics. These percentages are much greater in high-poverty areas. Among schools with the highest minority enrollments, for example, students have less than a 50% chance of getting a science or mathematics teacher who holds both a license and a degree in the field being taught.[27]

Thus, when the dismissal bell rings each day, untold thousands of American students depart for home having been taught by mathematics and science teachers ill-equipped for the job. Far too many are inexperienced beginners, with little or no training, and little or no mentoring by qualified colleagues. Astonishingly, in no other profession is so much of such ultimate worth entrusted to people with such uneven qualifications.

SHORT-TERM SOLUTION CREATES LONG-TERM PROBLEM

The most common solution to the shortage of qualified mathematics and science teachers is to assign those classes to out-of-field teachers. But merely being able to keep one chapter ahead of the students in an algebra or environmental science text does not a mathematics or science teacher make.

Predictably, underqualified teachers are most prevalent in urban schools. A recent survey taken among 40 large urban schools, for instance, showed that more than 90% of them had an immediate need for a certified mathematics or science teacher.[28]

What Happens in Most Classes

Despite the dramatic transformations throughout our society over the last half-century, teaching methods in mathematics and science classes have remained virtually unchanged. Classroom practice has still hardly begun to capitalize on the many dimensions of the learning process.

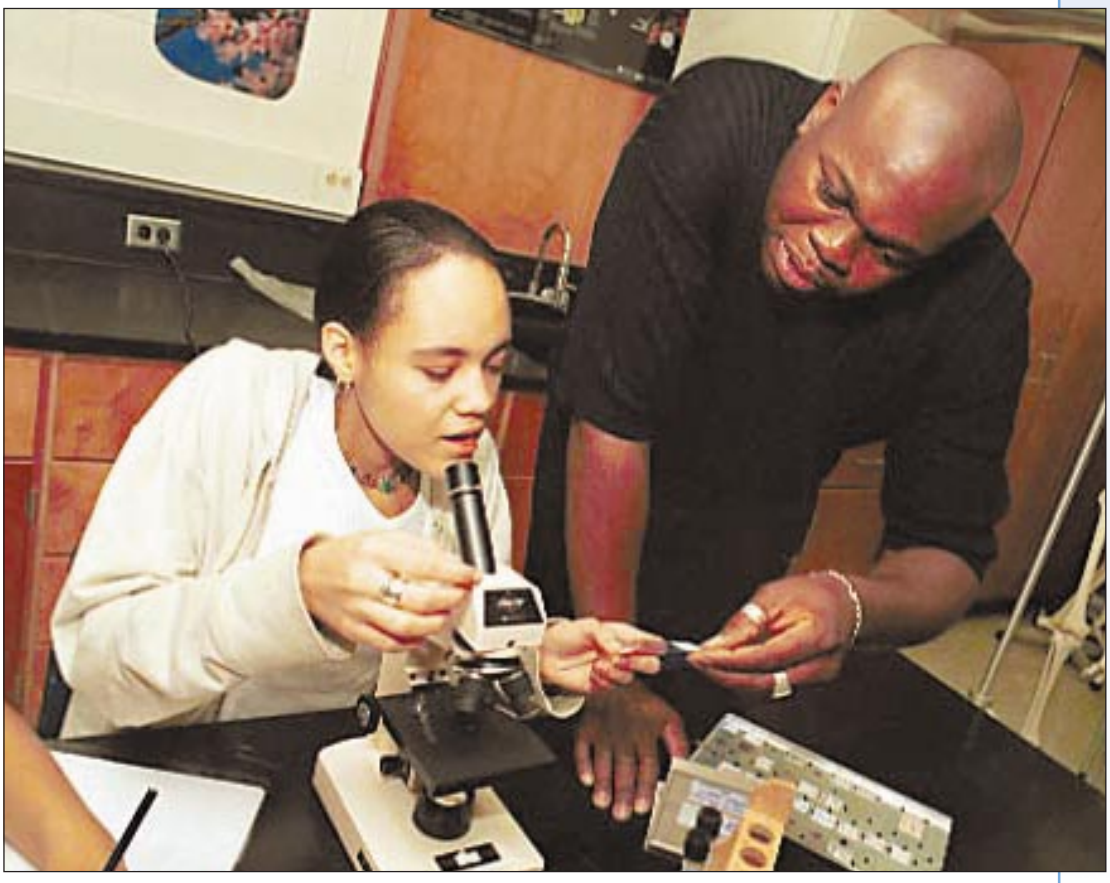
A videotape study of eighth-grade mathematics classes in the United States reveals that the basic teaching style in American mathematics classrooms remains essentially what it was two generations ago. The approach used for the lessons was numbingly predictable: (1) a review of previous material and homework, (2) a problem illustration by the teacher, (3) drill on low-level procedures that imitate those demonstrated by the teacher, (4) supervised seat work by students, often in isolation, (5) checking of seatwork problems, and (6) assignment of homework. In not one of 81 videotaped U.S. classes did students construct a mathematical proof.[29]

In Japan, by contrast, closely supervised, collaborative work among students is the norm. Teachers begin by presenting students with a mathematics problem employing principles they have not yet learned. They then work alone or in small groups to devise a solution. After a few minutes, students are called on to present their answers; the whole class works through the problems and solutions, uncovering the related mathematical concepts and reasoning. The students learn through reasoned discovery, not lecture alone.

Not incidentally, this approach is a natural outgrowth of the teaching culture in Japan, which accords teachers not only abundant time for preparation, but also for collaborative lesson planning. Fully 99% of all elementary teachers and 50% of all middle school teachers participate in lesson study groups that meet for two to five hours per week. The debilitating professional isolation of U.S. teachers stands in stark contrast to this pattern. A core conclusion from the videotape research: "The key to long-term improvement [in teaching] is to figure out how to generate, accumulate, and share professional knowledge."[30]

Instructional patterns in the United States do not yield much better results when it comes to the sciences. Tests of scientific knowledge and classroom observation indicate that most science students spend much of their time learning definitions, or the labels that apply to natural phenomena and scientific processes. In other words, much science instruction in our schools parallels what happens in a badly taught history unit on the Civil War, in which students learn nothing but the names of the generals and the dates of the battles. Seldom are students asked to master the "big" concepts that make science so powerful and fascinating.[31]

If the core of mathematics and science is about inquiry, then too many of today's mathematics and science classrooms come up short. Student are crippled by content limited to the "What?" They get only a little bit about the "How?" (or "How else?") and not nearly enough about the "Why?" Missing almost entirely is "Why should I care?" It is hard to imagine that students in these classes are gaining the conceptual and problem-solving skills they need to function effectively as workers and citizens in today's world—a world that increasingly depends on mathematics and science.



What Could Happen

We Need To Capture A Vision Of High-Quality Teaching

What kind of instruction in mathematics and science can justifiably be called "high-quality teaching?"

- A core premise of high-quality teaching is that the ability to teach, contrary to myth, is not "something you're born with"; it can be learned and refined over time. Specific teaching skills—for example, the ability to distinguish between what is most important for students to learn and what is hardest for them to understand—can only be acquired through training, mentoring, collaboration with peers, and practice.
- High-quality teaching requires that teachers have a deep knowledge of subject matter. For this there is no substitute.
- In high-quality teaching, the process of *inquiry*, not merely "giving instruction," is the very heart of what teachers do. Inquiry not only tests what students know, it presses students to put what they know to the test. It uses "hands on" approaches to learning, in which students participate in activities, exercises, and real-life situations to both learn and apply lesson content. It teaches students not only what to learn but how to learn.
- High-quality teaching not only encourages students to learn, it *insists* they learn.
- High-quality teaching, especially in the sciences, focuses on the skills of observation, information gathering, sorting, classifying, predicting, and testing. A good science or mathematics teacher encourages students to try new possibilities, to venture possible explanations, and to follow them to their logical conclusions.
- High-quality teaching fosters healthy skepticism. It encourages students to submit their work to questioning by others, to pull things apart and put them back together, and to reflect on how conclusions were reached.
- High-quality teaching allows for, recognizes, and builds on differences in the learning styles and abilities of students. It has the deepest respect for students as persons; it corrects without squelching; it builds on strengths rather than trying to stamp out weaknesses.
- High-quality teaching is grounded in a careful and thorough alignment of curriculum, assessment, and high standards for student learning.
- To keep its edge, high-quality teaching must be continually reshaped by the institutional structures that support it, i.e., by professional development, continuing education, the effective use of technology, and recognition and rewards.
- Finally, the effectiveness of high-quality teaching can be evaluated by the performance and achievement of the students who receive it.

Why isn't high-quality teaching universal?

For teachers to deliver high-quality teaching, they must be empowered to do so. Generating this kind of teaching means that school boards, administrators, parents, and policymakers must be willing to stand up for teachers as the primary drivers of student achievement. Teachers must be given the time they need within the school day to keep up with new developments in their fields, teaching aids, materials, and technology. Teachers must be encouraged to contribute knowledge back to their disciplines. They need the time and feedback necessary to reflect on their teaching, so they can get better at it.

Teacher empowerment also means according teachers the respect they deserve for their judgments about learning, rewarding their professionalism, and yes, paying them what they are worth. These concerns are addressed by the goals that follow.

Three Goals

The pressing national need for high-quality teaching described in this report demands a vigorous, national response that unifies the efforts of all stakeholders in mathematics and science education. To that end, three wide-ranging but intertwined goals focus our call for action at the local, state, and federal levels. Achieving these goals will involve the sustained efforts of legislators and other decision-makers, the business community, higher education, school boards and administrators, teachers, and parents. An intense, serious commitment to achieve these goals, through a coordinated set of well-funded action strategies, is needed immediately.

All together, the action strategies for achieving these goals nationally will cost more than $5 billion annually. Strategy by strategy, the financial responsibility must be shouldered by the governments and institutions best equipped to do so, whether at the federal, state, or local levels, by business and industry, or by higher education. The agenda laid out here details concrete steps that all Americans can take. The most important point to keep in focus is that the funds invested in mathematics and science education today can purchase a lifetime of leverage on the future of American school children and the nation as a whole.

Clearly, the cost of achieving these goals will create a noticeable line item in education budgets at every level. (An estimate of the costs associated with the first year of implementation of the goals concludes this report.) At the same time, however, the nation's balance sheet now shows a considerable surplus and the cost of delay is higher still. Those funds must therefore be put to work now, when and where they can most usefully equip our young people, and through them the nation itself, for the new century's challenges.

GOAL 1: Establish an ongoing system to improve the quality of mathematics and science teaching in grades K–12.

If high-quality teaching is the leverage point for improving mathematics and science education, and if professional development is a prerequisite for a well-qualified and effective teaching force, then teachers need a focused support *system* and enough time to grow as professionals.

Sadly and short-sightedly, however, professional development is too often treated not as a necessity but as a luxury item on the school budget. Many people erroneously believe that teachers are not working unless they are standing in front of a classroom. In fact, preparation time, individual study time, as well as time for peer contact and joint lesson planning, are vital sources of both competence and nourishment for all teachers.

But teachers are granted precious little time for any of these activities. Equally rare are extended periods of time set aside

SCALING UP

Several states and school districts already provide excellent instruction in mathematics and science. Their students' test scores provide evidence of high-quality teaching. But occasional oases of excellence are not enough to meet the nation's needs. That means scaling up our efforts to match our aspirations. Our perspective must be nationwide and we must intensify our efforts immediately: not next week, or next year, but now. Our aim can be no less than equipping every K-12 student in every school with an excellent education in mathematics and science. The three strategic goals of this report are therefore just as urgent as they are visionary.

The estimated costs that accompany the Action Strategies proposed here remind us that we will get only what we are willing to pay for.

WHAT IS A PROFESSIONAL?

A professional "professes" the values associated with a particular occupation, and has acquired the special core of knowledge and skills needed to serve others effectively through that occupation. If professionals do not maintain and expand their knowledge and skills, they will atrophy.

We have the resources and insights to build an even stronger base of professional knowledge about mathematics and science teaching. Where that is not available, it has to be developed.

for teachers to have challenging educational experiences of their own. In consequence, much-needed study and preparation time is routinely sacrificed to in-service events that are no more substantive than a broad-brush overview of this semester's teaching fad. High-quality professional development ought to be the lifeblood of American teaching; instead, it is used only to provide the occasional, anemic transfusion.

Everyone connected with and touched by the U.S. education system is responsible for changing the character of professional development and its impact. *Teachers* need to take responsibility for their own professionalism as they practice mathematics and science teaching and work to improve their knowledge and teaching skills. *Principals, superintendents and school boards* must make sure teachers have the time and resources they need to prepare and collaborate. *Teacher preparation institutions, state departments of education, and the federal government* all have a substantive policy role in enabling teachers, schools, and districts to realize improved teaching via professional development. The support of businesses, which stand squarely to benefit from improvements made in the quality of mathematics and science teaching, is also crucial to enriching the quality of professional development. *Professional associations and their members* can make their own important contributions through workshops, clinics, and new curricular initiatives.

The place to begin improving mathematics and science teaching is with a *system* that promotes high-quality professional development opportunities for all teachers. Such opportunities should build upon one another and reinforce accountability. The system must be rooted, first of all, in a clear determination of the professional development needs of teachers in every school and school district. That determination must be followed by an immediate response to the most pressing needs; a sustained response with the necessary leadership, resources, tools and time; and a continuing system that recognizes and rewards schools that demonstrate improved student achievement.

Despite progress in some states and districts, there remains an urgent need for wide-scale self-examination, strategic planning, and rapid implementation of a system of professional development tailored to the needs of those who provide instruction in science and mathematics, K–12. Action strategies for implementing such a system are outlined below; each is accompanied by concrete suggestions on how the work can be done and who can do it.

Action Strategies: What Needs to Happen

Needs Assessment: Each state must quickly undertake a full assessment of the professional development needs, district by district, of its mathematics and science teachers, K–12. As many stakeholders as possible must be involved in this self-

NEEDS ASSESSMENT

Who Will Make Them Happen and How?

- Some selected states will begin their needs assessments immediately. States should first establish criteria and protocols for conducting their needs assessment, then go on to identify and analyze state certification and recertification requirements. Once procedures and systems have been established and tested in these initial states, what is learned can be widely disseminated to all states.
- Governors, state legislatures, and state boards of education in each of the remaining states (thence districts) must work together quickly to allocate the federal, state, and local funds and staff needed to develop and oversee a similar assessment of the professional development needs of mathematics and science teachers.
- Two- and four-year colleges and universities, using their mathematics, science, and education faculties, can assist school districts and others in planning and implementing needs assessments.

SUMMER INSTITUTES
Who Will Make Them Happen and How?

- As with the needs assessments, selected states will establish protocols and evaluation criteria for Summer Institutes, working in concert with state boards of education. The lessons learned from these experiences will be widely disseminated to other states to inform their efforts.
- Governors, state legislatures, state boards of education, and districts in each of the remaining states must work together quickly, allocating funds and staff, to develop and oversee a series of Summer Institutes addressing the most pressing professional development needs of mathematics and science teachers.
- Federal, state, and local professional development funds must be allocated to this coordinated purpose—rather than in the diffuse way that is currently all too common. Teachers should be compensated for their participation in the Summer Institutes.
- Institutions of higher education and professional associations are well positioned to assist in planning, hosting, conducting, and evaluating Summer Institutes.

evaluation—teachers, administrators, parents, school boards, businesses, two- and four-year institutions of higher education, professional associations, and others. In addition to seeking to upgrade content knowledge and teaching skills, statewide needs assessments must also determine:
(1) whether schools offer a full complement of mathematics and science courses; (2) whether the quality of curricula, texts, and assessments strongly supports high-quality teaching and learning; (3) whether the necessary materials and resources (e.g., laboratories and equipment) are readily available; (4) whether teachers are adept in using technology; and (5) whether teacher certification and recertification guidelines are sufficiently ambitious. As a result, school districts will have a complete snapshot of the status of their science and mathematics teaching corps, enabling the ready identification of professional development tasks that must be targeted first.

Based on what is learned from these needs assessments, each state, with district input, must move immediately to implement a *system* of professional development, designed to address the short- and long-term needs of its mathematics and science teachers. To put this in perspective, collectively the states must plan to quickly reach the *1.7 million teachers nationwide* who provide instruction in science and mathematics.

Summer Institutes: In the near term, two-week Summer Institutes will address the most pressing problems, such as providing opportunities for upgrading content knowledge for out-of-field teachers, conducting subject-based workshops for all science and mathematics teachers, integrating technology into the teaching of mathematics and science, introducing new teaching methods, and improving skills for teaching specific subject matter by grade. Over the long term, states are urged to tailor their Institutes to teachers' identified needs and to make regular Institute attendance a critical component of teacher recertification, with the purpose of continually increasing teachers' science and mathematics knowledge base. In many locations, the powerful technology of distance learning can open Summer Institutes to a statewide teacher audience.

Inquiry Groups: However well they may have been prepared to teach, and whatever knowledge they may have gained in Summer Institutes, *all* teachers need continuing, collegial contact, peer

reinforcement and input from experts to sharpen their skills and deepen their subject knowledge. Building- and district-level Inquiry Groups are envisioned as communities of learning. They will provide a specific venue for teachers to share ideas, gain the benefit of one another's teaching experience, engage in common study to enrich their subject knowledge, learn more about technology, and design ways to incorporate local, state, and national educational developments (e.g., subject-matter learning standards) into their teaching. While critically important during the school year, Inquiry Groups must also continue through the summer, enabling teachers to explore some issues without the pressing responsibility of daily student contact. For districts moving to 11-month salary schedules, full participation in an Inquiry Group ought to be an integral part of every teacher's responsibilities when school is not in session.

Time for in-depth study through regular work with peer Inquiry Groups is a teacher's most valuable professional resource. *It must be considered sacrosanct*.

Perhaps most important, these groups can be a rich source of new knowledge about teaching itself, generated from the field. Such groups can readily take advantage of local resources (e.g., businesses, museums, laboratories), other Inquiry Groups from neighboring districts, and faculty from nearby two- and four-year higher education institutions. Inquiry Groups could also be networked electronically, via distance learning technology, for wider sharing of information, instruction, and resources.

Leadership Training: Summer Institutes and Inquiry Groups must be facilitated by teachers who are current with the most effective teaching methods in their disciplines, who have shown demonstrable results of higher student achievement in mathematics and science, and who are adept in the use of technology for teaching and learning. Although there are many such teachers, the demand far outpaces the supply. To remedy this, many more potential leaders must be identified and trained.

Internet Portal: High-quality mathematics and science teaching requires not only access to technology (especially the Internet) but also regular training in how to use it effectively. An Internet Portal, i.e., an interactive, conversational Web resource dedicated to science and mathematics instruction, would provide links to an ever-expanding knowledge base that would be invaluable in supporting high-quality professional development.

The Portal, functioning as a "virtual resource center" and updated frequently, would provide hyper-links to form a "one-stop-shopping" learning network. It would also codify what is already available on the Web elsewhere, while providing a framework for new entries over time. Among the activities and resources envisioned for the Portal are:

INQUIRY GROUPS

Who Will Make Them Happen and How?

- Districts must establish conditions that promote and support continuing learning communities among science and mathematics teachers in each school, focusing on teaching quality. Doing so will demand a reallocation of teacher time and professional development funds to focus on discipline-based efforts.
- Policies must be enacted by school boards, and rigorously enforced by school administrators, to ensure that this reallocation occurs.
- Access to a variety of Web-based resources—through an Internet Portal dedicated to mathematics and science teaching—must be readily available to all Inquiry Group participants.
- Parent organizations have a watchdog and advocacy role to play in ensuring that Inquiry Groups have the means and opportunity to succeed.

LEADERSHIP TRAINING

Who Will Make it Happen and How?

- Appropriate agencies within the federal government must provide the funding needed to train cadres of facilitators and help them, thereafter, to keep abreast of new insights and research in science and mathematics teaching.
- These trained leaders should work in their respective districts and states to organize and facilitate Summer Institutes and Inquiry Groups. They should also be proactive in helping colleagues develop their Internet and research skills.

THE INTERNET PORTAL
Who Will Make It Happen and How?

- Appropriate federal agencies, especially the National Science Foundation, must scale up current efforts to create a digital library that will serve as the foundation for an Internet Portal.
- States must provide search engines keyed to their respective state standards and curriculum frameworks for more tailored use of the information in the Portal.
- Businesses, particularly those in information management, have a crucial role to play in contributing to and sustaining the Internet Portal.
- Curriculum and software developers, publishers, and academics should collaborate with teachers in generating the resources and tools offered via the Portal.
- Local school boards must make it a matter of policy that mathematics and science teachers have access to, and training in how to use, the Internet Portal.

- An online professional journal that encourages mathematics and science teachers to engage in publishable research and to share new teaching strategies with colleagues, both nationwide and internationally;
- User-friendly access to the growing number of Web sites with real-time data and experiences to support high-quality teaching and learning;
- A dedicated database for mathematics and science teachers, containing teaching ideas, lesson plans, student work, and other resources;
- An interactive, online resource for conversations, meetings, and idea sharing;
- An outlet to distance-learning courses in science and math for K–12 students and their teachers; and
- Interactive video, both for observing good teachers and critiquing teachers' own teaching, for mentoring, and for online instruction.

Coordinating Council for Mathematics and Science Teaching: Implementing and sustaining the initiatives described above, as well as several of those that follow in subsequent goals, require special attention from a *nongovernmental* organization. A Coordinating Council for Mathematics and Science Teaching will serve primarily as a collaborative body. It will function as a broker and matchmaker, bringing together groups that have a stake in mathematics and science education. The Council will also monitor state and local progress on needs assessments, Summer Institutes, Leadership Training, and other initiatives, and make such information widely available. In addition, the Council will take a special interest in creating opportunities for states and localities to collaborate in implementing the goals and strategies offered in this report, particularly those related to the professional development needs of mathematics and science teachers. Key activities for the Council in this arena include:

- Encouraging state needs assessments and collecting and publishing data on mathematics and science teaching that emerge from the assessments;
- Helping schools and school districts consider ways to align their professional development system with state curricula, teaching guidelines, performance standards, and assessment frameworks;

- Disseminating models for restructuring the school day and teachers' responsibilities to provide sufficient time to support a system of ongoing professional development;
- Collecting and disseminating research on improving mathematics and science teaching; developing databases relevant to teaching; identifying and promoting "best practices" in mathematics and science teaching; facilitating nationwide communication among teachers; and
- Measuring progress and making the results of implementing these action strategies widely known to the public.

Rewards Programs: Just as we do our children a profound disservice when we fail to reward their effort, or worse, promote them beyond their merit, so do we cheat their teachers when we fail to recognize their success, or worse, reward them for mediocre performance. To increase the attractiveness of the professional development system, and to make clear that continual improvement in teaching methods is highly valued, all states and local districts must institute a program of recognition and rewards to deserving schools and teachers. Schools with exemplary professional development systems, and those that, *most importantly*, show improvement on rigorous assessments of student achievement in mathematics and science, must be recognized with monetary rewards for their teachers and other staff, and through well-publicized, showcase events. Such programs must speak directly to the bedrock issue of the accountability of our schools—and especially of teachers—for the performance of students.

GOAL 2: Increase significantly the number of mathematics and science teachers and improve the quality of their preparation.

The demand for teachers generally, and for certified and fully qualified mathematics and science teachers specifically, is far outpacing the supply. The most recent data available (1993-94) on nationwide vacancies indicate that 20% of the slots—about 6,500 individuals—were filled by uncertified teachers. A more recent survey indicates that the problem is not diminishing. The National Science Teachers Association has reported that 48% of all middle schools and 61% of all high schools responding reported difficulty in finding qualified science teachers.[32] In urban areas the problem intensifies: 95% of urban districts report an immediate need for high school science and mathematics teachers, while 80% report a need for middle school science and mathematics teachers.[33] These estimated shortages are likely to grow with the impending retirement of almost two-thirds of the current teaching force. The quality of instruction in mathematics and science will be compromised unless the pipeline of qualified teachers expands significantly.

An estimated 240,000 middle and high school mathematics and science teachers will be needed over the next 10 years.[34] Of this total, nearly 70% will be newcomers to the profession. The negative

COORDINATING COUNCIL

Who Will Make It Happen and How?

- Financial support for the Council must come from a diversified funding stream, including the federal and state governments, businesses, and foundations.
- Where appropriate, the Council will partner with existing groups to provide the necessary services and motivation to states and districts.
- Institutions of higher education will support the Council's mission by providing the training venues and the human resources needed to enact Council-brokered activities.

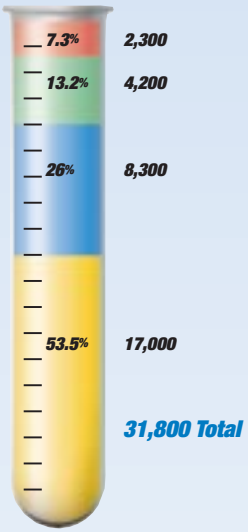
REWARDS PROGRAMS

Who Will Make Them Happen and How?

- U.S. corporations and businesses, which have a stake in improving mathematics and science education, should provide significant funds, over several years, to support rewards and recognition programs in those states and districts that have implemented a system of high-quality professional development and assessment.
- It makes sense to gradually move rewards and recognition programs under the umbrella of state and local education agencies, although a strong business presence is needed to keep school-business relationships viable and to impart to the public the importance of the business stake in mathematics and science education.

The Right Measurements

Middle and High School Mathematics and Science positions filled during the 1993-94 school year.



- Non-Certified New Teachers
- Non-Certified Returning and Transferring Teachers
- Certified New Teachers
- Certified Returning and Transferring Teachers

U.S. Department of Education National Center for Education Statistics, Schools and Staffing Survey (1993-94); and unpublished data.

EXEMPLARY MODELS

Who Will Make Them Happen and How?

- An appropriate federal agency, working with an array of highly respected professionals, will move quickly to set the criteria and process for identifying exemplary programs.
- This agency will also move, in a very timely fashion, to facilitate the identification process for new and redesignated models.
- Federal funds should be made available to the identified institutions for their use in supporting promising students to study science and mathematics teaching.

impact of the teacher shortage is compounded by the diffuse and therefore uneven quality of the education delivered by teacher preparation institutions. The sad fact is that many teacher preparation programs do not build an adequate knowledge base in their graduates. An aggressive recruitment program, therefore, must be accompanied by an equally aggressive, and simultaneous, effort to improve teacher preparation.[35]

To deal with these issues, two fundamental tasks must be accomplished: (1) identify exemplary models of teacher preparation that can be widely replicated, and (2) find ways to attract large numbers of qualified candidates into teaching (e.g., persons in mid-career seeking new challenges). We must train these individuals to high standards and provide them with the resources they need, throughout their careers, to meet the certification requirements and demands of high-quality teaching. Once employed, these new teachers can both contribute to and learn from Inquiry Groups that are part of a well-conceived professional development strategy in their respective schools.

The first step in such a strategy, however, must be a preparation program that imparts a deep understanding of content, teaches prospective teachers many ways to motivate young minds, especially with the appropriate use of technology, and instills a knowledge of—and basic skills in using—effective teaching methods in the discipline.

Action Strategies: What Needs to Happen

Exemplary Models: Identifying exemplary programs of teacher preparation around the country, and finding ways to encourage others to multiply their success, are basic to reaching Goal 2. To identify successful approaches and expand the pool of exemplary institutions and well-prepared new teachers, rigorous criteria are needed beyond those already used by credentialing and accrediting bodies. (Better-targeted performance criteria are indicated for teacher preparation institutions if for no other reason than the less-than-successful teaching generated by many of their graduates.) Designation as an exemplary program must be highly selective, a mark of prestige; nonetheless, there should be no artificial limit on the number of institutions accorded that status.

Each group of exemplary programs will keep its status for five years, at which time they will undergo a new review. Once identified, faculty at institutions with exemplary programs will need to collaborate with colleagues at other higher education institutions to increase the number of programs that can meet the exemplary criteria in subsequent years. In addition, designation as "Exemplary" should be required to qualify two- and four-year institutions to receive the federal funds needed to support full-tuition four-year scholarships. These new scholarships can entice high school students to become mathematics and science teachers and increase the number of undergraduates who can benefit from high-quality teacher preparation. When fully operational, more

than 1,500 scholarships will be available yearly to high-achieving students who are attracted and committed to math and science teaching as a career.

Teacher Recruitment: Once we can identify the kinds of teacher preparation programs that are most effective, and have a mechanism in place to increase the number of such programs, we can give full attention to an ambitious program to recruit students to enter the corps of mathematics and science teachers. Incentive-based strategies offer the most promise for attracting individuals capable of high-quality teaching, drawing from at least three groups of potential candidates:

- To address the pressing needs created by teacher shortages in mathematics and science, *recent college graduates and persons at mid-career* with baccalaureate (or higher) degrees in mathematics or science will be invited to compete for 3,000 prestigious, one-year, paid fellowships that lead to certification as mathematics and science teachers.[36] At the end of their training, Fellows will agree to be employed for five years, to teach in districts with math and science teacher shortages.[37]

- To attract *college students*, a federally funded loan program, based on financial need, is required to target those considering mathematics and science teaching as a career. These loans will be forgiven, contingent upon the students' agreement to teach for five years in districts with shortages of mathematics and science teachers. The number of available loans can be adjusted annually to reflect the demand; 6000 loans are appropriate for current shortages of qualified teachers.

- Although *high school seniors* typically explore various career options, many are open to the idea of teaching. To attract this group, 1500 scholars will be competitively chosen to attend one of the exemplary preparation institutions on a full-tuition scholarship. In return, these students must agree to teach for five years in areas with teacher shortages.

Mathematics and Science Teaching Academies: An entirely new kind of research- and school-based preparation program must be created to provide a year of teacher education for those with scientific and mathematical content knowledge. Specifically, 15 Mathematics and Science Teaching Academies must be competitively selected, one in each of the 10 federal regions, with 5 more strategically located. No new brick-and-mortar infrastructure is envisioned. Rather, each Academy will build on existing institutions and bring them together into a new kind of relationship. Each Academy will ideally comprise an administrative consortium of at least one institution of higher education (including two-year colleges), neighboring school districts, business partners, members of

RECRUITMENT

Who Will Make It Happen and How?

- The federal government must support an aggressive, national outreach, media campaign to attract young people to teaching careers in mathematics and science.

- Those in frequent and close contact with the academic progress of such students—parents, school counselors, principals, teachers, professors—must build on the campaign with encouragement and guidance for these prospective teachers. The Coordinating Council will disseminate materials and information in support of the campaign and stimulate recruitment strategies for mid-career and recent college graduates.

- Through appropriate federal agencies, funds will be available to support the different scholarship and loan programs.

- Appropriate federal agencies will administer the financial aid aspects of the programs.

MATHEMATICS and SCIENCE TEACHING ACADEMIES

Who Will Make Them Happen and How?

- Academies must be established through a competitive grant process administered by appropriate federal agencies and supported by federal funding.
- Higher education institutions will take the lead in the administration of the Academies. Members of the faculty from science, mathematics, and education departments will have substantive roles.
- Nearby school districts must provide internships for Fellows during their year of training, and districts with a demonstrated shortage will hire Fellows upon their completion of the Academy's program.
- Districts must also develop and implement induction programs for new mathematics and science teachers, including involvement in their Inquiry Groups.

the Eisenhower Math and Science Consortia, and perhaps others. The permanent staff at each Academy will be kept small, supplemented with visiting scholars on sabbatical.

Three thousand competitively selected Academy Fellows with degrees in mathematics and science will be identified from among recent college graduates and persons at mid-career who are seeking a new challenge in life. Fellows will be appointed annually to receive a one-year, intensive course in effective teaching methods in mathematics or science; each will receive a $30,000 stipend for the year. Training for all Fellows must include school-based internships that involve supervised teaching.

After an intense high-quality preparation program, these individuals will be ideal job candidates for school districts suffering from mathematics and science teacher shortages in middle and high schools. Federal funds, up to $10,000 per Fellow, will be available to the districts that hire Fellows at the conclusion of their course of study, with two provisos: that the funds be locally matched, and that a *district-wide* induction program be created for as many new mathematics and science teachers as possible. It is worth pointing out that districts that already have established Inquiry Groups will benefit greatly from the newly minted knowledge that Fellows bring to their posts, just as Fellows will benefit from sharing experiences with seasoned veterans.

Once established, all the Academies will work collaboratively to share knowledge and experience. Similarly, the Academies and exemplary undergraduate teacher preparation programs will work collaboratively to share lessons learned in their quest for high-quality preparation for teaching.

GOAL 3: Improve the working environment and make the teaching profession more attractive for K–12 mathematics and science teachers.

Our society frequently refuses to recognize the professional status of teachers, ranking them below doctors, lawyers, and clergy. Many Americans think "anyone can be a teacher" and that little expertise is required. And because teachers are not fully appreciated for the special knowledge and skills required to do their jobs, they are vulnerable to public attack.[38] This widespread attitude is simply wrongheaded.

The low esteem teachers experience is only one source of the disappointment they feel, however. The lack of positive regard for teachers is compounded when efforts to recruit new members to the teaching profession fail to solve the staffing problems of schools. Turnover in the nation's teaching force is high—about 14% overall in 1994-95, with somewhat higher rates among mathematics and science teachers.[39] The top reason mathematics and science teachers leave teaching is "dissatisfaction" with their working environment, a factor cited far more often among mathematics and science teachers

than others (40% vs. 29%).[40] The specific causes given for their unhappiness make a long list, but chief among them are these professional issues: lack of leadership and respect from principals, lack of classroom autonomy, lack of respect from students, poor support from administrators, overly large classes, and poorly equipped classrooms and laboratories.[41] But by far, the number one reason for dissatisfaction among mathematics and science teachers is "poor salary"—cited by 66% of those who leave their jobs.[42] This issue is examined separately at the conclusion of the report.

The professional environment of too many mathematics and science teachers contains too many of these negative factors. Their effect is to drive more and more teachers out of the profession, which leads to stop-gap strategies such as out-of-field teaching and temporary certification, which in turn deprofessionalize teaching even more—a vicious circle.

Energetic and sustained steps are needed to break out of this downward spiral. State education agencies, school districts, and schools must move immediately and aggressively to make mathematics and science teaching more attractive.[43] And, they must have the widespread support of local businesses and the public.

Not all these "dissatisfactions" can be remedied at once, but it is possible to launch a turnaround that will foster better teaching. Three action strategies are suggested here. First, beginning teachers, especially, need help in acclimating to the challenges and opportunities of teaching. Second, some business/school district partnerships have already proven themselves uniquely capable of the kind of collaboration that fosters high-quality teaching and makes the profession more attractive. More of these vital partnerships are needed. Third, veteran teachers who demonstrate improvement and who regularly seek new challenges should be encouraged to stay in the classroom and rewarded for their efforts. The following action strategies are accompanied by concrete suggestions on how the work can be done and who can do it.

Action Strategies: What Needs to Happen

Induction Programs: A first step is to set up special "induction" programs for new teachers, especially in districts that may not be able to hire Academy Fellows. This kind of program is routine throughout the business world as a means of easing new people into the workplace, imparting the "company culture," fostering employee loyalty, and acknowledging leadership and excellence in seasoned veterans. Such programs can also create formal mentoring relationships, including participation in Inquiry Groups, that focus on transmitting not only content matter but also vital knowledge and skills related to teaching itself. Other induction strategies include:

- Frequent, formal interaction with master teachers, including class observations and teaching critiques. Several states and districts have already launched such programs;
- Policies that ensure that new teachers do not inherit the most demanding teaching schedules and most challenging students;

INDUCTION PROGRAMS

Who Will Make Them Happen and How?

- State leaders, school board members, local superintendents, and principals must act with determination, realign priorities, and take the policy initiatives needed to develop the induction programs that can foster professionalism across the continuum of teaching experience.
- Professional associations have a powerful role to play in creating and offering model professional development and induction programs, as well as model mentoring programs.
- The Coordinating Council must provide a forum for sharing information about existing and new model induction programs and reporting on the effectiveness of such programs, especially regarding issues of retention and teaching quality.
- The American Federation of Teachers and the National Education Association have an enormous stake in professionalizing teaching. Superintendents and principals need to be able to count on union members to support efforts to develop induction programs aimed at improving the quality of mathematics and science education in grades K–12.

BUSINESS/SCHOOL DISTRICT PARTNERSHIPS
Who Will Make Them Happen and How?

- Business/district partnerships must focus on mechanisms for sharing knowledge, expertise, and resources. Together, they must define the best match between the needs and capabilities of the two partners.
- The Coordinating Council, working with groups such as the National Alliance of Business and the Business Coalition for Education Reform, must provide models of existing partnerships and encourage the development of new ones.
- Both businesses and school districts must assign a high-level staff person as a liaison with responsibility for maintaining and improving the partnership, coordinating the assignment of business personnel to the schools and vice versa, and developing appropriate activities.

- Policies aimed at focusing a new teacher's time and energy on *teaching*, e.g., by excluding or limiting extracurricular duties; and
- Policies that ensure instruction in the use of technology in general, including participation in the existing high-quality programs designed for this purpose, and in the use of the mathematics and science teaching Portal in particular.

Business/District Partnerships: Many businesses already serve their local communities in extraordinary ways. These enlightened companies are needed as models for others who can expand, rejuvenate, or establish new partnerships that will help strengthen professionalism in mathematics and science teaching. Acting with states, districts, and other stakeholders, business/district partnerships can take several steps to encourage teachers to stay in the classroom, continually sharpen their skills, optimize working conditions, and encourage widespread public support for mathematics and science education. Some of these steps—but not all—involve commitments of funds; all of them do involve business commitments of time and talent. Among the specific roles business/district partnerships can play are the following:

- Business/district partnerships can collaborate to provide facilities, materials, equipment, scholarship support, and other resources to enhance the learning environment in K–12 mathematics and science classrooms, and to support students preparing to become mathematics and science teachers. For example, a local business could stock a science laboratory or train teachers in the use of the Internet Portal;
- Partnerships can provide or help to generate community grants and incentives to schools that restructure time and personnel responsibilities for mathematics and science teachers, thereby enabling them to focus their energies on collaboration and high-quality teaching;
- Partnerships can help schools and school districts sustain induction programs for all teachers of mathematics and science, K-12. They might, for example, help raise funds to pay annual stipends to mentors. Local businesses might also offer new teachers and mentors opportunities for field-based learning experiences that can enhance teaching;
- Such partnerships can establish and run paid summer internship programs within companies for interested teachers, both as a means of expanding their skills and of enhancing their incomes;
- Business/district partnerships can develop "release time" programs that make employees available to act as mentors or to assist mathematics and science teachers in other ways—without loss of seniority or benefits. Similarly, business partners can work with colleges and universities to

significantly reduce the number of out-of-field mathematics and science teachers by helping to retrain unqualified teachers, or by releasing qualified employees to work in schools; and

- Business/district partnerships can serve as advocates for additional teachers to go through the advanced certification process of the National Board for Professional Teaching Standards and support the costs of participation.

But a caveat is in order here. As vitally important as the participation of the business community is in improving mathematics and science education, the long-term responsibility for public education remains with the public. The proper role of American business and business/district partnerships lies in helping to "jump-start" initiatives called for here, not in financing them indefinitely. Equally important is the pragmatic realization that some districts do not have a business base nearby. The needs of business-poor districts in rural and inner-city areas are just as urgent as those where businesses are prominent; therefore, states, school organization advocacy groups (e.g., PTAs and PTOs), and other voluntary associations must step into the breach to ensure that differences between districts are not deepened.

Career-long Incentives: All groups with a stake in mathematics and science education must provide incentives for deserving mathematics and science teachers to remain in teaching and improve their skills. These incentives must be directly tied to accountability measures for teachers that take student performance seriously as a criterion of high-quality teaching and teachers' professional competence.

Mathematics and science teachers, like other professionals, ought to be fully able to advance through a series of career stages that reflect both their intellectual and professional growth; teachers who demonstrate improvement in their teaching must be appropriately acknowledged.[44]

Often, the only opportunity for teachers to advance is to leave the classroom and take a position in school administration. In fact, achieving the goal of high-quality teaching demands that good teachers be able to flourish in the classroom. That can only happen when teachers have an open-ended opportunity to improve their teaching and be recognized for their accomplishments. Today, almost all teachers are paid on the basis of years of

CAREER-LONG INCENTIVES
Who Will Make Them Happen and How?

- All members of the local education community (principals, administrators, school boards, parents, civic leaders, etc.) must provide recognition to teachers whose students show higher achievement on high-quality measures.
- To encourage excellent teachers to remain in the classroom, school districts must create new salary structures that recognize added responsibilities and achievements.

experience and number of education units and degrees earned. More progressive salary structures—tied to increased levels of teacher responsibility and to job-performance criteria—are needed.

Teachers also need to know that they are valued. When appropriate, civic organizations ought to demonstrate the community's appreciation to hard-working, highly accomplished teachers.

Teacher Pay: The Litmus Test

Teachers in this country are scandalously underpaid, a fact that invariably affects the quality of teaching in our nation's classrooms. The fact is, many teachers experience their jobs as exercises in irony: they are expected to have high-quality qualifications and skills, but they are neither accorded professional status nor rewarded with a professional's salary. Creating high-quality teaching in mathematics and science education demands both.

What Teachers Earn: The National Center for Education Statistics reports that, on average, teachers earn 29% less than other workers with a baccalaureate degree ($35,048 per year compared to $49,362 per year in 1997), a differential that has nearly quadrupled during the economic expansion of the 1990s. The demands of the economy and workplace are widening this gap. Given that the national average starting salary for teachers is $25,735,[45] the teaching profession is nowhere near being a financially competitive option for most young people who leave college with backgrounds in mathematics and science. In fact, baccalaureate degree earners in these fields can earn twice as much in private industry as in teaching.[46] Making sure that teaching mathematics and science has appeal as a career option is directly linked to the potential for meaningful salary growth. It is hard to escape the conclusion that without better pay for mathematics and science teachers, the high-quality teaching needed in these fields will be very difficult to sustain.

One powerful litmus test of how serious we are about providing high-quality mathematics and science teaching is what we are willing to pay good mathematics and science teachers. That is not really so much a financial test as it is a policy one, not so much a matter of the pocketbook as one of political will. And that statement, in the end, leads to this final point.

Taking Personal Responsibility

This report has laid out a coordinated set of tasks for the key stakeholders in mathematics and science education. But the story is not yet complete. We *therefore put this challenge directly to the American people: if you have found our case persuasive, it is up to you to take responsibility for achieving these goals.*

Realistically, neither paying mathematics and science teachers what they are worth, nor any other issue raised in this report, is a problem that will be solved by "someone else." It is this nation's citizens and taxpayers whose priorities and principles should be honored in public policy, including—and in this context especially—in decisions about what teachers are paid.

THE VITAL ROLE OF LOCAL SCHOOL BOARDS

Local school boards, because they are the decision-making body closest to the classroom, play a central role in setting a new course. It is they who have the ultimate responsibility to bring high-quality teaching in mathematics and science to our schools. It is their job (within some state-imposed guidelines) to set local instructional priorities and policy, to determine budgets, and to set salary scales.

Perhaps most important of all, it is school boards that are accountable—to citizens, parents, and taxpayers alike—for the education our children receive. Whether elected or appointed, school board members serve at the sufferance of the public.

But to be accountable, school boards must be held accountable. They must be called on to interpret their actions and justify their decisions. And in America, making them responsive is the people's job.

So we put this agenda squarely before you:

- If you don't know how well children in your local schools are performing in mathematics and science on challenging state and district assessments, find out. How do their scores stack up against those of children in neighboring schools? Then decide if they are learning what they need to know to "hit the future running."

- If you are unaware of what mathematics and science teachers are paid where your children attend school, find out. Then decide what steps you will take to bring teacher salaries up to the professional level that reflects the value you, as parents and as taxpayers, put on their work and their performance.

- If you believe that out-of-field teaching, temporary certificates, and high turnover among mathematics and science teachers are unacceptable outcomes of current policies, and if you believe that high-quality teaching is the right direction to take, then declare yourself. It is up to you to put an end the former and ensure the latter.

- If you want your voice to be heard, call your child's principal, your school board representative, your local school superintendent. Call and write your representatives in state government. Contact the local chapters of the professional teachers' organizations whose members teach your children subjects such as arithmetic, biology, and algebra. Ask them: "What is being done *here* to attract more teachers into mathematics and science teaching?" "How many teachers *here* are teaching out-of-field?" "What are mathematics and science teachers paid *here* and why?" "What is the status of professional development in math and science instruction *here*?" "What do you need?" "How can I help?"

High-quality teaching in mathematics and science cannot be bought on the cheap. But it comes back—ten-, twenty-, a hundredfold—to the nation, the community, and especially to our own children, in the form of a better prepared workforce, a more productive economy, and a more creative people.

The time to find out what you can do and to whom you should speak is now. Go to the meetings; get involved. Only when those who sit in the seat of power understand the public's priorities can they act in the citizens' interest. And only you can declare that interest.

This Commission has done what it can do. It has studied the problem and it here offers the American people three goals. We believe they can be achieved, and we have offered ideas on how. Whether they *are* achieved is still to be decided. We know that it is not enough to call for change. In a democracy, the people create real change, not commissions.

As the Chinese proverb says, the time to plant the tree is now—*before it's too late.*

What Can You Do?

Every American has a stake in mathematics and science teaching for the 21st Century. Parents, teachers, administrators, school board members, higher education institutions, state political leaders, and business leaders have particularly critical roles to play in ensuring success. To improve student achievement in mathematics and science, everyone involved must first ask themselves several hard questions and then must take action.

The Commission targeted the seven stakeholder groups below. For each group, several questions are posed to direct attention to critical issues. A checklist of important steps is then provided to define a comprehensive plan for raising K-12 mathematics and science student achievement in states, districts and schools.

School Board and Superintendent Team

- Do your district's mathematics and science achievement levels compare favorably to achievement levels in neighboring districts, states and other countries?
- How many individuals assigned to teach mathematics and science in your district have a major or minor in these fields?
- Does your district teacher salary schedule compare favorably to that of neighboring districts?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Develop a common vision, with input from the community, for promoting a high level of student achievement in mathematics and science.
- ❑ Use accurate data to develop policies that will improve mathematics and science teaching.
- ❑ Commit funding to ensure that all mathematics and science teachers have ongoing collaborative opportunities to improve their skills and knowledge.
- ❑ Set a target date for hiring only fully certified teachers of mathematics and science and put in place the policies and programs necessary to meet the target.
- ❑ Aggressively recruit high-quality mathematics and science teachers from a nationwide pool, including those certified through alternative pathways (e.g., by offering signing bonuses or giving salary credit for all previous experience).
- ❑ Provide competitive salaries to attract and retain the best-qualified mathematics and science teachers.
- ❑ Establish induction programs to ensure that new mathematics and science teachers receive the support necessary to be effective.
- ❑ Develop mathematics and science teacher leaders who facilitate the continuous learning of their colleagues.
- ❑ Provide administrators and teachers with electronic and other forms of access to an ever-expanding knowledge base about mathematics and science teaching.

Principals

- Are you satisfied that the science and mathematics preparation that your students receive is adequate preparation for the next level of schooling?
- Are the new teachers that you hire adequately prepared?
- Are your teachers provided with sufficient time to work together to improve teaching and student learning?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Provide your teachers with significant professional development opportunities to improve their teaching year-round including in-depth study through Inquiry Groups with peers, mentors and outside experts and through Summer Institutes.
- ❑ Ensure that teachers and other school staff have electronic and other forms of access to the ever-expanding knowledge base about mathematics and science teaching.
- ❑ Ensure that new mathematics and science teachers have frequent interaction with mentor teachers, participate in Inquiry Groups, and have reasonable teaching loads.
- ❑ Should you have no option but to assign an out-of-field teacher, be certain that a mentor and other ongoing support is available.
- ❑ Ensure that opportunities to pursue careers in mathematics and science teaching are emphasized for students in your school.

Teachers

- Are your student's mathematics and science achievement levels on state and classroom assessments at an acceptably high level?
- Are you actively seeking to deepen your content knowledge?
- Are you actively seeking to learn new teaching methods for diverse student learners?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Actively seek new knowledge about teaching in your discipline, work with your peers on a continuing basis to improve your skills, and take full advantage of the professional development opportunities offered by your district and state.
- ❑ Actively work to improve your knowledge and skills to incorporate educational technology into your learning and teaching.
- ❑ Communicate to parents the specific standards that students are to meet at each grade level and update parents on their child's progress in meeting these standards.
- ❑ Regularly work with colleagues to compare the achievement level of your students against the standards in your district and state, identify areas for improvement, set goals, and make plans for achieving these goals.
- ❑ Actively share your knowledge and experience with new teachers.

Parents

- Do the mathematics and science achievement levels at your child's school compare favorably to achievement levels in neighboring schools?
- Do your child's teachers have the necessary background to teach the courses to which they are assigned?
- How does the teacher salary schedule in your school district compare to that of neighboring districts?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Learn about the mathematics and science standards that children are required to meet in your state and get a clear picture of how well your child's school is doing in meeting these standards.
- ❑ Support the principal's efforts at your child's school to hire well-qualified teachers and to provide them with opportunities to continually improve their skills.
- ❑ Support increased funding for programs that support quality mathematics and science teaching.

State Leadership

- Do your state's mathematics and science achievement levels compare favorably to achievement levels in neighboring states?
- How many out-of-field teachers are assigned to teach mathematics and science across your state?
- How do certification requirements for K-12 mathematics and science teachers in your state compare to those of neighboring states and national standards?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Identify the critical professional development needs of the individuals teaching mathematics and science through a district-by-district assessment.
- ❑ Develop policies and dedicate funding, based on identified needs, to upgrade content knowledge and improve the skills for all those teaching mathematics and science, K-12.
- ❑ Establish and implement a professional development model that addresses the specific needs of mathematics and science teachers and their students through Summer Institutes and Inquiry Groups.
- ❑ Establish and enforce high standards for mathematics and science teachers for initial and continuing certification.
- ❑ Develop career-long incentives and rewards for effective mathematics and science teachers that encourage them to remain in teaching and to continually upgrade their skills.
- ❑ Establish alternative pathways to teacher certification that encourage recent college graduates and people with degrees in mathematics and science to pursue teaching.

Higher Education Institutions

- How do your graduates perform as mathematics and science teachers after graduation? How does their performance compare to those from other programs?
- What portion of your mathematics and science education graduates teach and for how long?
- Do your graduates report that your program prepared them for successful teaching? Are schools that hire your graduates satisfied with the quality of their instruction?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Work closely with area schools to identify existing and future needs for highly qualified K-12 mathematics and science teachers.
- ❑ Ensure that your program meets criteria for exemplary math and science teacher preparation and actively contribute to the knowledge base in support of these criteria.
- ❑ Collaborate with area school districts to ensure a quality induction process for new mathematics and science teachers.
- ❑ Emphasize recruitment strategies and provide incentives for eligible students to become science and mathematics teachers.
- ❑ Evaluate and track teacher performance following graduation and use this information to improve your mathematics and science teacher preparation programs.

Business

- Does your business encourage its employees to work as advocates in the schools, with the goal of achieving high-quality mathematics and science education?
- Do your corporate philanthropic priorities help students and educators meet higher standards in mathematics and science?

If your answers to any of these questions are at all disquieting, the following checklist can inform efforts to promote higher student achievement:

- ❑ Work to increase the supply and quality of incoming mathematics and science teachers by advocating for policies, programs and investments that will make the teaching profession a more attractive career option.
- ❑ "Lend" qualified employees to act as part- or full-time teachers in local schools, without incurring loss of pay or benefits.
- ❑ Actively participate in reward and incentive programs that recognize excellence in mathematics and science teaching in local schools as measured by improved student achievement.
- ❑ Provide support for National Board for Professional Teaching Standards certification.
- ❑ Make regular contributions of time, materials and resources to enhance instruction in mathematics and science education in local schools.

Estimate of Costs in First Year

Prepared by the U.S. Department of Education Budget Office

	Action Strategy	Federal	State/Local[1]	Business	Public/Private
Goal 1	Needs Assessment[2,3]	$15,340,000	$7,660,000		
	Summer Institutes[2,5]	$1,214,000,000	$606,060,000		
	Inquiry Groups[2,6]	$1,574,950,000	$786,300,000		
	Leadership Training[4]	$112,000,000			
	Internet Portal	$50,000,000			
	Coordinating Council				$4,000,000
	Rewards Program			$500,000,000	
Goal 2	Scholarships (Exemplary Models)[7]	$18,000,000			
	Loan Forgiveness[8]	$36,000,000			
	Academies/Fellows[9,10]	$120,000,000			
Goal 3	Induction/Partnerships/Incentives/Salaries		*To be determined locally*		
	Sub Total:	$3,140,290,000	$1,400,020,000	$500,000,000	$4,000,000
				Total:	***$5,044,310,000***

[1] There are 56 units nationwide -- states, territories and Washington, D.C.

[2] Current authorizing legislation for the Eisenhower Professional Development State Grants (ESEA,IIB) requires that each participating Local Education Agency match every two dollars of federal funding with one dollar of its own resources. Such local resources can come from other federal programs or from non-federal sources. The same ratio is used here for those Strategies in which it is most appropriate.

[3] First year, one time cost.

[4] First year, one time cost for 15,000 leaders.

[5] One-fifth of the math/science teaching force (340,000 per year)

[6] All K-12 math/science teachers (1.7 million)

[7] Scholarships offered (1,500/year)

[8] Loans offered (6,000/year)

[9] Stipends and operating expenses (3,000 Fellow/year)

[10] Beginning in second year, an additional $30,000,000 needed for induction programs

September 2000

Endnotes

[1]*Report of the National Education Goals Panel*, Washington, D.C.: U.S. Department of Education, 1989.

[2]T. Husen, *International Study of Student Achievement in Mathematics*, New York: Wiley, 1967, and C. C. McKnight, *et al*., *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, Champaign, Ill.: Stipes, 1987, as cited in James W. Stigler and James Hiebert, *The Teaching Gap*, New York: The Free Press, 1999, p. 5.

[3]David Kearns and James Harvey, *A Legacy of Learning*, Washington, D.C.: Brookings Institution Press, 2000, pp. 29-30. In general science, American fourth-grade students ranked third among 26 nations; by eighth grade they were seventeenth among 41 nations; and by twelfth grade they were tied for eighteenth among 20 nations. In general, the mathematics pattern is similar. American students were twelfth among 26 nations in fourth grade, twenty-eighth among 41 nations in eighth grade; and twelfth-graders were tied for eighteenth among 20 nations. (Students were not assessed from the same number of nations in all grades.) See also the U.S. Department of Education, *National Digest of Education Statistics*, *1999*, Washington, D.C.: National Center for Education Statistics, 1999.

[4]Kearns and Harvey, *op. cit.*, p. 27.

[5]Although recent news about the rise in the average mathematics score on the SAT and the corresponding broadening of the student population taking the test is welcome, U.S. students remain behind the average performance level in mathematics attained more than 30 years ago. See *The Washington Post*, August 31, 2000, p. 1.

[6]Under Title I legislation that becomes effective in the spring of 2001, states are required to annually disseminate information, school by school, on student performance in reading and math. Anticipating the requirement, all but two states are currently posting at least some mathematics assessment data on the State Education Agency's (SEA) Web site; 35 states provide assessment data by specific grade levels and 32 states report mathematics proficiency levels. In science, reporting is spottier. Thirty-one states report assessment data; 21 states provide science assessment data by specific grade levels; but only 16 states report science proficiency levels. For parents, SEA Web addresses can be readily obtained with a phone call to their local school district. Information on state assessment data provided by Westat, Inc., unpublished tabulations compiled from SEA Web sites, Rockville, Md., Sept. 8, 2000.

[7]*The Wall Street Journal*, "Technology Spurs Economic Expansion," January 31, 2000.

[8]U.S. Department of Labor, "20 Million Jobs: January 1993-November 1999," A Report by the Council of Economic Advisers and the Chief Economist, U.S. Department of Labor, December 3, 1999, downloaded from http://www.dol.gov/_sec/public/media/reports/20mill/main.htm, March 13, 2000, as cited in Milton Goldberg and Susan L. Traiman, "Why Business Backs Education Standards," in Diane Ravitch, ed., *Brookings Papers on Education Policy*, Washington, D.C.: Brookings Institution, 2000 (forthcoming).

[9]*Ibid.*

[10]*Ibid.*

[11]*Workforce Economics*, National Alliance of Business, Occasional Report, Vol. 6, No. 1 (Spring, 2000), pp. 9-11.

[12]*Ibid*., p. 10.

[13]Philip R. Day and Robert H. McCabe, "Remedial Education: A Social and Economic Imperative," AACC Issue Paper, Washington, D.C.: American Association of Community Colleges, 1997.

[14]Interview with Robert Gardner, Director of Public Relations, Association for Manufacturing Technology, June 20, 2000, as cited in Goldberg and Traiman, *loc. cit*.

[15]*Training Magazine*, Annual Report, Minneapolis: Bil Communications, Vol. 36, No. 10 (1999), downloaded from http://www.trainingsupersite.com.

[16]Interview with Richard W. Judy, Hudson Institute, Indianapolis, April 19, 2000, as cited in Goldberg and Traiman, *loc. cit.*

[17]The vision of high-quality teaching in K–12 mathematics and science is expanded on and operationally defined in three reports that are currently guiding standards-based science and mathematics education: (1) American Association for the Advancement of Science, *Benchmarks for Science Literacy*, New York: Oxford University Press, 1993; (2) National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*, Reston, Va: NCTM, 2000; and (3) National Research Council, *National Science Education Standards*, Washington, D.C.: National Academy Press, 1996.

[18]National Research Council, *How Young People Learn*, Washington, D.C.: National Academy Press, 1999.

[19]Higher Education Research Institute, *The American Freshman: National Norms for Fall, 1998,* Los Angeles: University of California at Los Angeles, 1999.

[20]Linda Darling-Hammond, *What Matters Most: Teaching for America's Future*, New York: National Commission on Teaching and America's Future, 1996, Executive Summary.

[21]Linda Darling-Hammond, "Teacher Quality and Student Achievement: A Review of State Policy Evidence," Teaching Quality Policy Briefs, Number 2 (December, 1999), Washington, D.C.: Center for the Study of Teaching, downloaded from http://www.depts.washington/edu/ctpmail.

[22]Linda Darling-Hammond, *Supply, Demand, and Quality in Mathematics and Science Teaching*. Briefing for the National Commission on Mathematics and Science Education for the 21st Century, Washington, D.C., September, 1999.

[23]National Research Council, *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium*, Washington, D.C.: National Academy Press, 2000.

[24]Examples of two states that have produced impressive results by focusing on better teaching are Texas and North Carolina. In Texas, a study of grades 1–11 found that teachers' subject-matter expertise accounted for 40% of the difference on achievement tests. Disparities between white and minority students were almost entirely accounted for by the qualifications of their teachers. In North Carolina, students entered the 1990s near the bottom of the NAEP rankings in mathematics. After the State boosted minimum salaries, used scholarship programs to recruit more able students to teaching, invested in better teacher education curricula, created professional development academies, instituted mentoring programs for entering teachers, and created incentives for teachers to be certified by the National Board of Professional Teaching Standards, North Carolina students now score well above the NAEP averages. See "Who Should Teach?" *Education Week*, January 13, 2000.

[25]Linda Darling-Hammond, "Supply, Demand, and Quality in Mathematics and Science Teaching."

[26]*Ibid.*

[27]*Ibid.*

[28]Richard M. Ingersoll, "Turnover Among Mathematics and Science Teachers in the U.S.," Study Paper prepared for the National Commission on Mathematics and Science Teaching for the 21st Century, Washington, D.C., September, 1999; and Urban Teacher Collaborative, *The Urban Teacher Challenge: Teacher Demand and Supply in the Great City Schools*, Washington, D.C.: Council of Great City Schools, January, 2000.

[29]Steve Olson, "Candid Camera," *TEACHER MAGAZINE on the WEB*, May/June, 1999. Videotape, "Eighth-Grade Mathematics Lessons: United States, Japan, and Germany," Washington, D.C.: U.S. Department of Education, 1999, produced by Nanette Seago.

[30]James W. Stigler, Briefing for the National Commission on Mathematics and Science Teaching for the 21st Century, Washington, D.C., September, 1999, pp. 23 and 19 of the transcript.

[31]Division of Research, Evaluation, and Communication, Directorate for Education and Human Resources, *Indicators of Science and Mathematics Education*, *1995*, Arlington, Va.: National Science Foundation, 1996.

[32]*National Science Teachers Association Reports*, "Survey Indicates High Teacher Turnover, Job Dissatisfaction," Arlington, Va.: National Science Teachers Association, 2000, downloaded from http://www.nsta.org/reports/00jun2.asp.

[33]*The Urban Teacher Challenge: Teacher Demand in the Great City Schools*, *2000,* Washington, D.C.: Council of Great City Schools, 2000, pp. 9-11.

[34]Estimates based on projected fall 1999 counts of teachers and proportions from the U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1993-94; and Fast Response Survey, "Teacher Survey on Professional Development and Training."

[35]National Research Council, *op. cit.*

[36]Emily C. Feistritzer and David T. Chester. *Alternative Teacher Certification: A State-by-State Analysis 1998-99*. Washington, D.C.: National Center for Education Information, p. 6, downloaded from http://www.ncei.com/Alt-Teacher-Cert.htm. Alternative routes for preparing and licensing science and mathematics teachers provide ways to attract large numbers of highly educated and life-experienced adults who have the talent and enthusiasm to teach.

[37]Susan Sclafani, "Comparisons of Alternative Certification Program, Teach for America, and Certified Teachers in the Houston Independent School District," Briefing for the National Commission on Mathematics and Science Teaching for the 21st Century, Washington, D.C., May, 2000. The Houston Independent School district has found that the students of teachers certified through the Alternative Certification Program performed just as well as, or better than, students of teachers trained through traditional teacher preparation programs. Also, the retention rate of the alternatively certified teachers five years later was significantly higher.

[38]James W. Stigler and James Hiebert, *The Teaching Gap*, New York: The Free Press, 1999, pp. 170-71.

[39]Richard M. Ingersoll, *loc. cit.*, p.5.

[40]*Ibid.*, Figure 4, p.7.

[41]*Ibid.*, Table 1, p.6.

[42]*Ibid.*

[43]The Commission recognizes that the action steps recommended here could—and should—be made for all teachers, not just teachers of mathematics and science. But the need for improving the professional environment of mathematics and science teachers is particularly acute because of their shortage, and because of the salaries degree holders in these fields can command in the private sector.

[44]Adam Urbanski and Roger Erskine, "School Reform, TURN, and Teacher Compensation," *Phi Delta Kappan*, January, 2000, pp. 367-70. The Teacher Union Reform Network (TURN), composed of local school districts and the local affiliates of the AFT and the NEA, is a labor/management collaboration that rewards teachers who obtain certification by the National Board of Professional Teaching Standards (NBPTS). Participating teachers receive support for NBPTS fees or are granted special standing as mentors or lead teachers. Nine TURN locals provide bonuses, salary supplements for certification, or additional pay for teachers who act as mentors. In addition, the Consortium for Policy Research in Education has identified 15 States and 20 districts that offer financial rewards to teachers who obtain NBPTS certification. Teachers are generally provided with one-time rewards ranging from $2,000 to $10,000, and annual salary supplements ranging from $500 to $10,000 per year or from 1% to 12% of their base salary per year (see http://www.wcer.wisc.edu/cpre/teachercomp/reform/nbtpspay.thm).

[45]Steven Greenhouse, "Teachers' Pay: Adding Up the Impact of Raising Salaries," *The New York Times,* August 9, 1999.

[46]Ann Bradley, "High Tech Fields Luring Teachers from Education," *Education Week*, January 19, 2000. Indeed, the average annual teacher salary is only "a fraction of the annual bonus received by many thirty-somethings on Wall Street." Greenhouse, *loc. cit.*

Charter

AUTHORITY

The National Commission on Mathematics and Science Teaching for the 21st Century, (Commission) is established by the Secretary of Education and is governed by the provisions of the Federal Advisory Committee Act (FACA) (P. L. 92-463, as amended; 5 U.S.C.A. Appendix 2).

PURPOSE AND FUNCTIONS

The Office of the Under Secretary serves as the principal advisor to the Secretary by directing, coordinating, and recommending Department policy. Therefore, the Commission has been established in this office for the purpose of: (1) reviewing the current state of American K-12 mathematics and science education with a focus on the challenges of teacher recruitment, preparation, retention, and professional growth and (2) articulating the steps needed to strengthen the classroom practice of math and science teachers. The Commission would produce a report describing specific action steps that federal, state, and local policymakers can take to address math and science teacher supply and quality issues.

STRUCTURE

The Commission will be composed of not more than twenty-five members. Members shall be appointed from, but not limited to, the following groups: current or recent members of Congress, Governors, Mayors, State Legislators, Chief State School Officers, Nobel laureates, CEOs, teachers, University presidents, principals, parents, students, public representatives, and other distinguished leaders in the fields of mathematics and science. Ex officio, non-voting members, of the Commission, include the Secretary of Education or his designee, the Secretary of Defense, the Secretary of Energy, the Secretary of Transportation, the NASA Administrator, the Director of the Office of Science and Technology Policy, the Director of the National Science Foundation, and the President of the National Academy of Sciences.

Members shall be appointed by the Secretary for the duration of the Commission. Any vacancy in the Commission shall not affect its powers, but shall be filled in the same manner as the original appointment. The Secretary shall designate a member of the Commission to serve as the chairperson.

The Under Secretary names the Designated Federal Official (DFO) to the Commission.

MEETINGS

The Commission shall meet at the call of the Chairperson, with the concurrence of the Designated Federal Official or designee who is present at all meetings. The Commission shall meet at least four times, or more frequently, as may be necessary to carry out the Commission's responsibilities. Meetings are open to the public except as may be determined otherwise by the Under Secretary in accordance with Section 10(d) of the FACA. Adequate public notification will be given in advance of each meeting. Meetings will be conducted and records of the proceedings kept, as required by applicable laws.

A quorum of the Commission consists of a majority of the authorized members.

ESTIMATED ANNUAL COST

Members will serve without compensation. However, members may each receive reimbursement for travel expenses incident to attending Commission meetings, including per diem in lieu of subsistence, as authorized by the Federal travel regulations. Funds will be provided by the Department of Education to administer the Commission. The estimated annual person-years of staff support is: two (2) FTE. An estimated budget of $800,000 over two fiscal years has been allotted for this Commission.

REPORTS

Not later than September 30, 2000, the Commission shall submit a report to the Secretary that contains a detailed statement of the findings and conclusions resulting from the study, together with the Commission's recommendations. The Secretary will then submit the report to the President and Congress together with the recommendations of the Commission.

TERMINATION

The Commission shall terminate 90 days after the date on which the Commission submits its report to the Secretary.

The Commission is hereby chartered in accordance with Section 14(b) of FACA. This charter expires two years from the date of filing.

APPROVED:

August 12, 1999
Richard W. Riley, Secretary of Education
Establishment date: March 23, 1999
Filing date: April 6, 1999

Acknowledgments

The Commission wishes to express its deep gratitude to the many individuals and organizations without whose work our own labors would have been far more difficult and far less productive.

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The Commission's deliberations were greatly informed by the wisdom of many experts. These stimulating views were shared with us through commissioned papers and presentations. Commissioned paper authors included Richard Ingersoll; Edward Britton, Senta Raizen, Lynn Paine, and Mary Ann Huntley; Beatriz Chu Clewell and Laurie B. Forcier; as well as Brian Lord and Barbara Miller. Presenters included Dennis Bartels, Barnett Berry, Barbara Blumenthal, Barbara Cervone, Cindy Chapman, Susan Collins, Linda Darling-Hammond, Richard Elmore, William Firestone, Thomas Gillett, Gary Hart, Janice Jackson, Carolyn Kelley, Michael Lach, Donald Langenberg, Michal Lomask, Susan Loucks-Horsley, Iris Metts, Tom Payzant, Susan Sclafani, Nanette Seago, Gail Shroyer, Elliot Solloway, James W. Stigler, Uri Treisman, John Vaille, and Suzanne Wilson.

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September 2000

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