IN THE NATIONAL INTEREST

THE FEDERAL GOVERNMENT IN THE REFORM OF K–12 MATH AND SCIENCE EDUCATION

SEPTEMBER 1991
Reprinted MAY 1993

A Report of the
CARNEGIE COMMISSION
ON SCIENCE, TECHNOLOGY, AND GOVERNMENT

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All who have meditated on the art of governing Mankind have been convinced that the fate of empires depends on the education of their youth.

—*Aristotle*

ACKNOWLEDGMENTS

This report of the Carnegie Commission on Science, Technology, and Government was prepared by its Task Force on K–12 Mathematics and Science Education and adopted by the Commission at its meeting on June 26, 1991. The members of the Task Force were:

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The Task Force established an Advisory Council whose members were generous with their criticism and advice and contributed many important ideas based on their broad range of expertise; however, the findings of this report are the responsibility of the Carnegie Commission and its Task Force. The members of the Task Force and its Advisory Council and their affiliations are listed at the end of this report. Also listed are the members of the Carnegie Commission on Science, Technology, and Government and its Advisory Council.

The Task Force benefited from discussions with a number of government officials, among them J. Thomas Ratchford, Associate Director, Office of Science and Technology Policy; Walter Massey, Director, National Science Foundation; Ted Sanders, then Deputy Secretary, Department of Education; Christopher Cross, then Assistant Secretary for Educational Research and Improvement, Department of Education; Luther Williams, Assistant Director, Education and Human Resources, National Science Foundation; and Peggy Dufour, Executive Director, Committee on Education and Human Resources, Federal Coordinating Council for Science, Engineering, and Technology.

The Commission is grateful to Dr. Branscomb for his leader-

* David Kearns resigned from the Task Force on May 20, 1991, when he was confirmed as Deputy Secretary of Education.

ship, to the members of the Task Force and its advisors, to Rollin B. Johnson, the project director, and to David Z. Robinson, who served as principal liaison to the Commission and its staff.

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EXECUTIVE SUMMARY

A large number—probably a majority—of American public schools are failing to prepare their students adequately for the jobs of the future, for life in a diverse culture, or for the civic responsibilities so essential to democracy. The President and governors are committed to educational reform aimed at improving overly regimented schools with dispirited teachers and unmotivated students. These efforts are meant to produce fully functional institutions with properly trained, motivated teachers who use modern materials and teaching methods in creative environments and develop strong incentives for student progress.

Unfortunately, that may not be enough for disadvantaged students from poor communities. In the year 2000, when the national goals agreed upon by the President and governors call for American students to be "first in the world" in mathematics and science, one American child in four will be poor; one child in three will be a minority group member; and one child in twelve will lack the English language proficiency required for learning. School reform alone will not suffice to address these sources of disadvantage. Yet the Task Force on K–12 Mathematics and Science Education is convinced that education is the best hope for all children, and that math and science skills are especially critical for good jobs, for further education, and for effective participation in an increasingly technological world. We also believe that rapid progress is possible, despite the aspects of disadvantage that beset many schools, students, and families.

The charge given the Task Force by the Carnegie Commission was to examine how the federal government is organized to make decisions and implement change in the reform of math and science education, and to identify changes in organizational structure and decision-making processes that will help the federal government to be an effective partner in education reform. Why focus on math and science education when the schools are beset with systemic problems not specific to any subject and by teaching problems in every subject area? There are at least two reasons why the federal government should pay special attention to math and science education: the increasing demand for numeracy and problem-solving ability in tomorrow's world, and the federal government's special responsibility for assuring the nation's technical capability to address national goals for the economy, environment, health, and security.

The Task Force shares with most Americans a sense of urgency for bold initiatives that will provide real help to the nation's schools and renew public confidence that dramatic progress can be made. There is no shortage of motivated Americans with good ideas about how to serve our children better. In short supply, however, is the institutional

capacity to aggregate enough resources, to build a national consensus for action, and—most important—to persist with a specific program of reform long enough for it to take effect, at least a decade and maybe two.

The federal government should, therefore, support the most promising initiatives in the country and build a constituency for launching them on a scale that will make a substantial difference in every school in America. The Task Force recommendations are intended to help the federal government identify the best responses to the challenges and support them more swiftly, wholeheartedly, and intelligently.

Elements of a Federal Strategy

The Task Force devised a strategy for math and science education reform with four elements:

Commit to change both how schools are organized and run and what goes on inside the classroom. This requires the action of two lead agencies, the Department of Education and the National Science Foundation, working together through new mechanisms for collaboration with each other and with other agencies.

Deploy the resources of the technology-based agencies of the federal government to improve math and science education and to expand the supply of professionally trained scientists and mathematicians serving the nation as teachers and technical professionals.

Leverage state and private initiatives and support effective change through greater emphasis on flexible, competitively evaluated funding mechanisms and the best available understanding of the education system and of teaching and learning strategies.

Build an informed, broadly participatory, and productive collaboration among leaders of states and communities, federal agencies and Congress, private institutions, and the technical community, using a variety of new institutional mechanisms to ensure that federal activities are both effective and supportive.

Priority Roles for the Federal Government

Foremost among the federal responsibilities is the leadership role of the President himself. **The Task Force urges the President to use the full prestige and influence of his office to mobilize all Americans for a sustained, national, bipartisan reform effect.**

The Task Force developed specific recommendations for action by federal agencies in the following areas:

- **Provide fully qualified math and science teachers for every school** by recruiting teachers from under-represented groups; creating a single professional path to either teaching or practice in mathematics and science; and enhancing the knowledge, skills, and motivation of current teachers.

- **Decide what students need to know and know how to do by establishing requirements for the jobs of the future.** Engage the business community, scientists, and citizens in this effort. Develop methods of assessment appropriate to this goal.

- **Strengthen educational systems research and establish broad-based support for basic cognitive and applied learning research and field testing of innovations.** A coordinated reform effort requires systems research and "systems engineering" based on the best analytical understanding of the K–12 education system.

- **Ensure diffusion of successful innovations:** provide access for all schools and all students to tested educational improvements and support their successful adoption. Do not be satisfied with successful demonstrations alone.

- **Empower all federal science agencies to take leadership roles in the reform of K–12 math and science education**. Every science agency of the government should have an explicit education charter defining its responsibilities to address pre-college issues that lie within the agency's special technical expertise and human resource requirements.

- **Encourage private sector development of educational materials, curricula, textbooks, and software for new educational technology**. Educational innovators in the private sector not only make significant educational

investments but are able to diffuse innovations throughout the country.

- **Support science centers and museums, educational television, and other sources of "informal" education.** Nontraditional education is a powerful way to motivate students and interest parents in the serious study of mathematics and science and to explode negative stereotypes of science and scientists.

- **Provide an information and referral service to document innovations and help innovators locate federal support for K–12 math and science activities.** Individuals outside the federal agencies have difficulty in locating the correct agency through which to gain access to program materials, services, and information.

Who Should Do What?

The Task Force recommends that federal science agencies play more significant roles in the reform effort:

- The *National Science Foundation* should take the lead in mobilizing the nation's universities and science professionals to revitalize math and science teacher education, curricula, materials, and technology; support cognitive and applied learning research; and stimulate science education in unconventional settings. NSF should broaden its education experience beyond education research.

- The *Department of Education* should take the lead role for systemic change, for educational systems analysis to inform the reform strategy, for assessment of progress, and for the diffusion of successful innovations. The Office of Educational Research and Improvement (OERI) of DoEd should help the nation develop a "cerebral cortex" for education reform, and should acquire the capability to manage the kind of competitive, innovative programs necessary for rapid progress in math and science reform.

- The *Department of Labor* should become a more active participant, particularly with regard to defining goals for

educational content and skills needed for the jobs of the future.

- The *Department of Energy* should continue its leadership of the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), and through that mechanism ensure that all the R&D-intensive agencies coordinate their contributions to math and science educational progress.

- The *Department of Health and Human Services*, especially the National Institutes of Health and the National Institute of Mental Health, should design and carry out an appropriate long-range program, coordinated with NSF and DoEd, to ensure the nation's supply of quality health professionals as well as its future health.

- The *Department of Defense* should create model schools to demonstrate its capabilities in educational technology, processes, and programs; transfer them to the private sector; and facilitate the entry of demobilized personnel with math and science training into public school teaching.

Because the math and science reform effort requires urgency, vision, and dynamism, all technical agencies should develop a more streamlined and responsive infrastructure.

New Institutions

Besides strengthening existing offices dealing with math and science education, the DoEd and NSF should create a mechanism for collaboration—a *Joint Office for Math and Science Improvement.* It would report directly and jointly to the Secretary of Education and the Director of NSF. We recommend that outside advice to DoEd and NSF be channeled through an *advisory panel reporting to the Joint Office* to facilitate close collaboration between these agencies.

To support the national reform effort, DoEd should set up, with NSF participation, a *national center for educational systems analysis* that can serve as "systems engineer" for new efforts to accumulate research knowledge to guide reform, evaluate the effectiveness of reform initiatives, and diffuse best educational practice; it should include a clearinghouse for educational information. A Federally

Funded Research and Development Center (FFRDC) might be the appropriate institutional form.

A nongovernmental *national center for educational content and assessment* should be created, perhaps under the National Education Goals Panel, to build consensus on what American students should know and know how to do, and to assess their progress.

The National Education Goals Panel should be supplemented by a *council of education reform leaders* from outside government together with senior officials from the Executive Branch, Congress, and the states, e.g., the directors of the Office of Science and Technology Policy (OSTP) and NSF, chairs or staff directors of key education committees of Congress, governors, and chief state and city school officers. This council would support the work of the Goals Panel and would convene a biennial *national conference on educational improvement* sponsored by either the Goals Panel or by OERI to review the national strategy on math and science reform, and the progress toward national math and science goals.

Money Matters

Given that state and local governments fund 94 percent of school budgets, the federal government's role in reform should be to leverage state and private investments and produce change in the system, not to sustain it as it is. There is an immediate and substantial need for reorientation of federal education funding toward educational reform.

The Task Force recommends that, as a long-term goal, a designated proportion (perhaps 10 percent) of DoEd's program funding be allocated for discretionary activities aimed at more effective achievement of program goals. These activities would be devoted to change-oriented, competitive, professionally reviewed programs that provide incentives for reform to states and communities. As this flexibility would allow DoEd programs to be more effective in serving the intended groups of students, learning in science and mathematics would be enhanced along with all other parts of the curriculum.

This flexibility is also needed in the only existing DoEd program that targets mathematics and science. To this end, **the Administration and Congress should convert all the funding for the Eisenhower grants program in DoEd to a competitive, peer-reviewed program.** This would almost double the funding directed toward enhancing the performance of K–12 math and science teaching.

There is a strong case for greater priority attention and funding by the federal government specifically for math and science education. Indeed, science and mathematics are the only areas of schooling in which American students are explicitly intended by the President and governors to become "first in the world." But in 1991 the federal government budgeted only $515 million, or only 4 percent of its total contribution to public school revenues, directly for math and science education.

The Task Force concludes that more of the federal pre-college education investment should be targeted to mathematics and science. The Task Force recommends that all federal agencies concerned with science and technology devote some percentage of their R&D funds to math and science education. Since the federal government is the largest single employer of math and science professionals, it has an interest and an obligation to reinvest in the education pipeline. These funds, too, could be administered through a competitive grants process to encourage the best innovators and the best ideas.

Mechanisms for Coordination and Management

For oversight of the math and science reform effort, two channels of White House oversight (in addition to the Office of Management and Budget) are important. The Domestic Policy Council, with the Secretary of Education as chair of its Education subcommittee, coordinates overall education policy and should give mathematics and science a high priority in the strategy. The President's Assistant for Science and Technology uses the Committee on Education and Human Resources (CEHR) of FCCSET as an extension of the OSTP staff to encourage and coordinate activities of the Department of Education and the fifteen agencies with math and science content in their missions.

As part of the quest for an integrated federal strategy, CEHR should become a standing committee of FCCSET, with a full-time staff devoted to the coordination of agency activities and the review of agency strategies for K–12 math and science improvement. The Director of OSTP should assign to an associate director full-time responsibility for math and science education issues.

Mechanism for Congressional Review

The many congressional committees with jurisdiction over DoEd, NSF, and other engaged agencies should cooperatively review the activities such agencies may undertake to accelerate K–12 math and science education reform, and give priority to math and science issues in the intensified program of federal action. A *temporary Select Committee on Math and Science Education* might be a useful instrument for this purpose. Where statutory limitations hinder promising agency activity, they should be removed.

■

Is there reason to be optimistic about lifting the capabilities of American students to "first in the world" in the next decade? The current situation holds out great promise of dramatic progress. On the other hand, few areas of social development have more often seen hopes crushed and cynicism prevail.

The one best hope for success is impassioned, persistent, nonpartisan leadership by every American able to make a contribution—but most importantly by the President. His crusade in the cause of education, if taken up by governors, congressional and other leaders, and by presidents who follow, can turn this situation around. We can once again be proud of our schools and confident that future generations of young Americans will be equipped to lead the nation to new levels of greatness.

PART I
THE SOCIAL CONTEXT FOR A FEDERAL REFORM EFFORT

This report is about the serious shortcomings in U.S. math and science education, and what the federal government can and should do in order to play a much more effective role in the national effort to remedy those shortcomings.

Inadequacies in pre-college math and science education are a chronic and serious threat to our nation's future. The national interest is strongly bound up in the ability of Americans to compete technologically. This requires not only an adequate supply of scientific and technical professionals but a work force able to solve problems and use the tools of a knowledge-intensive economy. All young people, including the non-college-bound, the disadvantaged, and young women, must be given the opportunity to become competent in mathematics and science.

A large number—probably a majority—of American public schools are failing to prepare their students adequately for the jobs of the future, for life in a diverse culture, or for the civic responsibilities so essential to democracy. This conclusion is supported by both expert and political assessment,[1] even though some public schools provide an excellent education for college-bound children from middle- and working-class families. Most families, in fact, think their local schools are fine—not realizing how inadequate their children's education may be in light of tomorrow's higher demands for skills and judgment.[2]

Most efforts at school reform, including those to which the President and governors are committed, are aimed at improving overly regimented schools staffed by dispirited teachers and attended by unmotivated students. These efforts are meant to produce fully functional institutions with properly trained, motivated teachers who use modern materials and teaching methods in creative environments and develop strong incentives for student progress. The current division of federal and state accountability, even with today's per-pupil expenditures, may be able to achieve this transformation in many of America's public schools. Unfortunately, that may not be enough for disadvantaged students from poor communities.

For the most rapidly growing segment of the children in our land—the poor and other disadvantaged children—public schools and the other social institutions on which they depend are failing to reverse a downward spiral that threatens to relegate the majority of these children to a lifetime of second-class citizenship. In the year 2000, when the national goals agreed upon by the President and governors call for American students to be best in the world in mathematics and

science, one American child in four will be poor; one child in three will be a member of a minority group; and one child in twelve will not be sufficiently proficient in English to learn without special assistance.[3] The state of American public education is therefore a reflection—indeed, a victim—of the nation's social condition. With many children in impoverished urban communities facing inadequate educational stimulation and even basic nutrition at home, current financial, political, and institutional arrangements do not offer a means of escape from the spiral of despair. School reform alone will not suffice.

Yet the Task Force on K–12 Mathematics and Science Education is convinced that education is the best hope for all children, and that math and science skills are especially critical for good jobs, for further education, and for effective participation in an increasingly technological world. We also believe rapid progress is possible, despite the aspects of disadvantage that beset many schools, students, and families. This report is directed to the federal government's opportunity to contribute to that progress much more effectively than it does today.

The charge given the Task Force by the Carnegie Commission was to examine how the federal government is organized to make decisions and implement change in the reform of math and science education, and to identify changes in organizational structure and decision-making processes that will help the federal government to be an effective partner in education reform. The many Americans who are driving education reform efforts around the country may feel that few ideas for improvement originate in federal agencies. From their perspective, it is more important for the federal government to identify the most promising initiatives in the country and to build a constituency for launching them on a large enough scale to make a substantial difference in every school in America. Members of the Task Force share this sense of urgency. Bold and dramatic initiatives that will provide real help to schools may also renew public confidence that dramatic improvements can be made in the nation's public schools.

It has been noted before that radical reforms are sometimes more likely to be adopted than evolutionary steps.[4] But the education problem is not a shortage of motivated Americans with good ideas about how to serve our children better: it is a failure to create the necessary institutional capacity, to aggregate enough resources, and—most important—to persist with a specific program of reform for at least a decade or two. Can the government at federal, state, and local levels create those institutions, find those resources, and provide continuity of effort through bad times as well as good? If not, how else can our democracy assemble the capacity to act in its own national interest?

Thus, while this report does highlight a number of challenges requiring dramatic national action, its focus is on helping the federal government better identify the best responses to those challenges and support them swiftly, wholeheartedly, and intelligently. We discuss

the most-needed improvements in the way the federal government encourages, evaluates, and supports reform. We have made a serious attempt to help the President, his cabinet, Congress, and the states and communities make better use of their resources by recommending ways to increase the institutional capability to attack the nation's education problems—specifically in mathematics and science—with all the skill, judgment, and organized effort of which this nation is uniquely capable.

PART II

Inadequacies in Pre-college Math and Science Education: A Chronic and Serious Threat to the Nation's Future

A long series of reports[5] citing poor student achievement, vicious cycles of poverty and crime, illiterate and innumerate job applicants, remedial education investments by businesses and by the military, unequal educational opportunity, and shortages of American scientists, engineers, and technicians are vivid and convincing testimony that our public school system is failing to prepare all our young people for the future, and that this failing is particularly serious—in both degree and consequence—in mathematics and science.

There is, indeed, a serious problem with U.S. math and science education. When 47 percent of our nation's seventeen-year-olds cannot convert 9 parts out of 100 to a percentage,[6] we know that math education is not working. When 63 percent of American adults think that lasers work by focusing sound waves,[7] we know that science education in this country is not working. According to the Department of Education, only 7 percent of high school seniors are prepared for college-level science courses.[8] A school system whose graduates are ignorant about science, repelled by mathematics, and confused by technology is a system that is not working well.[9] Many refer to this state of affairs as a "crisis." If so, it is a crisis become chronic.

The crisis in math and science education was first recognized 34 years ago when the Soviet Sputnik could be seen crossing American skies every 96 minutes, reminding us not to take our technical excellence for granted. At that time government was primarily concerned about the adequacy of the number and quality of professional scientists, engineers, and mathematicians needed to assure our freedom from a Soviet threat. The National Defense Education Act (the source of the only major pre-college math/science program remaining in the Department of Education today) began the first of several waves of education reform.

In the past ten years, the United States has experienced two more major waves of educational reform, this time recognizing that a secure and competitive nation must have a better-informed citizenry, and a better-trained work force prepared for lifelong learning. The alarm of the early eighties[10] brought stricter standards, but no substantive change in how schools are staffed and run, and little positive result beyond an increasingly aroused public.

By the middle and late eighties, designs for systemic change were widely adopted by the governors,[11] but there was marked

reluctance on the part of the federal government to address the problem with the urgency it deserved.[12] The states undertook many isolated innovations,[13] and many governors gave priority attention to reform. But too often the effort faded with the end of a governor's term, the onset of hard times, or the absence of an effective strategy drawing on all the needed resources, public and private, state and federal. The sustained effort to address all the critical, interdependent elements of K–12 schooling was not there.

In September 1989, the President and governors made a number of dramatic commitments at an "education summit" in Charlottesville, Virginia. Among them: *By the year 2000, U.S. students will be first in the world in science and mathematics achievement.* Governors, congressional leaders, and Administration officials[14] are now working together through the National Education Goals Panel, and independently through proposed legislation, to reach that goal.

What does "first in the world in science and mathematics" mean? In terms that are relevant to an America in rapid demographic transition,[15] it means a level of math and science competence that will best prepare all Americans for the kinds of jobs that produce a competitive and growing economy, keep our citizenry informed and capable of self-government, and ensure that U.S. scientists and engineers are as creative and productive as those of any other nation.[16]

The Task Force believes that math and science education should receive priority attention as a specific focus area in federal pre-college education reform initiatives. However, math and science educational improvement must be undertaken in the context of systemic reform of K–12 education as a whole: teacher capability and diversity, school structure and management, and student motivation. Federal programs in general school reform and in math and science education should be concurrent, coordinated efforts.

PART III

ASSUMPTIONS TO GUIDE FEDERAL STRATEGY AND ORGANIZATION

American schools have been subjected to pressures for reform since at least the 1920s. "A central paradox of education ... is that schools, possibly more than any institution in our society, are constantly changing in response to external pressures; yet they never seem to change in ways that satisfy reformers."[17] Throughout this history there runs a contrast between the urgency, enthusiasm, energy, creativity, and serious effort that reformers have brought to the task, and the slow, ineffective, short-lived efforts to diffuse local successes to other schools.

Each reform effort was rapidly supplanted by the next "new" idea. Reforms have been based on simplistic rather than sophisticated understanding of teaching and learning; they have rarely had the benefit of an overall strategy. Systemic change has been preempted by clever but fleeting and relatively superficial change, to which the education system is highly resistant. Progress has more often faded away than endured.

But the urgent, serious efforts of teachers, administrators, parents, and citizens are more vital than ever to a new reform agenda. *The challenge is to engage all elements of communities in the effort, and give their commitment a better chance to be effective than ever before.* The federal government can, if properly staffed, organized, and "missioned," make a decisive contribution to that end.

The following assumptions underlie our recommendations on how the federal government should decide its strategy for math and science education improvement, how it should organize itself to carry out that strategy, and how agency missions should be allocated.

- **There is no time to waste**. Not all children are receiving adequate preschool education, and in any case none of the children benefiting from preschool intervention today will have graduated from high school by the year 2000. Children now entering elementary school will encounter many teachers with weak educational backgrounds in mathematics and science. The National Science Teachers Association estimates that only about 35,000 of the 1 million elementary school teachers are specifically trained for math and science teaching. According to leading professional associations in math and science education, 67 percent of elementary science teachers have inadequate course preparation in science and 82 percent are deficient in mathematics.[18] Every school day, students in these grades come to school naturally curious about the world and go home having learned

to hate science and mathematics a little more.

The graduates of the class of 2000 have already finished third grade. How can these graduates expect to be best in the world in science if, when they reach middle school, they find that 86 percent of the math teachers and 69 percent of the science teachers fall short of standards for course-work preparation set by professional associations of math and science educators? When they reach high school, will they still find that 71 percent of their biology teachers, 69 percent of their chemistry teachers, and 88 percent of their math teachers have substandard preparation in their subjects, as is the case today?

Considering the magnitude of the problem, it is clear that extraordinary efforts, both short and long term, will be required to help children in every grade during this decade. With adequate remediation, current students in all grades can make up for lost ground, but it will take perhaps another decade before each child benefits fully from improvement at all levels, preschool to 12th grade, and remediation becomes much less necessary.

■ **Deep and effective change in the K–12 education system is needed if the goal is ever to be met.** There is widespread agreement that most American schools have limited control over how they teach, are encrusted with bureaucracy, and are frequently staffed with inadequately prepared and motivated teachers who teach outdated curricula and use strategies driven by inappropriate testing. This agreement has created a receptive climate for some radical institutional experimentation. However, reform will be very difficult to accomplish with the resources now available, since most state education budgets are in crisis, and federal contributions to K–12 education (discussed in Part IV) are modest by comparison. The most immediate priority is to achieve much greater leverage with the funds now available. Change is also needed in the capabilities of the federal agencies and the policies that guide them if the federal government is to be a fully effective partner with the states, the private sector, and concerned citizens in achieving the national education goals. Growing evidence of the deepening commitment of the business community to education reform makes it particularly important that federal agencies be able to take advantage of private-sector experience in identifying weaknesses and implementing structural change and effective management. This is already occurring at the state level, where a number of chief executive officers of large corporations affiliated with The Business Roundtable have teamed up with governors to institute essential elements of reform in state policy.[19]

■ **Student performance will not improve nationally until the teacher force is improved nationally.** Who will teach science and mathematics to the graduates of 2000? Will they be fully prepared? Over 60 percent of junior high school principals report difficulty in

hiring physics, chemistry, and computer science teachers.[20] Currently, 30 percent of U.S. high schools offer no physics courses, 17 percent offer no chemistry courses, and 70 percent offer no earth or space science courses. Fewer than 50 percent of high school graduates of the class of 1987 took chemistry, and only about 20 percent took physics. Only 7 percent of high school graduates evaluated in a national study by the Department of Education had the preparation needed to take college-level courses in science.

These dismal statistics paint a picture of students whose educational opportunities are far below what the nation can and should sustain. This is not surprising when one considers that their teachers have come from the same schools and that those who enroll in college-level teacher training generally come from the lower levels of high school academic performance. A high priority must be accorded to helping the teachers we have and attracting the best new talent to teaching.

■ **Reform strategies must be informed by the best available understanding of the education system and of teaching and learning practice.** That understanding must rest on a sound base of education research and on evaluation of what works, what does not, and why. Recent advances in education research have the potential to improve mathematics and science education greatly. Basic research in cognitive science is revealing how people learn mathematics and science, how the learning context affects learning, and what barriers may block understanding. The potential for a breakthrough in learning effectiveness is there. But too little effort has been devoted to applied research, to bringing these ideas into realistic school settings and curricula, testing them in the field, and implementing those that work. Even under the best of circumstances, translation of major research insights into practice takes a long time.

■ **Effective educational innovations must be available to all schools.** A conspicuous shortcoming of reform efforts to date is the absence of effective incentives and facilities for the diffusion of better teaching methods, content goals and curriculum materials designed for them, and support services for teachers. Past experience shows that many innovations are quite successful, but their rate of adoption by other districts is painfully slow. To reach the national goals, or even to come close, *a greatly accelerated rate of diffusion of best practice is required.* Two approaches are available: national incentives to adopt standard content goals combined with more appropriate assessment of progress, and network-based distribution of quality-assured materials, methods, and services.

Targeted efforts to improve rural and urban schools—arguably the greatest challenge to reform—are vital. Access to information and assistance in adopting the best practices and materials in these schools

should be the first priority. Parental involvement must be encouraged through all possible means to keep education high on the family agenda even when children are not at school. Mechanisms for aiding parental involvement and for providing special help, particularly for single-parent families and families in poverty, must be instituted.

■ **Specific reforms must also address what goes on inside the classroom, especially with regard to science and mathematics.** Changes in structure and organization, important as they are, will not be enough. Education reform must be top-down, bottom-up, inside-out, and outside-in.[21] "Reformed" schools* will have the same parents, the same students, and much the same educational process, until those schools adopt content standards for what students should know, and until that content is embodied in new curricula taught by better-trained teachers and measured by better assessment methods.

Special Problems of Math and Science Education

There is little dispute that a number of outstanding problems specific to math and science education remain to be addressed:

- Rote learning in mathematics and science, aggravated by the emphasis on standardized testing, leaves students without the capacity to think quantitatively and solve problems for themselves.
- Even in schools that offer science courses, the sequential nature of courses in different science subjects deprives students of the opportunity for integrated learning.
- The rapid obsolescence of scientific knowledge necessitates an approach to teacher training that is different from that for most other subjects.
- Declining minority representation (relative to the mix of students) is a particularly serious problem among math and science teachers and other professionals in technical fields.

* "New American Schools" are envisioned in *America 2000.* These schools, initially one in each congressional district, are designed by each community with one-time federal review and start-up support to adopt and reach the National Education Goals.

This is particularly important in mathematics and science, which pose problems different from those of other subjects taught in the schools.

Enhancing the human relationships among teachers, and between teachers and students, will greatly enhance the performance of both. Teachers with strong collegial relationships and students who are not anonymous occupants of a classroom will be more motivated. Parents and the home environment are equally critical to learning outcomes—especially in motivating students to apply themselves wholeheartedly to the most rewarding, and often the most challenging, courses of study.[22]

Children come to school naturally curious about the world, always experimenting and learning how it affects them and how they can change it. The public schools, parents, and communities should do everything possible to nurture, encourage, and develop that curiosity and that natural tendency to experiment. Children should be guided in how to ask questions about the world, and how science and technology can help them answer more and more sophisticated questions. The excitement of pushing the limits of technology, or at least of using the latest technology, should be communicated. The ways science and technology have helped people and have transformed the world should be stressed to motivate children to pursue science and mathematics with zeal in the classroom.

■ **All young people, including the non-college bound, can and should be competent in science and mathematics; in particular, efforts should be made to draw in women and minority men.** The crippling *fallacy that math and science ability is innate, and that many or most young people cannot learn mathematics and science*, though disproved by sound research,[23] persists in the minds of both parents and educators. This perverse idea becomes self-fulfilling when poor academic performance is blamed on the children instead of their parents, their schools, and their communities. The result is the exclusion of a large proportion of children from the math/science talent pool. As Harvey Brooks put it, "It is remarkable and paradoxical to me that the country in the world that is most dedicated to the proposition that everyone is equal is the first to accept the notion of differences in learning ability—something which is much less accepted in Europe and Japan than in the U.S."[24]

Today's system of education discourages most young women and young minority men from the pursuit of mathematics and science, creates the expectation of failure, and promotes the *fallacy that women and minorities will not be in the front ranks of technical achievement.* This discourages the fastest-growing segment of the school population, unfairly deprives these young people of the skills needed to hold jobs with a future, and cheats the nation of a substantial source of needed technical talent.

We must also dispel the *fallacy that students disadvantaged by*

poverty, race, or language in urban and rural schools are not needed to support the technical base in this country. Students in poverty comprise nearly 25 percent of our student base and thus 25 percent of our potential technical expertise. Because their school systems cannot attract the best teachers or supply the latest teaching materials and environments, poor urban and rural students are shortchanged in their education. The benefits to our society of lifting these students out of poverty can be immense. The results of Head Start and other programs have already shown this to be true. From a purely economic perspective, education can shift a growing fraction of the population from a sink for public expenditure to a source of national wealth.

Another excuse for accepting student failure to master work in science and mathematics is the *fallacy that these subjects are only important for the immediately college bound.* The Secretary's Commission on Achieving Necessary Skills (SCANS) in the Department of Labor is addressing what high school graduates need to know and know how to do in the jobs of tomorrow. SCANS* is analyzing the need for both foundation skills, e.g. literacy and numeracy, and functional skills, which are heavily technical and include complex problem analysis, understanding of production systems, etc. A strong focus on preparing students for real jobs and facilitating the school-to-work transition should drive K–12 education goals and is critically needed for the revitalization of the U.S. economy.

National Will and National Scope

The U.S. can succeed at educating and preparing our citizens when there is the national will and the leadership to do so. In an age when national security is defined by economic strength and environmental protection as much as by military readiness, a well-educated and well-trained work force is more essential than ever. Therefore, America must mount a national offensive in education with the same bold leadership, commitment, and professionalism that it devotes to national defense. However, the task of educational reform will be much more difficult to achieve than a quick and decisive military victory, even if substantial new resources were available. The goals of education are more diffuse, the problems are systemic, and the education structure is highly decentralized and adapted to local needs

* See Glossary of Acronyms for a complete list of acronyms used in the text.

and local visions. Hence, *the reform of the nineties must be national in scope, well coordinated, long-term in vision, persistent in execution, and committed to the expectation of success in math and science by every child in every American schoolroom.*

The federal government's responsibility for public education has a long history. Jefferson, Madison, and Hamilton had clear ideas about the connection between education and the national interest but left the means for carrying out this responsibility undefined in the Constitution. *This report's underlying view of the federal role is that there are national interests in educational quality and equity that go beyond state interests, but the primary responsibility for both educational policy and administration rests with the states, cities, and communities. Thus the federal government should dedicate its efforts to helping the states and communities reform and improve the system, leveraging state efforts rather than displacing them.*[25] *New institutional arrangements to enhance the collaboration of federal, state, and private reform activities are required.*

Elements of a Federal Strategy

These assumptions led the Task Force to formulate a four-element federal strategy for math and science education reform:

- *Determine to change both how schools are organized and run and what goes on inside the classroom.* This requires the action of two lead agencies, the Department of Education and the National Science Foundation, working together through new mechanisms for collaboration with each other and with other agencies.

- *Deploy the resources of the technology-based agencies of the federal government* to improve math and science education and to expand the supply of professionally trained scientists and mathematicians serving the nation as teachers and technical professionals.

- *Leverage state and private initiatives and support effective change through greater emphasis on flexible, competitively evaluated funding mechanisms* informed by the best available understanding of the education system and of teaching and learning strategies.

- *Build an informed, broadly participatory, and productive collaboration among leaders of states and communities, federal agencies and Congress, private institutions, and the technical community*, using a variety of new institutional mechanisms to ensure that federal activities are both effective and supportive.

The goal is a federal structure for math and science education that will survive changes in political climate and enable government to be a more effective partner in this national endeavor than it has been in the past.

PART IV
FEDERAL ACTIVITIES IN MATH AND SCIENCE EDUCATION

This section describes what the federal government is doing in math and science education and what more it could be doing, through which agencies, and with what resources.

CURRENT STRATEGIES

The Administration has put forward two strategic plans for its role in education reform. *By the Year 2000: First in the World*, prepared by the Committee on Education and Human Resources (CEHR) of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), describes an effort by sixteen agencies and three Executive offices to support math and science education at all levels. It was released in February 1991 as an official part of the President's budget, and requests an increase of $146 million for pre-college education activities. At the pre-college level, the report emphasizes teacher preparation, curriculum and materials development, organizational reform, and student opportunities. The report is particularly important in view of the absence of close collaboration among many of these agencies in the past, especially between the National Science Foundation (NSF) and the Department of Education (DoEd), which together control 86 percent of the federal investment in pre-college math and science improvement.

America 2000: An Education Strategy, a report released by the President and the Department of Education in April 1991, calls for systemic change in pre-college education. It promises that the Administration will "reward progress and spur change"; a $690 million increment in the Department of Education FY 1992 budget is requested to fund its initiation. Much of the reform strategy described in *America 2000* is based on empirical trials of new school concepts and ways to expand parental choice. Dealing with K–12 schools as a whole, it does not focus specifically on mathematics and science. Indeed, the FCCSET report, released two months earlier, is not mentioned.

The *America 2000* strategy is bottom-up (i.e., decentralized, originating locally) and outside-in (i.e., initiated by non-school orga-

nizations). The *By the Year 2000* strategy is top-down (created at the state or national level) and inside-out (created by teachers, students, administrators, or parents). Whatever the comprehensive program eventually agreed upon by Congress and the Administration, we believe that all four directions of strategy must be used in concert if the nation is to reform its schools successfully.

The Major Federal Players

Two agencies of the federal government share primary responsibility for programs in K–12 education: the National Science Foundation and the Department of Education. NSF is the agency most specifically concerned with improving K–12 math and science education, and is best prepared today to mobilize the nation's best talent in this endeavor. DoEd is responsible for K–12 education across all disciplines, is experienced in the conflicts and complexities of educational politics and in addressing systemic problems that afflict all elements of schooling, and has the networks in place for more effective diffusion of innovations.

NSF accesses the best research capabilities in the nation, including cognitive science and learning research that should inform strategies for educational improvement. It is experienced in running competitive programs to support the best ideas arising outside the

The National Science Foundation

The primary mission of the National Science Foundation is the support of the nation's professional scientific and technological capabilities, through support for basic research. Out of NSF's $2.4 billion budget request for FY 1991, 81 percent is for scientific research, mostly at universities. But Congress also assigned to NSF responsibility for improving science, mathematics, and engineering education at all levels. For this activity, conducted in the Directorate for Education and Human Services, $251 million was requested in FY 1991, of which 66 percent was for K–12 education. Today, the pre-college program is receiving increasing attention as concerns about the impact of poor schooling on the nation's technical excellence grow.[26]

government and has an excellent reputation for integrity, technical sophistication, and the use of peer judgment in program selection. The research universities, which have the most to offer to future science teachers, are NSF's constituency. NSF has the capability to develop and test educational materials, methods, and tools for assessment, and to create institutional innovations. However, because of its modest budget and its competing science research mission, NSF alone cannot carry the federal role in math and science education reform.

The Department of Education's active participation in math and science education reform is essential, because progress in mathematics and science will be made only by literate, numerate students in fully functioning schools throughout the nation. Even if the nation's need for professional scientists and engineers were to be fully met by those

The Department of Education

The Department of Education has a long history. In 1867 a non-cabinet-level education department (soon called an Office of Education) was formed, and was associated with a variety of federal agencies. Beginning in the 1960s, the federal education responsibility was sited in the Office of Education in the Department of Health, Education, and Welfare (HEW). This office was given Department status by Congress in 1979, when HEW was divided into the Department of Health and Human Services and DoEd. DoEd strongly emphasizes providing equitable educational opportunity for all, including the poor, the handicapped, and the learning-impaired. Serving disadvantaged students more effectively calls for reform and innovations which are not necessarily the same initiatives needed to address math and science educational issues. The major K–12 spending programs of the Department of Education were devised primarily to reduce the within-district inequities of state and local spending on schools and students, and to help specific groups of students with special needs that are poorly met by the schools. These include programs of the Office of Elementary and Secondary Education ($7.8 billion in FY 1991 outlays), Special Education and Rehabilitation Services ($4.4 billion), and Bilingual Education ($193 million). The major programs in these offices are Chapter 1 programs for disadvantaged schools and students; the Education for All Handicapped Children Act (P.L. 94-142); and bilingual education grants to school districts (ESEA, Title VII, Part A).[27] Few of DoEd's programs are subject-specific, and its statutes place some constraints on its role in curriculum development and other activities pivotal to education improvement.

schools of superior quality and by the immigration of foreign scientists, both equality of opportunity and the quest for the best talent demand that special attention be given to young women, minorities, and the poor. The scale of the equity effort required is far beyond NSF's capability, and DoEd must assist through its efforts to leverage state action. But DoEd will need the collaboration of NSF, particularly for those activities that must draw on the talents of science, math, and engineering professionals, such as research-based development of innovative materials, curricula, and methods for teacher preparation in mathematics and science.

NSF and DoEd each has statutory responsibility for federal efforts supporting the reform of math and science education. Redundancy is not a problem; these are very different agencies and their responsibilities are complementary. The resources, skills, and cultures of both agencies are required if rapid progress is to be made toward the national goals for mathematics and science.

Some fourteen other agencies, of which the Departments of Health and Human Services (HHS), Labor (DoL), Energy (DoE), Defense (DoD), and the National Aeronautics and Space Administration (NASA) are particularly important, are in a position to make significant contributions to these goals. The Secretary of Energy has a key role as chairman of CEHR, which coordinates the efforts of the many agencies involved.

However, in terms of dollar investments, NSF and DoEd are the major players in pre-college math and science education. The other agencies together account for only 14 percent of the total federal investment in activities directly related to K–12 math and science education.[28]

Money Matters: Federal Spending for Reform and Improvement

Within the federal government, NSF and DoEd have the primary federal mission responsibility and budget authorization for math and science education (see boxes for details).

According to the recent inventory by the FCCSET Committee on Education and Human Resources, all agencies together spent only $515 million specifically for pre-college math and science in 1991, $406 million of that being directed at formal, in-classroom activity.[29]

Why is it that the federal government directs the equivalent of only 4 percent of its total K–12 public school expenditures[30] to the one

area of schooling—science and mathematics—in which American students are intended by the President and governors to become "first in the world"?

There is a strong case for priority attention and funding by the federal government specifically for math and science education:

- Quantitative problem solving, reasoning, and basic scientific understanding are, along with literacy, essential skills for protecting the United States' comparative advantage in the increasingly information-intensive world economy. From a trade perspective, this is a legitimate and major federal concern.

- Federal agencies finance almost half the nation's research and development ($64 billion out of $145.5 billion in 1990), and federal investments in science and engineering make critical contributions to industrial competitiveness and hence to economic well-being.[31] Shortcomings in K–12 math and science education may put federal missions, the economy, and other national interests dependent on science, mathematics, and engineering professionals at risk.

Federal Expenditures for K–12 Math and Science Education

NSF's total FY 1991 budget outlays are estimated at $2.4 billion, with $213 million (9 percent) going to K–12 education. Virtually all of this is directed toward math and science education.

DoEd's total FY 1991 budget outlays are estimated at $24.8 billion, with $7.8 billion (31 percent) going to K–12 education, most of which is devoted to categorical programs that allocate funds to states and school districts on the basis of fixed formulae. DoEd invests only $228 million, or less than 1 percent of its total budget and less than 4 percent of its K–12 budget, on pre-college math and science education.[32] Almost all of this is Eisenhower Program funds. This investment is only slightly more than NSF's, even though DoEd's total budget is ten times that of NSF.

The rest of the agencies combined devote far less money—only $74 million—to pre-college math and science education than either NSF or DoEd.

- Support for pre-college math, science, and engineering education has been a statutory responsibility of the National Science Foundation since 1950.

- Federal agencies, especially NSF, have excellent access to university resources that are essential not only for educational research but for educating young people for both teaching and research.

- Successful teaching of mathematics and science is specifically dependent on subject-matter competence, and an unacceptably large proportion of teachers in the schools do not possess the requisite background.

- The federal science agencies in FCCSET (which operate or finance over 750 laboratories with over a hundred thousand scientists and engineers) have that subject-matter competence, have been encouraged to include education in their responsibilities, and have the capability to make a much bigger contribution than they do today.

- There is less political controversy over the content of math and science curricula than in other areas, such as ethnocentric and multilingual teaching, and therefore less ideological objection to federal participation in reform of mathematics and science (with the lingering controversy about evolution vs. creationism an important exception).

- The President indicated his priorities by giving math and science education priority attention in the FY 1992 budget request (a 28 percent increase).

The Task Force concludes that 4 percent of the total federal pre-college educational investment, which itself is only 6 percent of total public school revenues, is an inadequate reflection of the priority accorded to math and science education in the national goals.

But would increasing expenditures in the current programs of the Department of Education solve the math and science education problem? There is no question that substantial expenditures are necessary to redress the crippling societal problems that impede or prevent the schools from being more effective, such as poverty, crime, and parental neglect. Although education will not eliminate these conditions, it is a critical tool for helping young people escape them. Therefore it is especially urgent that educational opportunities in low-income areas be rapidly improved.

More funding could speed the reform effort in the entire cur-

riculum, including science and mathematics. The FY 1992 budget requests an additional $690 million to support the *America 2000* strategy, over and above existing funds in the Department of Education and other agencies. For mathematics and science in particular, the FCCSET budget requests an additional $146 million above last year's $514 million, to a total of $660 million. Together, these increases amount to $836 million in new funding for school reform. (With the additional $150–200 million requested from the business community for the *America 2000* project, this amounts to about $1 billion in new funding for federal initiatives in education reform.)

Many believe that far more should be appropriated for improving the schools. Most immediately important, however, is how funding will be used, and how well the agencies are prepared to use it. The right question, then, is: Does the federal government have, or can it acquire, a unique and effective capability, working with the states, to achieve the national educational goals in time?

With federal contributions unlikely to increase dramatically under present fiscal conditions, **the federal government's role in reform should be to leverage state and private investments and produce change in the system, not to sustain it as it is**. But real change, brought to every state and every community, cannot be achieved by subsidies for the existing system nor by exhortation. Real change requires responding boldly to original ideas from inside and outside the educational community, assessing them for effectiveness, and institutionalizing them throughout the country when they are successful. The role of the federal government, then, is not a passive one, but is both empowering of and responsive to ideas from within schools and from outside the educational system on how schools, and the condition of children ill-prepared to come to school, can be improved.

Federal K–12 Education Expenditures

Pre-college education is the only education most Americans will experience and is the only formal education common to all. Since 1920, the financial contribution of the federal government to total pre-college education revenues has been small compared to state and local expenditures. In 1980 the federal share of total public school education revenues peaked at 10 percent. Since then it has declined gradually and today it stands at about 6 percent.[33] The bulk (over $200 billion) is funded by state (50 percent) and local (44 percent) contributions.[34] The federal government is not the financial heavy weight in the K–12 education arena.

A substantial reorientation of education funding toward educational reform is needed quickly. The states are occasionally able to assemble moneys to finance a program to upgrade the public schools or improve instruction. When they are, the amounts are generally minuscule in relation to school operating costs. Inevitably, when the local economy turns down, fixed costs consume whatever latitude has been assembled. *If only 10 percent of the DoEd's $7.8 billion annual elementary and secondary education expenditure were appropriated for funding incentives for improvement in all aspects of the education system, this, added to NSF funding, would produce over a billion dollars for reform.* Even when spread across much of the country, such an amount would represent a unique resource for planning and leveraging change at the level of a state, city, or community.

How much flexibility in funding for reform is currently available to the federal agencies? It is difficult to pull out which parts of the billions spent by the federal government on K–12 education are for change, but we believe the fraction is much too small. The FCCSET survey suggests that resource allocation priorities are not oriented toward the planning and implementation of systemic change. The FCCSET agencies together are investing only 11 percent of the federal spending in pre-college math and science education on systemic change, evaluation and assessment, and diffusion of innovations.[35] Thus the flexible funds available for these vital functions, which are not supported by state and local funding, are less than 1 percent of the annual federal K–12 budget. *The government should consider that, because they draw upon the trained math and science personnel of the nation, federal agencies should earmark some percentage of their research and development funding for math and science education.* This would significantly improve the directed funding for enhancing the math and science pipeline. If the percentage were set at 10 percent of R&D funding, for example, another $4.8 billion would be generated for math and science education.[36]

Resources for Math and Science Improvement

How might a federal strategy for general education reform be strengthened? In order to recruit the best ideas from the best innovators, the DoEd needs more funding flexibility.

The Task Force recommends that, as a long-term goal, a designated fraction (perhaps 10 percent) of DoEd's program funding be allocated for discretionary activities aimed at more effective achievement of its program goals. These activities would

be devoted to change-oriented, competitive, professionally reviewed programs that provide incentives for reform to states and communities. As this flexibility would allow DoEd programs to be more effective in serving the intended groups of students, learning in science and mathematics would be enhanced along with all other parts of the curriculum. These activities would be designed in collaboration with states and communities to support constructive change in ways that serve the same population to which each categorical program is directed. Over time, the returns on better use of the formula-allocated funds would result in an overall benefit-to-cost improvement.

A first priority is to strengthen DoEd in order to persuade Congress and the governors that DoEd has the capability to manage such programs with the needed professionalism. OERI is a likely office for the management of these programs. Such programs would be competitive, managed against clear objectives with measured out-

The Eisenhower Mathematics and Science Education Programs

In math and science education, the largest federal program is the Eisenhower Program administered by DoEd as part of the National Defense Education Act. About $202 million is distributed to the states by formula through the Eisenhower State Mathematics and Science Education Program, which is managed by the Office of Elementary and Secondary Education. Three-quarters of the funds received by the states are then distributed by formula grants to counties or school districts. These grants are intended to improve math and science teaching through in-service training of teachers, but because there is no competition for grants or follow up on outcomes by DoEd, many feel that this program has much less impact than it could have. The other portion of the Eisenhower Program, representing only about 5 percent of the overall Eisenhower funds, is a competitive grants program called the Eisenhower National Mathematics and Science Program, administered by the Office of Educational Research and Improvement. This smaller portion has better mechanisms for review and accountability and a better record of attention to reform. For example, the Eisenhower National Program has contributed funding to the National Science Teachers Association's Scope, Sequence and Coordination program and to Project 2061 of the American Association for the Advancement of Science, in both cases sharing costs with NSF.

comes, and targeted to the pursuit of the national interests in education and achievement of the national goals.

How might a federal strategy aimed at rapid improvement in math and science education be strengthened? The most immediate step forward would be for the Administration and Congress to convert all the funding for the Eisenhower grants program in DoEd to a competitive, peer-reviewed program. Today these grants (see box opposite) are almost all allocated by a population-based formula with limited oversight and accountability, and thus may not be serving their intended purpose of in-service teacher training as efficiently as they might.

The Task Force recommends that the $202 million Eisenhower State Mathematics and Science Education Program be made fully competitive and devoted to change and improvement in math and science education. This program, now managed by the Office of Elementary and Secondary Education, would be combined with the $12 million competitive Eisenhower National Program and both would be administered by the Office of Educational Reform and Improvement (OERI). Together with existing competitive programs at NSF, this would almost double the funding available for enhancing the performance of K–12 math and science teaching.

The Task Force further recommends that all federal agencies concerned with science and technology should devote some percentage of their research and development funds to math and science education. While many of the agencies support efforts in post-secondary education, the immediate need is for additional funding to be directed toward K–12 math and science education. These funds, too, could be administered through a competitive grants process, which would encourage the best innovators and the best ideas.

PART V

PRIORITY ROLES FOR THE FEDERAL GOVERNMENT IN MATH AND SCIENCE EDUCATION

Earlier in this report, we concluded that the federal role is not to subsidize the basic operating costs of schools* but to induce constructive change and assist the states with the diffusion of new policies, structures, tools, and innovations to all the schools. Federal officials and agencies possess unique capabilities to facilitate that process of constructive change.

ROLE FOR THE PRESIDENT

Foremost among federal responsibilities is the leadership role of the President himself. The President has acknowledged his personal responsibility to provide that leadership in his *America 2000* report: "The President, the Department of Education, and the entire Cabinet will help keep the focus on this [reform] strategy, will spotlight areas of trouble as well as areas of excellence, will reward progress and spur change." The most difficult requirement for rapid educational progress is the necessity of building a national coalition for change. Parents and other citizens, school boards, principals and teachers, chief state school officers, business leaders, teacher educators, state legislators, Congress, and many others must collaborate if the national goals are to be reached. The most difficult group to reach may well be the public, particularly some older voters whose children are no longer in school and who take a cynical attitude toward the likelihood of real improvement in the schools. **The Task Force urges the President to use the full prestige and influence of his office to mobilize all Americans for a sustained, national, bipartisan reform effort.**

*An important exception is the need for federal funding to support equity programs: rapidly expanding the number of disadvantaged students pursuing science and mathematics, enhancing the quality of their science and math teachers, and creating incentives for their professional education for teaching or research careers. However, even these DoEd "Chapter 1" investments might be used more effectively to leverage state investments and to influence state policies on equitable allocation of funding for schools.

Roles for the Agencies

The National Science Foundation (NSF) and the Department of Education (DoEd) are the only federal agencies with a legislative mandate for broad-based educational improvement and change. Their contributions make up 86 percent of the total federal formal education support for pre-college math and science education, as determined by the Committee on Education and Human Resources of FCCSET. For this reason, the following discussion focuses primarily on NSF and DoEd.

Specific Recommendations for Federal Agency Action: Eight Key Institutional and Program Innovations

The Task Force has identified eight areas for action at the federal level that deserve high priority. Most of these require institutional innovations or modifications. For each area, we suggest how responsibility could be allocated among NSF, DoEd, and other agencies.

- **Provide fully qualified math and science teachers for every school, by (a) enhancing the knowledge, skills, and motivation of current math and science teachers, (b) ensuring fully professional training for math and science teachers from diverse backgrounds, and (c) recruiting math and science teachers for schools that do not have them.**

Enhancing teacher skills and knowledge: With a small investment compared to the current level of federal education expenditures, the nation could retrain 50,000 teachers per year over the next decade, thus empowering a half-million math and science teachers to transmit the excitement of learning to a major fraction of our minority population and our children in poverty. (According to Leon Lederman, the Chicago Academy project and others show that quality retraining costs about $10,000 for the initial training and $2,000 for follow-up per teacher; the annual expense for training 50,000 teachers is thus about $600 million.) Teacher summer institutes have been NSF's most popular programs for K–12 math and science education in the past. They gave teachers self-confidence by bringing them up-to-date in

science, but by most accounts, teachers' experiences were not linked well to what they faced on return to their classrooms. This teacher training model should be rethought to include training in how to teach the basics of science, in new methods arising from cognitive science, and in the transfer and use of the best educational materials and technology. As noted above, special attention should be given to measures for helping teachers adopt what they learn in institutes—for example, by bringing teams (rather than individuals) from the same school to support the pursuit of improvement objectives they have defined and to overcome institutional resistance to change.

Encouraging the establishment of voluntary professional board accreditation for superior teachers would do much to enhance the quality of teachers. The National Board for Professional Teaching Standards* is setting standards for professional board certification for superior teaching ability. Congress has authorized DoEd to match private contributions to finance the development of the necessary assessments of how teachers meet those standards.

Ensuring fully professional teacher training, including the single professional path to either teaching or practice in mathematics and science: Colleges and universities with strong math and science faculties should provide an undergraduate major in math or science leading to a bachelor's degree, with electives that qualify a student for a teaching certificate or entry to graduate study, or both. (Vanderbilt University, for example, with the cooperation of the State of Tennessee education authorities, encourages all its undergraduates to pursue this option, which can be fulfilled with the proper choice of electives without any sacrifice of the requirements for the science major. This approach was recommended in the Carnegie Corporation's study *A Nation Prepared: Teachers for the 21st Century.*[11]) The National Science Foundation should encourage this integration of undergraduate preparation of future science teachers and researchers. This approach offers NSF a means to align the interests of both its research and education constituencies and allows federal investment in higher education in science and mathematics to be leveraged to produce more well-qualified teachers. Specific incentives should be created to attract minorities into the profession, so that in ten years there would be enough fully qualified math and science teachers and researchers to more nearly match the demographics of the student body, thus providing role models for all students.

Colleges and universities, along with science centers and museums, are among the institutions appropriate for encouraging young people, especially minorities and women, to pursue professional

*Creation of a board of this kind was a principal recommendation of the Carnegie Task Force on Teaching as a Profession. The National Board is a private professional body, whose board of directors has a majority of active classroom teachers, devoted to setting standards and providing teacher assessments for professional board qualifications in teaching.

education in math and science. Professional societies and other not-for-profit institutions,[37] together with national laboratories (e.g., in DoE and NIH) and other laboratories, can also make substantial contributions to in-service teacher training and classroom enhancement.

Recruiting qualified math and science teachers for every school: There are many urban and rural schools without qualified and adequately trained math and science teachers. One way of addressing this problem is through a teacher corps program whereby needy schools could apply for teachers to be assigned for a fixed time, provided the school district commits itself to picking up the full costs of those teachers after this period. Alternative paths to teaching certification will be needed to meet this goal. Another approach to addressing this need is through competitive grants for teacher training programs targeted to the inner city and rural areas.

The falling supply of math and science graduates for both school teaching and professional practice, as well as the quality of preparation of the teacher work force, are matters of serious concern. As Nobel physics laureate Sheldon Glashow put it, "What I hope for by the year 2001 is that middle and high school teachers know more about science than their students are expected to learn."

- **Establish a national center for educational content and assessment.**

A federally funded but independent center should be created to reach a consensus and advise the nation on what students need to know and what competencies they require to be productive in the workplace of today and tomorrow. This work would have a critical influence on curricula, teaching materials, and teacher training. Mathematics and science should have high priority in this work, and might form the focus of its initial work.

That such an institution can be very important is demonstrated by the National Assessment Governing Board (NAGB), a congressionally established, OERI-funded, independent body that recently completed an assessment of eighth- grade math performance in U.S. schools. NAGB is introducing open-ended questions that test students' reasoning ability. This kind of work has important implications for how any national assessment is done.

Research to develop better testing methods, defined in relation to the descriptions of educational content, should be undertaken by such an independent institution. Once the assessment methods have been worked out, the assessments must be competently administered by an independent organization. The same institution could serve this purpose.

Such a center might well be established under the guidance of the National Education Goals Panel, which would ensure that the states, Congress, and professional organizations are full partners in this

work. The Department of Labor should have a significant role in it. The consensus it seeks should embrace not only the diverse parts of the education community but also parents, employers, and citizens generally.

- **Strengthen educational systems research and analysis to support the reform strategy. Establish broad-based support for basic cognitive and applied learning research and field testing of innovations resulting from this research.**

Inadequate attention is being given by federal agencies to research and analysis of the K–12 educational system to ensure that public policy alternatives are based on solid evidence and strong basic and applied research. Without a strong capability to pull together the best data and analysis in this area, federal officials will have great difficulty resolving conflicting views about what the national strategy should be, and what the federal role is in it. *The Task Force suggests that serious consideration be given to establishing a center (organized as a Federally Funded Research and Development Center) charged with assembling the best analytical understanding of the K–12 education system and providing "systems engineering" support for educational reform programs.* This center should promote the closest possible relationship between university researchers and users of research results in the schools, such that practice informs research even as researchers inform practice. The center should be established by DoEd, most likely by the Office of Educational Research and Improvement, but with NSF participation.

The last two decades have seen important advances in understanding of math and science learning. Unfortunately, the number of experienced researchers is small, and the field has suffered from lack of stable funding. In addition, there has been serious underinvestment in applied research on translating new learning theories into classroom practice, with field experiments to validate it.[38] NSF estimates that it devotes only a $7 million education research effort to that objective[39]; the DoEd Research and Development Centers make additional investments of a similar magnitude. While educational research has suffered from a lack of consistent support and attention to quality in the past, rapid progress in cognitive science and applied learning research is possible if the research is funded competitively in response to the best proposals from university experts and others. In addition to DoEd and NSF, FCCSET should encourage other agencies to support peer-reviewed research from diverse sources.

- **Ensure diffusion of successful innovations: provide access for all schools and all students to tested educational improvements and support their successful adoption.**

It has been characteristic of educational research that many innovations have been shown to be very effective when tested in one or a few schools, yet few have been widely adopted. Neither the federal agencies nor the education networks within states have been effective in promoting widespread adoption of promising programs. There must be much greater emphasis on diffusion and adoption of the best education products and initiatives the nation can devise. Of the $515 million devoted to math and science education by federal agencies in FY 1991, only $5 million, or 1 percent, was devoted to the diffusion of promising innovations. This is wholly inadequate.

If diffusion and adoption are not facilitated, the expenditures on school reform, education research, and other activity that the states cannot hope to fund themselves, will have been wasted. DoEd's current efforts at diffusion, through the National Diffusion Network and the Educational Resource Information Center, are underfunded, have a poor reputation for turnaround time, and lack the collaborative relationships required for successful technology transfer. A major upgrading of this capability is required.

Successful diffusion of new ideas, materials, and methods requires active collaboration between schools and those who have successfully practiced the innovations. The Michigan Partnership, with associated educational extension services, represents an important effort to provide such services.

The private sector should be encouraged to participate in diffusion activities. The textbook and computer software industries make considerable investments in the development of integrated curriculum materials, and are important intermediaries in the dissemination of curriculum innovation in math and science as well as other fields. K–12 schools should have access to sources of support, materials, in-service training, and other services from both public and private sources.

This could be facilitated inexpensively by access to an electronic information network such as the proposed National Research and Education Network (NREN). NSF has been the leader in the development of NREN's predecessor, the INTERNET, and plays a major role in the Federal Networking Council, which will determine how NREN is to be created and managed. If teachers and principals could have inexpensive access to sources of materials and expert guidance on their use, costs could be minimized. But distributing ideas and information to guide the adoption of successful ideas is not sufficient; some form of extension service, presumably state-operated, is needed in addition. Extension services of the Department of Agriculture, which have been highly successful, provide a model, but the extension agent model is expensive—half of the USDA R&D budget is devoted to extension services.

One means of facilitating diffusion and adoption might be a two-stage funding incentive to outside organizations, which could re-

ceive a grant for initial demonstration of an innovation, to be followed, if successful, by a larger grant to finance wider-scale implementation.[40]

- **Empower all federal science agencies to take leadership roles in the reform of K–12 math and science education.**

Major innovative projects undertaken by communities, cities, and states to improve math and science education should be able to come to the federal government for guidance, evaluation, and an opportunity to compete for funding. The President's *America 2000* report promises to "unleash America's creative genius to invent and establish a New Generation of American Schools, one by one, community by community."[41] The goal is to create over 535 such schools (at least one in each congressional district) by 1996. While this directive could win political support, targeting urban and rural schools would address the major problem areas and be a more dramatic test of reform strategy. Indeed, 250 out of the 16,000 school districts in the country educate 30 percent of all schoolchildren.[42] DoEd, with its involvement in the school network in every state, is the obvious federal leader in this effort. However, NSF can offer important insights into how schools might be organized to access the scientific expertise of the community, national laboratories, and universities and research institutions receiving government funding. Indeed, NSF has access to an immense scientific network. The scientific capability of this nation is a huge asset which has not been properly mobilized. NSF in particular and the science agencies in general (through FCCSET) should do more to tap this resource.

Improvements in math and science instruction require reform of the school environment, and this reform requires the cooperation of chief state school officers, local school officials, teacher organizations, universities, the private sector, and citizens' groups. Agencies can encourage and stimulate such cooperation. For example, NSF has initiated the Statewide Systemic Initiatives program (SSI) for math and science education, placing states in competition for grants to create detailed collaborative reform plans. This program has promise, since the states, including some that did not receive grants, have made substantial progress toward building consensus for reform. If such programs are to reach all the states, NSF will be hard-pressed to finance them. NSF's SSI program might be considered the model for an expanded effort of this kind by DoEd once OERI has demonstrated the relevant managerial capacity.*

*There is concern that DoEd does not have sufficient staff or experience with objective peer-review standards to take responsibility for the SSI program. The Task Force recommendations on staffing and funding address those shortcomings.

Every science agency of the government should have an explicit education charter defining its responsibilities to address pre-college issues—materials, elements of curricula, teacher skills and knowledge upgrading, outreach of scientists and engineers to the schools, encouragement of university/school linkages—that lie within the agency's special technical expertise and the agency's human resource requirements.

■ **Encourage private-sector development of educational materials, curricula, textbooks, and software for new educational technology.**

NSF, with its excellent relationship with university scientists, professional societies, and the science academies, has historically played a leading role in math and science curriculum development, and continues to do so.[43]

However, NSF has given insufficient attention to collaboration with educational innovators in the private sector: textbook publishers, educational software firms, and video producers, who not only make significant educational investments but have the capability to diffuse innovations throughout the country. NSF should go beyond the support of research and invest in prototype development, with primary reliance on private firms for commercialization.

■ **Encourage science centers and museums, educational television, and other sources of "informal" education.**

Ample evidence of the power of nontraditional education to interest students in the study of science and mathematics and to explode negative stereotypes of science and scientists—for example, through science centers and museums, television, and science fairs—suggests that this should be a significant component of the federal strategy. Many of the best science centers—San Francisco's Exploratorium and Chicago's Museum of Science and Industry, for example—go far beyond the vital role of motivating young people to be interested in science, and create much-needed educational materials. The Lawrence Hall of Science in Berkeley, California, for example, produces science teaching materials used by 100,000 teachers and 5,000,000 students.[44] This is another area in which the private sector can be more involved, both through foundations and by opening laboratories and making personnel available to the K–12 classroom. Some kind of coordinated encouragement could be managed through a DoEd/NSF matching grant program.

The FCCSET report notes that $100 million, nearly 20 percent, of the $515 million invested by federal agencies in pre-college math and science education, is devoted to nontraditional educational environments. Since these activities touch the spirit and excitement of sci-

ence common to all the technical agencies in CEHR, NSF and the other science agencies should be the main contributors.

- **Provide an information and referral service to document innovations and help innovators locate programs, services, information, and support for K–12 math and science activities.**

Individuals outside the federal agencies have difficulty locating the correct agency through which to gain access to program materials, services, and information—a particularly severe problem, given the large number of participating agencies. A central office is needed in which requests for possible federal sponsorship of nonfederal activities are screened and referred to the appropriate agency.

It would also be valuable to develop a comprehensive picture of who is doing what, by collecting information on innovations originating outside the federal government. This would most appropriately be housed in DoEd, as such an office would probably not be discipline-specific. Large programs, or those appropriate for multiagency support, would be identified and referred to CEHR to identify and assemble cooperative resources. Much of the function described here is analogous to the very successful National Library of Medicine, and like that library's MEDLARS service, should be integrated with the networks providing education diffusion services.

The complexity of these efforts for change and the links between the responsibilities assigned to DoEd and NSF demonstrate how essential it is for the two agencies to develop a very close working relationship. This does not imply that other agencies of the government should be excluded from any of these activities. Lead responsibility for each endeavor, however, should be assigned to one or the other of these two players. The Task Force recognizes that some time must elapse before DoEd has all the needed professional capabilities and NSF has developed the educational practice expertise and the relationships with officials in states, cities, and communities necessary for full effectiveness of their efforts.

Who Should Do What for Math and Science Education?

In summary, responsibility for the recommended elements of reform and innovation can be distributed between DoEd and NSF as follows:

Primary missions for NSF:

- New math and science teacher recruitment.
- Math and science teacher education revitalization.
- Math and science teacher enhancement.
- Innovative curricula and educational materials.
- Cognitive and applied learning research; field testing innovations.
- Nontraditional, motivational education activities.

Primary missions for DoEd:

- Education research, field testing and education systems analysis to inform the reform strategy.
- Research on assessments of educational progress and their national applications.
- Incentives for state reform initiatives.
- Rapid diffusion and adoption of successful innovations.
- Innovative means of operating schools.
- Clearinghouse and referral service for guiding new efforts.

PART VI

STRENGTHENING THE KEY FEDERAL AGENCIES

Before existing institutions and agencies can be effective in a new, systemic reform initiative, they must acquire the mission capability and personnel required to sustain a significant effort.

THE DEPARTMENT OF EDUCATION AND THE NATIONAL SCIENCE FOUNDATION

In order to take the lead on the initiatives outlined above, the Department of Education (DoEd) and the National Science Foundation (NSF) need to be strengthened. DoEd, and especially the Office of Educational Research and Improvement (OERI), should give priority attention to the competence, experience, and management policies necessary to operate the kind of competitive, targeted programs required to make rapid progress in mathematics, science, and other disciplines. OERI needs to augment its staff with experienced and respected scientists and mathematicians familiar with managing innovations that are devised outside the government. To ensure the continued infusion of talent, DoEd should ask Congress to authorize the appointment of a limited number of "rotators," as NSF does. DoEd should then be given greater latitude in the use of its funds in pursuit of the national goals.

Until recently, the NSF Education and Human Resource Directorate followed the practices of the research directorates in NSF in responding to unsolicited research proposals, primarily from university faculty. It now practices a more directed style, making program announcements in pursuit of an agency strategy, and working directly with states and schools in many of its K–12 activities. To be even more effective, NSF needs to gain additional staff with field experience in K–12 education, strengthen its relationships with all elements of the educational system, and build a better balance between permanent professional staff and rotators, who are essential for increasing effectiveness and maintaining access to new ideas. Arrangements for close and effective collaboration with DoEd are of critical importance.

Other Federal Agencies

By taking the initiative on behalf of a government-wide effort to upgrade math and science education throughout the nation, the Secretary of Energy demonstrated the power of agencies with vast technical resources to take a long-term view of their missions and act accordingly. The Department of Energy should continue its leadership of the Committee on Education and Human Resources (CEHR) of the Federal Coordinating Council for Science, Engineering, and Technology. Through that mechanism, all R&D-intensive agencies can coordinate their contributions to math and science educational progress. The FCCSET report *By The Year 2000* summarizes for the first time the great variety of other agency activities touching on K–12 math and science education, from programs of direct support of school-based activity and informal education to the voluntary activities of federal laboratory personnel. In some agencies, the activities derive from an agency-specific charter (e.g., the Department of the Interior's Youth Conservation Corps, programs for Native American youth, and other programs totaling $22 million; the Agriculture Department's 4-H Youth Development School Enrichment Program, costing $42.5 million; and the Department of Labor's many efforts to enhance the competence of our technical work force). In other agencies, the mission is implicit because of their dependence on a continuing source of quality scientists and engineers.

If orchestrated into a more coherent strategy for educational improvement, the benefits of these programs might be leveraged substantially. In addition, certain agencies with an abundance of technical talent have specific opportunities to make a contribution that the Administration and Congress might seize and put into effect. Examples of such efforts by three agencies are given below. If, however, these and other agencies are to make more substantial contributions to pre-college math and science education, they will need clearer statutory authorization to do so than they have now. In a later section, we will recommend steps to be taken by the President and Congress to address this issue.

National Institutes of Health

The National Institutes of Health (NIH) and the National Institute of Mental Health have research mandates similar to that of NSF, but are directly oriented toward basic and applied health research. Their involvement in education is heavily oriented toward postgraduate and professional medical education. In 1991, NIH's pre-college

math and science education investment was $22 million, or about 0.2 percent of its total budget; its participation in undergraduate education was $61 million, or 0.6 percent of its total budget; and its graduate investment was $414 million, or about 4 percent of its total budget.

As the shortcomings in K–12 math and science education begin to affect the health professions in the same way they are affecting the physical sciences and engineering, NIH will need to play a major role and invest more heavily in early intervention to attract students and to help prepare them in science and mathematics.

The Task Force recommends that NIH study the future impact of deficiencies in K–12 math and science education on the nation's health-related research and professional human resources, assess the extent of its responsibility to address the human resource pipeline on which the nation's health and health industry depend, and design a long-range program, coordinated with NSF and DoEd, based on the findings.

Department of Defense

The investment of the Department of Defense (DoD) in math and science education is even more skewed toward higher education than is the case in NIH. However, DoD has great experience with efficient skills training and has unique capabilities and resources at hand that may be very useful in the current reform efforts in the pre-college area. DoD has been very aggressive in educational technologies, has success in training of students at all levels of ability and socioeconomic background, and has proficiency at teacher training. As part of the President's interest in "a new generation of American schools," DoD might undertake to demonstrate its capabilities in model schools serving defense-impacted communities.

The Task Force recommends that the Department of Defense, recognizing the increasingly sophisticated technical skills required of the voluntary military forces, consider creating model federal schools in which to demonstrate DoD capabilities in educational technology and processes, and transferring these capabilities to the civilian sector.

Department of Labor

The Department of Labor (DoL) may be the sleeping giant of the national math and science education reform effort. With its command of resources, outreach, and direct links to American competitiveness, it has the potential to become a partner in math and

science education on the scale of NSF and DoEd. Until very recently, most people have separated the world of work from the world of school. This is the crux of the mammoth problem of the school-to-work transition in the United States (which is much more successfully dealt with in a number of other countries, notably Germany and Sweden).

In the future, DoL will have a profound influence on school curricula through its specification of the knowledge base and skills base needed to move from school to the workplace. Its analysis of technical competencies will have a profound effect in the areas of science and mathematics. DoL should support and encourage high school apprenticeships and other programs to facilitate school-to-work transitions and other meaningful ways of integrating school and career paths.

The Task Force believes that math and science education would benefit from increased interaction among the Department of Labor, NSF, and DoEd; a mechanism for this interaction, perhaps through the Federal Coordinating Council for Science, Engineering, and Technology, should be devised.

Other Agencies

Other agencies with strong technical capabilities have much to offer the public schools in mathematics and science. Some, like the Department of Energy and NASA, have national laboratories of great strength and depth, and can not only contribute to schools in their communities but can motivate teachers and provide innovative ideas to developers of curriculum and teaching materials. Still others, like the Departments of Agriculture and Interior and the Environmental Protection Agency, have a widely distributed federal professional presence and, through programs like the 4-H Clubs, can reach very large numbers of young people. Still others, such as the Department of Commerce, can help enlist businesses and other institutions in the reform effort. Specialized agencies, such as the Smithsonian Institution, have unique resources not available elsewhere. These opportunities have been extensively surveyed by FCCSET and, if properly supported and coordinated, these agencies can make a big contribution.

The Task Force recommends that the coordination and accountability for math and science education activities of all the technically based government agencies should be firmly and permanently supported through the FCCSET structure.

PART VII
DECIDING ADMINISTRATION POLICY AND OVERSIGHT

The questions to be addressed in this section are:

- *Where should responsibility for decision making on policy, strategy, and agency mission assignments for K–12 education be located?*
- *Where should decisions on operational responsibility for K–12 math and science education reform activities be made?*

ADMINISTRATION POLICY AND OVERSIGHT

Ultimately, of course, the President decides both questions. But the parallel and seemingly independent origins of the *America 2000* and the FCCSET (*By the Year 2000*) strategies, mentioned above, point to the need to clarify responsibilities within the Executive Office. Further, the dispersion of responsibility across the Administration, Congress, the states, and the private sector points to the need for a continuing mechanism for interlacing their strategies.

The President has made education a highly visible part of his domestic policy. The Assistant to the President for Economic and Domestic Policy has been a focal point in the White House staff for promulgating the strategy expressed in *America 2000.* However, overall education policy clearly falls within the province of the Domestic Policy Council (DPC),* and the responsibility for defending and developing the education reform strategy falls primarily to the Secretary of Education, who has also assumed the chairmanship of the Education Policy subcommittee of DPC.

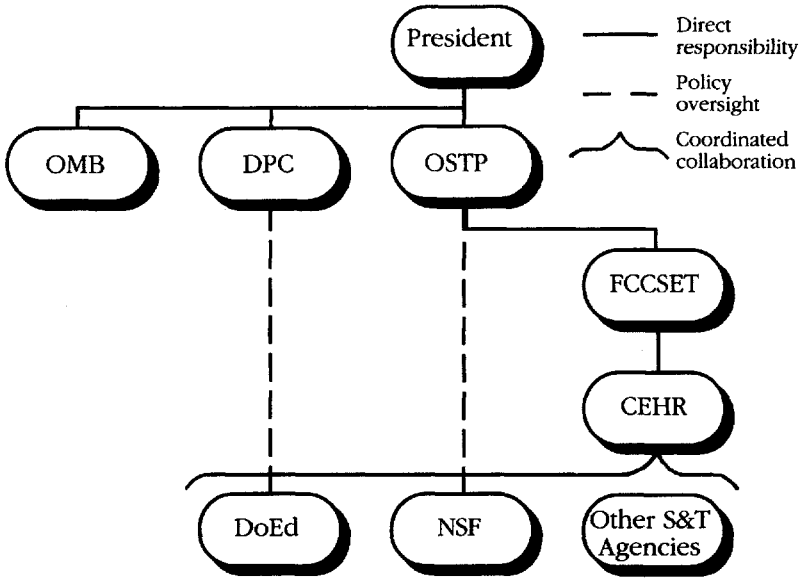
For questions of math and science education specifically, the primary staff responsibility in the White House falls to Dr. D. Allan

* There is a largely moribund organization on the books called the Federal Interagency Committee on Education, but it has apparently been superseded by FCCSET and other offices in the Executive Office of the President.

Bromley, the President's Science and Technology Adviser, who also serves as director of the Office of Science and Technology Policy (OSTP). Dr. Bromley sits on the DPC and also chairs the FCCSET and uses its CEHR to help coordinate the work of the many federal agencies most involved with scientific and technical matters.

The Task Force concludes that two existing channels of White House oversight of math and science education activities, in addition to the Office of Management and Budget (OMB), are both required: (a) DPC for overall education policy (largely through DoEd), and (b) OSTP, through its FCCSET structure, overseeing NSF, DoEd, and some fourteen other agencies.

Figure 1. Organizational chart of policy oversight for federal K–12 math and science education activities.



- The Executive Office of the President (EOP) interacts with DoEd through the Domestic Policy Council (DPC) to define overall education policy, but in mathematics and science, OSTP and CEHR have the stronger role.
- The EOP interacts with NSF on overall science issues through OSTP.
- The math and science education activities of NSF, DoEd, and all the other agencies are reviewed and coordinated by FCCSET's CEHR, reporting through OSTP to the President.

This form of organization (Figure 1) is not as clean as a single channel of authority with unique assignments of staff oversight responsibility, but it reflects the reality that, while math and science education is a vitally important matter in its own right, it is embedded in the overall K–12 education system which is the focus of a highly visible set of domestic policy issues going far beyond mathematics and science.

CEHR has proved a very useful instrument at a time when many agencies depend heavily on the human resources produced by the math and science education process, and when NSF and DoEd, the two agencies with primary missions in this area, have had little experience in collaboration. Progress in developing a comprehensive federal agency strategy on math and science education has been made possible in part because CEHR is chaired by an influential member of FCCSET from an agency other than NSF or DoEd (Admiral James Watkins, Secretary of Energy, is chair of CEHR), and that OMB is well represented. This mechanism may not be necessary in five or ten years, when the joint development of NSF and DoEd activities should have matured and when active relationships with the other member agencies have strengthened.

The Task Force recommends that the OSTP appropriation be expanded to provide funding for the operation of CEHR as a standing committee of FCCSET. In the interest of an integrated federal strategy, a full-time staff should coordinate agency activities and review agency strategies for K–12 math and science improvement. The current pattern of two vice-chairs of CEHR drawn from senior executives at DoEd and NSF should be continued.

Within OSTP, the Associate Director for Policy and International Affairs manages K–12 math and science education issues, helping Dr. Bromley provide oversight for CEHR. If CEHR is to have a continuing role in the review and coordination of K–12 math and science education, the demands on the time of OSTP staff will be a substantial burden. We recommend that the director of OSTP assign to one of the associate directors full-time responsibility for math and science education. This associate director could also cover basic research, to which education issues are closely linked. The K–12 math and science education issue could be the sole responsibility of an assistant director.

The FCCSET report observes that the "vast network of Federal scientific laboratories, technical facilities, and expert personnel, and the science- and mathematics-related information and materials they produce ... have a previously unrecognized and under-utilized potential for rapidly improving the basic science knowledge of American teachers and students."[45] FCCSET makes an excellent case that all of these efforts will be more effective if they are orchestrated into an integrated federal response.[46] Although the report advances a multi-

agency strategy to this end, it does not address explicitly the statutory basis for the pre-college activities of these agencies (other than NSF and DoEd). While advocating more emphasis on pre-college activities (relative to graduate and postgraduate programs), the report may not constitute a sufficiently strong mandate to produce the desired agency response.

The nation faced a similar situation just after World War II, when wartime research activities were being terminated and the government was searching for policies to replace war work with peacetime investments in research in fulfillment of federal missions, both civilian and military. A particular concern, reflected in Vannevar Bush's 1945 report to President Truman,[47] was that the nation would underinvest in that component of research of greatest value over the long term: basic research carried out in university laboratories. The practical interpretation of Bush's recommendations came in 1947 in what is known as the Steelman report.[48] The Steelman report set goals for federal R&D funding (1 percent of GNP) and for public and private R&D (3 percent of GNP); it also proposed a rate of progress toward these goals (15 percent per annum). A few years later President Eisenhower issued an Executive Order establishing the principle that every agency making substantial use of science and technology resources should proportionately reinvest in the source of that knowledge—basic science.

Today, Americans find themselves in a similar situation. But this time it is deficiencies in the skill base, in addition to the knowledge base, that may frustrate the attainment of national goals. The FCCSET report shows that agency heads are making efforts to use their resources to participate in public education reform, especially in mathematics and science. But their mandate to do so is sometimes limited, sometimes unclear.

The Task Force is concerned that, despite the President's encouragement to the agencies to make a contribution to K–12 math and science education and the broad support in Congress for educational progress, the budget process will impede the "integrated federal response" called for in the FCCSET report. Agency officials defending their budgets before skeptical appropriations subcommittees may find it difficult to defend long-term commitments in science education without clear mandates from the President and Congress.

Accordingly, the Task Force recommends that every agency dependent for its mission on a strengthened system of math and science education invest in improving the education pipeline that creates the needed skills. This policy should be put forward in an Executive Order, with implementation to be guided by OSTP, OMB, and FCCSET. OMB should review the statutory flexibility of each of the agencies to see if enabling statutes need amendment.

Assignment of Operational Responsibilities to the Federal Agencies

There are various alternatives for assigning lead responsibility for planning and directing activities in K–12 math and science education. These alternatives are (a) to give lead responsibility to an office in the Executive Office of the President, presumably OSTP; (b) to assign the full responsibility to DoEd, with NSF and other agencies in support; (c) to give NSF lead responsibility for math and science education, relieving DoEd of this area of education; and (d) to merge DoEd and NSF into a single Department of Education and Science. (These options are discussed in the Appendix.)

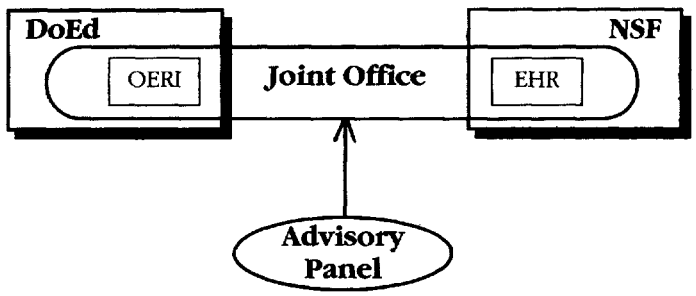
The Task Force concludes that overall responsibility for leading federal K–12 math and science education reform should be shared between NSF and DoEd, with each assigned specific responsibilities. Timely achievement of national goals for K–12 math and science education reform demands capabilities and legislative authority unique to DoEd and to NSF; both agencies must play important and distinct, but interdependent, roles. In this partnership, DoEd will play a lead role in systemic change; NSF will play a lead role in research-intensive activities and teacher training specific to mathematics and science, drawing on the professional talent in the nation's universities and laboratories.

A DoEd/NSF Joint Office for K–12 Math and Science Improvement

As Walter Massey, the new director of NSF, put it, "Separating science from science education is wrong, but separating science education from education is wrong, too."[49] As noted in Parts IV, V, and VI of this report, math and science education should not be the sole province of either NSF or DoEd. NSF and DoEd are far and away the major federal players financially and programmatically in formal math and science education. They require a special joint structure or collaborative device apart from the FCCSET structure to take advantage of their complementary strengths, coordinate similar efforts, maintain communications, ensure common policies in dealing with the states, and maximize agency accountability.[50] This structure should also allow the two agencies to approach congressional committees jointly on math and science education matters.

The Task Force recommends that DoEd and NSF create a mechanism for collaboration such as a Joint Office for Math and Science Improvement. It would report directly and jointly to the Secretary of Education and the Director of NSF.[51]

Figure 2. Recommended Joint Office for Math and Science Improvement.



DoEd and NSF would collaborate in managing interdependent responsibilities through a mechanism such as a Joint Office for Math and Science Improvement, linking the DoEd's Office of Educational Research and Improvement (OERI) and NSF's Directorate for Education and Human Resources (EHR).

The mission of the Joint Office (Figure 2) would be to ensure coordination of policy, joint management of programs, and communication between the two agencies. To do this, it needs a small, highly professional staff that will make use of existing agency facilities and experience. The opportunity to have a significant influence on policy would assist in attracting an outstanding executive director.

Because of the very large number of interested parties and sources of expertise in any program involving federal, state, and private partnerships, it is important that the two agencies in such a Joint Office have access to the same sources of outside advice. One way of accomplishing this is an *advisory panel for mathematics and science, reporting to the Joint Office.* This panel should consist of both educators and scientists.

Congressional Committee Review

The education committees of Congress, in both the House and Senate, are structurally divided along lines of responsibility much like the executive agencies. The House Science, Space and Technology Committee writes legislation and provides budget authority for NSF's research and education activities, as well as those of NASA and other independent agencies. The House Committee on Education and Labor has similar legislative jurisdiction over DoEd, as well as the Department of Labor and others. The situation is similar in the Senate. The support of both sets of committees will be necessary if a tightly coordinated federal program of math and science education reform is to be successful.

The Task Force recommends that the education and science committees, particularly those with jurisdiction over DoEd and NSF, cooperatively review Executive Branch proposals to coordinate K–12 math and science education activities, and determine together the priority that math and science issues are to enjoy in the intensified program of federal action. One possibility might be the creation of *a temporary Select Committee on K–12 Math and Science Education* to bring together the appropriate committees in the House and Senate.

Mechanisms for Funding Reform

The Task Force believes that, once the Administration and Congress are convinced that significant budget increases for K–12 math and science education reform will achieve significant results, additional resources will be made available. Whether such increases become a reality now or later, existing federal funds must be spent more effectively. As federal government support accounts for only 6 percent of school budgets, some mechanism is needed to ensure that this funding is leveraged and targeted to reform efforts.

To this end, Congress should give DoEd new legislative authority to guide the spending of an increasing proportion of that 6 percent, i.e., to make the grants more competitive, to coordinate and evaluate them, and to terminate funding if grants are not well used to promote reform and equity. For math and science education reform, the Office of Educational Research and Improvement or the proposed Joint Office should be the site of most

of this activity. Congress should also give DoEd the additional flexibility required for effective collaboration and joint funding of projects with NSF and other agencies under CEHR guidelines. For example, because of statutory restrictions on DoEd activities in curriculum development, DoEd has experienced some difficulties in co-sponsoring initiatives, such as Project 2061, with NSF.

The Task Force recommends that Congress remove any statutory restrictions that might impede the close collaboration between NSF and DoEd on math and science education projects.

PART VIII

Building a National Strategy for Improving Math and Science Education

How might the federal government and the states improve their ability to execute their education reform strategies, addressing the complex relationships among federal agencies, the states, private groups, and Congress?

In Part II we called attention to the National Education Goals Panel (NEGP) within which key governors, the congressional leadership, and senior figures in the Administration assess progress toward the national goals for the year 2000. This high level of representation is essential to sustain the commitment to the goals. NEGP has assembled working groups of experts to guide the requirements for data needed from the states and agencies for recommending standards and measuring progress. However, broader representation is needed now for successful future implementation of findings.

The Task Force recommends that the National Education Goals Panel be supplemented by an Education Council composed of senior education and science officials from the Executive Branch, Congress, and the states. The directors of OSTP and NSF, chairs and staff directors of relevant congressional committees, and leading state school officers should be included to provide a stronger capability for implementation of consensus strategies for math and science education.

To form those strategies, the views of federal, state, and local government on reform strategy and priorities should be periodically brought together with the views of the business community, teacher organizations, school boards, educational research experts, parents' groups, and many other groups deeply committed to the national reform effort. Therefore, **the Task Force further recommends that the Education Council convene a biennial National Conference on Educational Improvement sponsored by the Goals Panel or OERI. The conference would be organized to review the national strategy on math and science reform and the progress toward national math and science goals. The outcome of this biennial conference should be a public assessment of the pace of progress and the identification of needed changes in strategy.**

Closing Statement

This report suggests ways the federal government can accelerate educational progress in math and science in our schools. Precisely because the federal government has no operational responsibility for local schools, it is free to focus its investments on encouraging systemic change and providing new ideas, materials, teacher training and other resources that the states have great difficulty providing for themselves, with special attention to disadvantaged students.

To these ends, it is essential to rebuild the competence of the Department of Education, so that it earns the confidence of Congress and the public and gains more freedom to innovate. Equally important is increasing the commitment of the science-intensive federal agencies, which have access to the nation's scientific and engineering capabilities and the nation's universities. These capabilities, today the best in the world, are invaluable assets in the quest for world leadership in precollege mathematics and science achievement.

Is there reason to be optimistic about lifting the capabilities of American students to "first in the world" in the next decade? The current situation has more possibilities for dramatic progress than have been seen for many years. On the other hand, few areas of social development have more often seen hopes crushed and cynicism prevail.

The most likely path to failure, and ultimately to the destruction of the American dream, is not what happens in DoEd, NSF, or even the statehouses and school board offices. It is the complacency of too many American parents who are unaware that their children's future is at risk, the myopia of too many retired Americans who do not understand that poor schools threaten their safety and social security, and social conditions that result in too many children entering school unprepared. Most unfortunate is the tragic message our current system sends to young women, minorities, and the poor: you haven't the talent to master mathematics and science, so you shouldn't even try.

The one best hope for success is impassioned, persistent, nonpartisan leadership by every American able to make a contribution—but most importantly by the President. His crusade in the cause of education, if taken up by governors, congressional and other leaders, and by presidents who follow, can turn this situation around. We can once again be proud of our schools and confident that future generations of young Americans are equipped to lead the nation to new levels of greatness.

APPENDIX

Alternative Assignments of Federal Management Responsibility for K–12 Math and Science Education

The Task Force has recommended that both NSF and DoEd have essential and distinct responsibilities for K–12 math and science education. However, these responsibilities are strongly interdependent: neither agency will be successful in achieving the pace and depth of progress required to meet the national goals without the cooperation of the other. Thus, we have discussed how the agencies might organize to work cooperatively, for example, by establishing a Joint Office for Math and Science Improvement. Further, we call attention to the importance of oversight by OSTP and OMB, and note the usefulness of FCCSET and its Committee on Education and Human Resources to such oversight.

What are the alternative organizational arrangements for achieving the same end, and why were they not recommended? There are merits as well as disadvantages, in our view, in each of four other alternatives:

1. Assign lead responsibility for federal K–12 math and science education activities to OSTP or to a senior executive on FCCSET.

We have recommended that OSTP, operating through FCCSET's Committee on Education and Human Resources, coordinate the federal agencies and review their strategies. In theory, the chair of this committee could also be given lead responsibility, working through the committee, to engage the maximum number of federal agencies in the task in order both to engage their talents and spread the cost; and given that two agencies (NSF and DoEd) divide the math and science responsibility almost equally today, there is a case to be made for giving the balancing role to a third party. Indeed, the Secretary of Energy has shown himself to be an articulate and committed advocate for federal effectiveness in K–12 math and science education.

However, the Task Force feels that the primary responsibility should be on the shoulders of one or both of the principal operating agencies. Giving FCCSET responsibility for managing the math and science education strategy risks separating responsibility from accountability. Although CEHR has proven itself effective, it is a staff body, and its effectiveness depends too heavily on the leadership of the head of an agency for which education is not the primary mission.

2. Assign lead responsibility to DoEd.

The "cleanest" solution from a management perspective is to give DoEd the role of lead agency, with NSF expected to accommodate its math and science education activities to the strategies of DoEd, or—in the more extreme form of this option—to transfer NSF K–12 education activities to DoEd, as favored by one member of the Task Force.

During the past decade, few experts in education reform would have advocated this approach, for DoEd was widely regarded as ineffective and lacking in sufficient competence. Until recently, DoEd was generally unresponsive to initiatives taken by NSF to open up channels of cooperation. Few in the university educational research community would have preferred this choice, and today many state education officials prefer dealing with NSF rather than with DoEd.

Recent events support optimism that DoEd is to be rejuvenated. Its total budget swamps that of NSF; DoEd has much higher political visibility and leverage. Virtually every member of Congress cares about public schools; only a few have taken a deep interest in science.

However, organizational decisions today should reflect today's reality. DoEd, whose mission has been a matter of controversy almost from its inception,* has never had the opportunity to develop its capabilities. It has little capacity in math and science education beyond some experienced senior staff in the Office of Educational Research and Improvement and one or two other offices. Congress has not yet indicated its willingness to unleash DoEd as the agent for structural change in pre-college education, nor has DoEd shown how its internal capability is to be upgraded.

The Task Force hopes that DoEd will acquire the sophistication to take a leadership position in educational innovation and diffusion in math and science as well as in other fields. However, the importance of integrating the national strategy for math and science teaching into the strategy for national leadership in math and science research is so great that NSF will always be needed to play a major role.

* Within 18 months of its establishment, President Reagan came into office and recommended that the Department of Education be abolished. While this was not done, there were deep differences of view between the Reagan Administration and Congress over the mission and budget of this agency for the next eight years.

3. Assign lead responsibility to NSF.

Another possibility is that NSF be given the lead agency responsibility for math and science education improvement, with DoEd expected to accommodate its programs to NSF's strategy as they relate to math and science. This arrangement draws most directly on the statutory assignments of mission, and reflects the much greater strength of NSF staff in math and science than is found today in DoEd. Thus, recruitment of students and teachers, teacher training and retraining, curriculum development, and education research in mathematics and science would all be developed by NSF. NSF's launching of the Systemic Statewide Initiative indicates that NSF can indeed address systemic issues and can work with leaders in the states. DoEd would be a secondary player employed primarily for its diffusion capability.

Such an arrangement would require a major expansion of the NSF K–12 education budget, something that may not be acceptable to its research constituency, and implies that DoEd, a much bigger agency with far higher political visibility, would in fact follow NSF's lead. Neither prospect seems realistic. In any case, the larger job of systemic school reform clearly requires efforts outside mathematics and science, and should provide the context for NSF's focused effort on these subjects.

4. Create a Department of Education and Science.

There is a fourth alternative, although favored by almost no one in the U.S. scientific community. Many other industrialized democracies have Ministries of Education and Science, combining the functions that in the U.S. are assigned to NSF and the Department of Education. We do not recommend it for this country. The diversity of state-supported public and private universities is a major asset in the U.S., as is the competitive research support system from multiple federal sources. The independence of universities from federal control also facilitates institutional innovation, including cooperative relationships between university science and industry. There are also powerful reasons to believe that a Department of Education and Science would not be in the best interests of U.S. excellence in scientific research, a very important concern going beyond the scope of this report.

ENDNOTES

1. See, for example: U.S. Department of Education, *A Nation at Risk*, Washington, D.C., 1983; Commission on the Skills of the American Workforce, *America's Choice: High Skills or Low Wages*, National Center on Education and the Economy, 1990; Committee on Education and Human Resources, *By the Year 2000: First in the World*, Federal Coordinating Council for Science, Engineering, and Technology, February 1991.

2. A recent survey by the National Association of Independent Schools reports that three out of every four parents are satisfied with the public schools their children attend, and 45 percent say they would continue to send their children to public schools even if cost were not a concern: *USA Today*, Wednesday, July 24, 1991; p. 2D. See also Arthur Powell, Eleanor Farrar and David Cohen, *Shopping Mall High School*, Boston: Houghton Mifflin, 1985.

3. Based on continuation of present trends and the following sources: Children's Defense Fund, *Child Poverty in America*, Washington, D.C., June 1991, p. 2; Jeanne E. Griffith, Mary J. Frase, and John H. Ralph, "American Education: The Challenge of Change," *Population Bulletin*, Vol. 44, No. 4, December 1989, p. 10.; Joan M. First and John W. Carrera, *New Voices: Immigrant Students in U.S. Public Schools*, National Coalition of Advocates for Students, Boston, MA, 1988, p. 43, and National Center for Education Statistics, *Projections of Education Statistics to 2001, An Update*, U.S. Department of Education, Washington, D.C., December 1990, Table 1, p. 4.

4. Carnegie Task Force on Teaching as a Profession, *A Nation Prepared: Teachers for the 21st Century*, Carnegie Corporation of New York, 1986.

5. Among such studies are The National Science Board Commission on PreCollege Education in Mathematics, Science, and Technology, *Educating Americans for the 21st Century*, National Science Foundation, 1983; U.S. Department of Education, *A Nation at Risk*, Washington, D.C., 1983; Task Force on Teaching as a Profession, *A Nation Prepared: Teachers for the 21st Century*, Carnegie Forum on Education and the Economy, 1986; U.S. Congress Office of Technology Assessment, *Elementary and Secondary Education for Science and Engineering*, Washington, D.C., 1988; Corporate Task Force on Education, *Undereducated Uncompetitive USA*, Union Carbide Corporation, 1989; Quality Education for Minorities Project, *Education That Works: An Action Plan for the Education of Minorities*, Cambridge, 1990; Commission on the Skills of the American Workforce, *America's Choice: High Skills or Low Wages*, National Center on Education and the Economy, 1990.

6. J. A. Dossey, I. V. S. Mullis, M. M. Lindquist, and D. L. Chambers, *The Mathematics Report Card: Are We Measuring Up?* Princeton: Educational Testing Service, 1988.

7. Robert Langreth, *Science*, Vol. 251, 1991, p.1024.

8. Federal Coordinating Council for Science, Engineering, and Technology, Committee on Education and Human Resources, *By the Year 2000*, 1991, p. 40.

9. F. James Rutherford, *Reflections on the Federal Role in the Reform of Science Education*, Feb. 9, 1990, p. 1: an unpublished paper prepared for the Carnegie Commission on Science, Technology, and Government.

10. U.S. Department of Education, *A Nation at Risk*, Washington, D.C., 1983.

11. Task Force on Teaching as a Profession, *A Nation Prepared: Teachers for the 21st Century*, Carnegie Corporation of New York, 1986. This reform strategy emphasized increased qualifications, responsibility, and accountability for teachers and was adopted without dissent by the governors at the National Governors Association meeting of August 1986.

12. In 1981, upon assuming office, the President announced his intention to terminate the recently formed Department of Education, and the budget for NSF's Science Education Directorate was eliminated. Although the NSF Education Directorate was abolished, it was re-established a few years later, and the Department of Education suffered budget reductions but continued to exist.

13. Examples include systemic reform initiated by a number of governors; private reform initiatives in collaboration with cities, as in Chicago; creation of dozens of magnet and other special schools for mathematics and science; "school adoption" initiatives by private industry; peer mentoring programs for disadvantaged students; and the expansion of computer firms and not-for-profit institutions into new educational technologies.

14. The membership of the National Education Goals Panel includes—from the Administration, the White House Chief of Staff, the Director of the Office of Management and Budget, the Assistant to the President for Economic and Domestic Policy, and the Secretary of Education; from Congress, the Majority and Minority Leaders of the House and Senate; from the states, the governors of Colorado, Missouri, Indiana, Iowa, South Carolina, and Washington.

15. The ethnic mix in the country among children under eighteen changed between 1980 and 1987 from 51.0 million white, 9.3 million black, and 1.7 million Hispanic to 50.4 million, 9.5 million, and 2.6 million, respectively (Source: Department of Education, *The Condition of Education 1990*, Table 1:18-1). Minority populations have grown dramatically since 1987; by the year 2000, some states will have "majority minority" populations.

16. The Task Force suggests that, in addition to a dramatic reduction in school dropouts, especially among disadvantaged students, an attainable minimum goal can be expressed as follows: Ensure that the mathematics and science education preparation of all high school graduates will allow them to be successful in entry-level technical positions in the work force or to pursue successfully a quantitatively based field of study in college without the need for remedial assistance. Math and science preparation will enable graduates to fulfill their civic responsibilities with an understanding of the scientific dimensions of policies and decisions that affect our citizens and the world.

17. Richard F. Elmore, "Innovation in Education Policy," Conference on Fundamental Questions of Innovation, Governors Center, Duke University, May 3–5, 1991.

18. Federal Coordinating Council for Science, Engineering, and Technology, 8, p.6.

19. See The Business Roundtable, *Essential Components of a Successful Education System: The Business Roundtable Education Public Policy Agenda*, New York, 1990.

20. Federal Coordinating Council on Science, Engineering, and Technology, p.26.

21. James Rutherford, "Reflections on the Federal Role in the Reform of Science Education," Feb. 9, 1990, p. 6; prepared for the Carnegie Commission on Science, Technology, and Government; unpublished. "Top-down" refers to statewide or

national policies applicable to many schools; "bottom-up" to changes originating at the local level. "Inside-out" changes are created by teachers and others in the schools; "outside-in" changes originate outside the education system.

22. Robert Langreth, "School Science Surveyed," *Science*, Vol. 251, p. 102, March 1991.

23. There is ample evidence that differences in learning ability are related to the speed of learning rather than what can ultimately be learned. A given level of learning requires more effort on the part of some, but the capacity for learning is nowhere near saturated for even the least gifted in our society. See Herbert Walberg, "Educational Effectiveness: Psychological Problems and Possibilities," in *Issues in Science Education: Science Competence in a Social and Ecological Context*, Thorsten Husen and John Keeves (eds.), Pergamon Press, 1991.

24. For elaboration of this idea see Harvey Brooks, "Educating and Training the U.S. Workforce for the Twenty-first Century," in Dorothy Zinberg (ed.), *The Changing University*, NATO, 1991.

25. For an excellent discussion of this issue, see Richard F. Elmore and Susan Fuhrman. "The National Interest and the Federal Role in Education," *Publius: The Journal of Federalism*, Vol. 20, No. 3, pp. 149–162, 1990.

26. American Association for the Advancement of Science, *Research and Development FY 1991*, Washington, D.C., 1990, p. 78.

27. These programs were authorized to fund initiatives in virtually all school districts, to assure that services for special groups served them directly, and to fund and motivate local educators to deliver those services. Many of the largest programs also required evaluation at local, state, and federal levels; grants to enhance the abilities of state education agencies; and support for R&D programs to improve teaching, curricula, and materials for disadvantaged students. Paul Hill, *The Federal Role in Education: A Strategy for the 1990's*, National Center on Education and the Economy, Rochester, NY, 1989.

28. Sources: Office of Management and Budget, *Budget of the U.S. Government FY 1992*, p. IV–78; Federal Coordinating Council for Science, Engineering, and Technology, Committee on Education and Human Resources, *By the Year 2000: First in the World*, February 1991, p. 313.

29. $100 million goes to "informal education," or off-school-site education: museums, libraries, educational video and computer programs, etc.; $9 million is for evaluation and assessment of both formal and informal programs. FCCSET CEHR report, *By the Year 2000: First in the World*, February 1991.

30. The FCCSET CEHR report, [30], p. 313, states that FY 1991 direct federal investment in formal and informal science and math education in the schools was $515 million. Of this, $406 million was directed at school-based, in-classroom activity; this is only 3 percent of the $13.2 billion total school revenues received by public schools from the federal government in 1991. The informal (museums, television, laboratory extension, etc.) spending was $100 million, and, while not part of public school revenues, compares at only 1 percent of the total school revenues. The $13.2 billion figure is calculated from the federal share of education revenues to public schools (6.2 percent in 1989; U.S. Department of Education, *The Condition of Education 1991*, p. 86), and the total school revenues from all sources for 1990 ($213.3 billion; *ibid.*, p. 88).

31. The Task Force on Science, Technology, and Economic Performance of the Carnegie Commission on Science, Technology, and Government has addressed these issues in its report *Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base,* September 1991.

32. Since significant parts of the Chapter I, II, and III programs in DoEd do benefit math and science education (along with other disciplines), a more generous accounting might reach a little over $1 billion, but CEHR made the judgment that it was more appropriate to base the accounting on efforts specifically targeted to math and science education.

33. Office of Educational Research and Improvement, U.S. Department of Education, *The Condition of Education, 1990,* Vol. I, Elementary and Secondary Education, p. 168.

34. U.S. Department of Education, *Projection of Education Statistics to 2001,* December 1990; Table 37, p. 62.

35. For science and mathematics specifically, the $515 million 1991 budget for formal pre-college education, as determined by the FCCSET CEHR, includes $312 million (61 percent) for teacher preparation programs, $86 million (17 percent) for curriculum and materials development, and $42 million (8 percent) for student incentives and opportunities. However, this budget includes only $40 million (8 percent) for comprehensive reform programs and organizational and systemic change; $10 million (2 percent) for applications of technology to education; $9 million (2 percent) for program evaluation and assessment; and $5 million (1 percent) for diffusion of information and technical assistance. These categories are presented with the caution that they are the result of post hoc efforts of an interagency committee to categorize very different programs. The categories under which each program was created within each agency may have been different from those chosen here; similarly, a program may have the characteristics of more than one category applied by the interagency committee, or may not fall into any particular category.

36. Total 1991 R&D funding (not including spending on facilities) for all agencies was estimated at $65 billion; 10 percent of this is $6.5 billion. Total agency spending on math and science education at all levels in 1991 is estimated at $1.7 billion. Thus, the increment from such a program would be about $4.8 billion. Sources: American Association for the Advancement of Science, *AAAS Report IV: Research and Development FY 1992,* Washington, 1991, Table II-1, p. 135; Committee on Education and Human Resources, *By the Year 2000,* Federal Coordinating Council for Science, Engineering, and Technology, 1991, p. 313.

37. The National Geographic Society, for example, has established a Geographic Education Foundation which trains substantial numbers of teachers of geography, and supports geography education through television and other programs. The "Kidnet" interactive computer network program, funded by NSF, brings hands-on scientific skills to middle school students across the country.

38. The categories into which the CEHR allocated the federal agencies' current math and science education activities do not include an explicit category for "research." The agencies do engage in relatively modest amounts of applied educational research, which in the CEHR expenditure compilation is assigned to the most appropriate area of application. For example, where the research is associated with development of curriculum, it is included with development under the heading "pre-college curriculum materials." See *By the Year 2000,* [1], pp. 120, 283.

39. Estimate by Assistant Director for Education and Human Resources Luther Williams, May 25, 1991.

40. This concept is similar to the two-stage grants for research awarded by federal agencies under the Small Business Innovative Research program. After receiving initial support for research, and a subsequent showing of potential for commercialization, the grantee may receive a fivefold larger grant to take the work to the next stage of application.

41. U.S. Department of Education, *America 2000: An Education Strategy*, Washington, D.C., April 1991, p. 15.

42. Shirley Malcom, testimony to Senate Committee on Labor and Human Resources, 19 April 1990, p. 19.

43. *Project 2061*, a collaboration among NSF, the American Association for the Advancement of Science, Carnegie Corporation of New York, and others, represents a comprehensive effort to define an integrated and contemporary view of what adults should know about science, with the development of appropriate materials for use in K–12 schools. The NSF is also funding the *Scope, Sequence, and Coordination* project of the National Science Teachers Association, which is designed to teach a range of science courses every year starting in middle school, as opposed to the traditional "layer cake" approach, with one course per year starting in high school.

44. Interview with Glenn Seaborg, Chairman, Lawrence Hall of Science; June 6, 1991.

45. *By the Year 2000,* [1], p. 2.

46. *By the Year 2000,* [1], p. 16.

47. Vannevar Bush, *Science, the Endless Frontier*, submitted to President Truman, July 5, 1945, republished by the National Science Foundation, May 1980.

48. President's Scientific Research Board, *Science and Public Policy: Administration for Research*, 3 vols. Washington DC: Government Printing Office, Vol. 1, p. 26, 1947.

49. Walter Massey, presentation to the Task Force on K–12 Mathematics and Science Education of the Carnegie Commission on Science, Technology, and Government, March 25, 1991.

50. The current FCCSET Committee on Education and Human Resources is not a substitute for this. It is a device for reporting to the President through his science adviser, and it is concerned with missions and resource allocation, not with operations. Further, it covers the activities of too many agencies in addition to NSF and DoEd.

51. Since it is only through a joint decision by the two agency heads that a stable balance can be struck between collaboration in shared responsibilities and coordinated but separate activities, it is essential that the director of the Joint Office have direct access to the two principals in the event there are disagreements between the two agencies. However, the director must operate collegially with the key officials of each agency: the Assistant Director of NSF for Education and Human Resources and, presumably, the assistant secretary responsible for OERI of the Department of Education. A management device to ensure their active involvement in the work of the Joint Office will have to be created by the two principals.

GLOSSARY OF ACRONYMS

AAAS	American Association for the Advancement of Science
CEHR	Committee on Education and Human Resources, FCCSET
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DoEd	Department of Education
DoI	Department of the Interior
DoL	Department of Labor
DPC	Domestic Policy Council
EHR	Directorate for Education and Human Resources, NSF
EOP	Executive Office of the President
EPA	Environmental Protection Agency
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
FFRDC	Federally Funded Research and Development Center
FICE	Federal Interagency Committee on Education, EOP
HEW	Department of Health, Education, and Welfare, now HHS
HHS	Department of Health and Human Services
NAGB	National Assessment Governing Board
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NIMH	National Institute of Mental Health
NREN	National Research and Education Network
NSF	National Science Foundation
NSTA	National Science Teachers Association
OERI	Office of Educational Research and Improvement, DoEd
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy, EOP
SCANS	Secretary's Commission on Achieving Necessary Skills, DoL
SSC	Scope, Sequence, and Coordination program, NSTA
SSI	Statewide Systemic Initiatives program, NSF
USDA	U.S. Department of Agriculture

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