EXPANDING THE INSTITUTIONS OF SCIENCE

A Speech by Bruce Alberts, President
National Academy of Sciences
Presented at the Academy's 138th Annual Meeting
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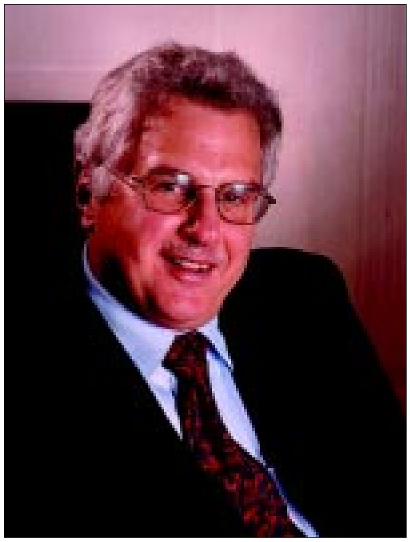
We scientists certainly live in exciting times. I don't have to convince this audience that the many innovations derived each year from science provide the key to our continued economic prosperity, to our national defense, and to improving the health of both our people and our environment. They are also critical for maintaining America's respected position as a leader of the world of nations. According to a study we did at the request of the secretary of state, America's unparalleled capabilities in science, technology, and health are among the nation's strongest assets. These strengths can provide support for the implementation of a foreign policy that will contribute to the creation of a more secure, prosperous, and democratic world for the benefit of the American people (*The Pervasive Role of Science, Technology, and Health in Foreign Policy*, NRC, 1999).

Although such conclusions are obvious to us, we cannot take these truths to be self-evident to others. Making the connection between the vitality of our nation and a vigorous, merit-based federal investment in *all* areas of science and technology requires an ongoing effort in public education that engages the entire scientific community — whether in academia, industry, or government. And each time that a new administration arrives in Washington, we must work extra hard to explain the central importance of the publicly supported U.S. scientific enterprise to the executive branch and to Congress.

A good sign is the adoption this year by the Office of Management and Budget (OMB) of several central recommendations of our 1995 report *Allocating Federal Funds for Science and Technology*, an effort chaired by Frank Press. For the first time, OMB has presented its breakdown of the president's budget in terms of the total investment in generating new knowledge — the so-called "FS&T budget" that was recommended by the Press committee. Simultaneously, OMB has also picked up that report's emphasis on the importance of allocating resources through a competitive merit review process. We will, of



Bruce Alberts, president, National Academy of Sciences

course, need to keep reminding OMB and the Congress of another key recommendation in the report: the importance of sustaining a broad portfolio of scientific research across all federal agencies.

I am often asked about the impact of the many different reports that we produce each year. It is clear from many examples like the Press study — or our recent report on arsenic that is currently in the news — that our work does have tremendous impact. Even though one may need to wait five or even ten years for our advice to take full effect, what we do is critical for the nation's future.

As I speak, we are in the midst of important studies on a wide range of controversial issues — some undertaken with our own limited funds. Examples of topics include stem cells, human cloning, global warming, Internet privacy, energy policies, and how the National Institutes of Health is organized to conduct research.

During my term as president, I have had the privilege of being educated by the 1,000 staff and 6,000 volunteers working each year for our operating arm — the National Research Council. As you will see, many of their reports have provided new insights into critical issues, and they have played a major part in reshaping my own thinking about the potential role of science in the United States and the world. I would like to share some of this thinking with you today.

Strengthening the National Academies

Let me start by talking about our own organization, the National Academy of Sciences. We all have a strong tendency to take institutions like ours for granted, as if they arise naturally — without effort. Personally, I can remember being amazed as a college freshman to discover the key role that strong institutions play in shaping society. Only when we were assigned some scholarly writings on institutions did I realize that it is not enough to have a large number of talented, well-meaning individuals working to improve a community or a nation. These individuals need an institution that allows them to work together effectively toward a common goal.

For nearly eight years now, we have been working to strengthen our institution, the National Academies — the name we now use for the combination of the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council. In particular, we are renewing our emphasis on making the National Academies a learning organization — that is, an institution that continually improves by analyzing its successes and failures and incorporates this self-knowledge into training programs for its staff and volunteers.

In the remainder of my talk, I would like to share some thoughts with you on three fundamental questions that we have been asking ourselves as an institution. In each of the three areas to be discussed, the Academies are seriously contemplating some new endeavors — approaching them as a scientist would: by designing experiments that involve taking risks, and honestly evaluating the results before proceeding further.

The three questions are:

1. How can what we have learned in developing the National Academies be used to establish new institutions that serve to strengthen science and spread its benefits throughout society?

2. How can the National Academies take advantage of the computer and telecommunications revolution to spread the rich store of knowledge and know-how derived from our thousands of studies?

3. How can the National Academies make a science out of education to increase the capabilities of all people — while, at the same time, supporting teachers and creating a society more understanding of science, its goals, and its conclusions?

I shall start by addressing question number one.

Creating new institutions

Last year, I briefly described to you the promise of a new international organization, called the InterAcademy Council (IAC), that would be focused on providing scientific advice to the world. I am very pleased to announce that the IAC now exists, having been founded by the world's scientific Academies in the Netherlands last October. It is directed by a board composed of 15 Academy presidents, representing the nations shown in Figure 1. This group of presidents had its first meeting in January, and we are about to embark on our first study. I have the privilege of being a co-chair of this organization for its first five years — together with the president of the Indian National Science Academy, Dr. Goverdhan Mehta.

In general, the IAC will respond to requests from other institutions — such as the United Nations or the World Bank — for advice on important issues, just as the National Academies respond to requests from the U.S. government. The IAC's first study is focused on increasing science and technology capacities around the world. Other examples of the kinds of global issues that might be explored include intellectual property rights in modern biology, assuring the safety of genetically modified foods, or world standards for science and math education in the 21st century.

I want to emphasize that the IAC is intended to fill gaps in the current armory of international science advice on important issues. Of course, many types of advice are already handled well by the International Council for Science (ICSU) or by intergovernmental mechanisms.

The 15 Science Academy Presidents who will Govern the InterAcademy Council (IAC)

Academy	Population
China	1,240,000,000
India	1,000,000,000
United States	272,000,000
Brazil	171,000,000
Russia	146,000,000
Japan	126,000,000
Mexico	100,000,000
Germany	82,000,000
United Kingdom	59,100,000
France	58,900,000
South Africa	43,400,000
Malaysia	21,300,000
Sweden	8,910,000
Israel	5,740,000
Third World Academy of Sciences	—

Secretariat at the Netherlands Academy, Amsterdam

FIGURE 1

The IAC has been designed as a flexible 21st-century institution, based on electronic communications, with only a very small secretariat. By a vote of any 10 of its 15 presidents, the IAC Board will approve of task statements for projects, establish a balanced, expert international committee to carry out a study, and certify that each written report has satisfied an anonymous peer-review process before it is publicly released. All of this should sound quite familiar to you, because these procedures are very similar to those that we have worked out over the years for our own National Research Council.

On the home front, the National Academies have also been wondering if what we know can be made more useful at the state level. As more responsibilities are transferred to the states from the federal government, it has become increasingly evident that having an organization similar to the National Research Council in many of our 50 states could be of considerable value.

This is, of course, not a new idea. In fact, a few state organizations of this type already exist. Consider, for example, the California Council on Science and Technology. But those state organizations that exist are still struggling to gain the kind of respect from their state governments that we enjoy from the federal government. Should the National Academies experiment with a few state-level alliances, aimed at using our resources to increase the effectiveness of these state analogs? Thus far, I have spoken with one experienced governor who believes that such an effort would be worthwhile. I welcome suggestions from our members concerning which states — and which organizations within those states — might be ready for such an experiment.

Increasing the benefits of science for the world

My second question concerns expanding the usefulness and impact of the information in the thousands of reports issued from the National Academies. Our Web site at <national-academies.org> now links to the full text of more than 2,000 of our reports. These reports, totaling more than 400,000 pages, answer questions posed by our government on topics that range from the risks of toxic chemicals, to ecosystem preservation, to preventive medicine, to providing and maintaining safe drinking-water supplies. It has become a cliché to state that, in today's world, knowledge and know-how will determine the health and wealth of nations. For this reason, I strongly suspect that a large fraction of the information on our Web site would be useful to people across the globe.

In principle, anyone connected to the Web anywhere can read everything we have written for free. But, in this age of information overload, we will need to make the material in our reports much more accessible if some of our potential audiences are to use it. We finally found the finances this year to convert all of our posted reports to the markup language called XML. This conversion will enable us to present Web pages, build collections, or extract data to meet specific needs more easily. Consider, for example, the 80 or so reports that we have posted on the Web on various water issues. Most of these reports have been written for U.S. policymakers, but they also contain important advice for many others. How could we rearrange and aggregate this material in ways that would make it valuable to those working on water issues with women's organizations in Africa, for instance, or to the water departments of governments around the world?

After struggling with a way to approach this problem, we have come to realize that — if we are to be successful in spreading our scientific and technical knowledge throughout the world — we need to think much more like a successful modern corporation in identifying and respecting our "customers." In other words, we need to do intensive market research, in which we interact closely with those who might be able to use our knowledge and attempt to meet their needs. Ten years ago, this type of research would have required a major investment in "traveling agents" of the National Academies. Now, the new interconnected world of the Internet easily facilitates consultation with those who might benefit from our work. But it would constitute a major change — both in practical terms and philosophically — for us to make a serious commitment to a continual repackaging of information on our Web site, in response to the needs of potential users.

How might we do this? Two years ago I described my visit to India, where I first became aware of innovative efforts to use the Internet to bring scientific knowledge to bear on improving the quality of life in impoverished communities. At that time, I inaugurated one of the "Information Villages" created by foreign associate M.S. Swaminathan, near Chennai. Early this year, I revisited the same village to receive a progress report from the local women who had been operating the computers that connect their farming village to a regional wireless Internet network. In this village, some 1,000 people had learned to use the computers, including many children. In particular, the women had clearly been empowered, and they enthusiastically reported how their sudden access to information about crops, weather, market prices, and government programs had improved the life of the village. This information had already saved lives in a nearby village where data from a U.S. Navy weather Web site is used to alert fishermen of impending high seas; in other villages not connected to the network, the fishing boats went to sea in a developing typhoon and met disaster.

It is straightforward to envision a not-too-distant future where all of the world's scientists are connected to the World Wide Web. This network represents, however, only the top level in the global knowledge system illustrated in Figure 2. If science is to become a major force for good around the globe, it

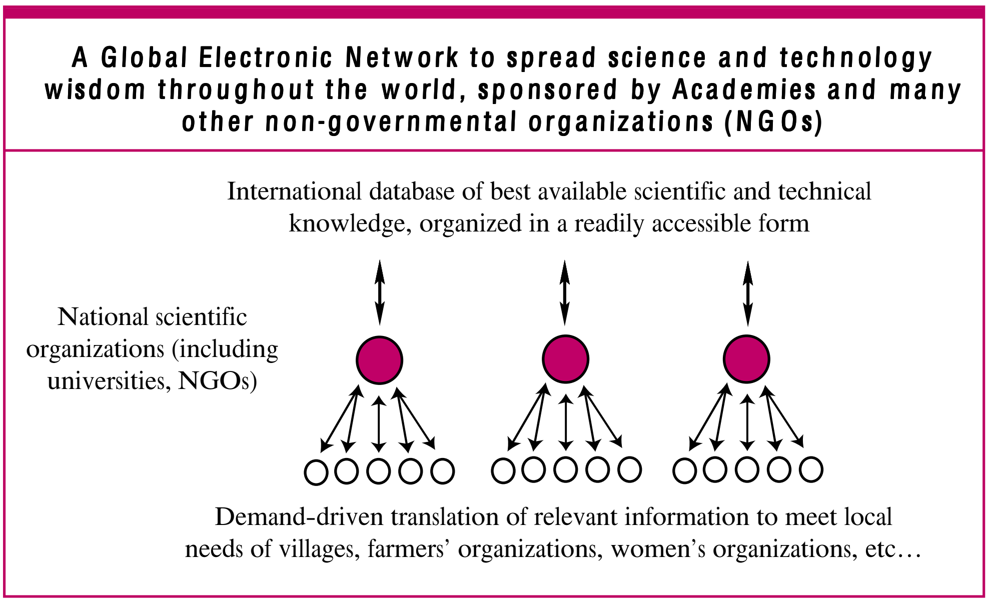


FIGURE 2

must reach more than just scientists and professional elites. Reaching the rest of the people in the world will require a second level of "adapter organizations" — the local universities, governments, clinics, and nongovernmental organizations — which understand and are in direct contact with the most needy citizens in their societies. One of these organizations is the one I visited, the M.S. Swaminathan Foundation, which translates selected information gleaned from the Internet into the local language in a readily accessible form.

Who are our customers? Our direct customers are not likely to be the farmers or fishermen. Instead, we should be reaching the many adapter organizations that are in touch with the needs of their local populations. One of our goals for the coming year is to carry out an experiment with a small subset of these groups. Through Internet feedback from them, we will attempt to create a new section of our Web site that is useful to these organizations, and thereby useful to the millions of people they are trying to serve.

A second, very different set of potential "customers" for us are the many high school and college students who use Web resources to write reports on various aspects of environmental science and science policy. Their needs are, of course, much different than those of rural villagers, and perhaps more easily recognized by those of us in Washington. Even so, I strongly suspect that we would benefit from developing a second customer network, in which a select group of teachers tells us what parts of our many reports are most useful to them. In this way, we could hope to make our Web site a major information source for students.

As with all experiments, it will be critical to approach any project we undertake with care. We must also be willing to accept the risk of failure. Perhaps the bulk of our reports, written largely for government scientists and bureaucrats, cannot be made truly useful for a different set of customers. But we certainly should try a few experiments to see if we have been missing a great opportunity.

Making a science out of education

Those of you who remember why I agreed to become president of the National Academy of Sciences in 1993 will not be surprised that my third question concerns education. As befits the Academy, we have two major projects under way that deal directly with education as a science. In one of these, a distinguished committee composed of a diverse mix of scientists has been trying to answer the following question, posed to us by the government: What constitutes good scientific evidence in education research? Is the only way to reach valid conclusions through randomized, double-blind trials? If not, what types of controls suffice?

In a parallel effort, a second committee is deeply involved in an intensive effort to test whether our nation is ready to support a set of vigorous education research networks. Here, a large group of researchers would be recruited to work together, often in school settings, to address a particular high-priority question. The first phase of this effort produced a report (Figure 3) that proposed such a strategic education research partnership, or SERP. Two of the four questions that were recommended for focused research are: How can we increase students' motivation to learn? And how do we incorporate what we know about how people learn to create more effective teaching and learning in our schools?

In attempting to make a science out of education, we have a long way to go. But I am happy to report that we already have had some terrific successes. One of these successes was a major report on reading published several years ago, which tried to settle the well-known battle between phonics and whole language advocates. This report, titled *Preventing Reading Difficulties in Young Children*, was praised on the front page of the *New York Times* as the report that should "end the reading wars." From it, we produced a popular version for parents and caregivers, called *Starting Out Right*, that has sold about 120,000 copies. Very recently, the Mexican government has produced a Spanish translation, which we hope will be equally successful.

The effect of our reading report led the U.S. Department of Education to ask us to attempt the same thing for mathematics. As those of you from California will know, the recent math wars have been nearly as fierce as those that occurred earlier in reading. Our math committee contained proponents on both sides, and it included three members of the National Academy of Sciences. Their major consensus report, called *Adding It Up*, was released only a few months ago. We have high hopes that this report will calm the math education debates, so that our nation can move forward with the critical task of providing children with a much higher quality of math education than they are receiving today.

Perhaps the hottest issue in the current education debate concerns high-stakes exams. Everyone today, including our corporate executives, our 50 state governors, and President Bush, are quite rightly demanding accountability on the part of our school systems. This has led to an increased emphasis on student testing as a way of evaluating not only students, but also teachers and schools. In general, such high-stakes assessments will drive teaching to match the tests. It is therefore absolutely critical that we test for what we really want students to know.

Our just-released major report on the subject, called *Knowing What Students Know: The Science and Design of Educational Assessments*, has been three years in the making. The report concludes that, because of computer and telecommunications technologies, there is a real hope that assessment practices can change to emphasize the more complex and important aspects of student learning. As someone who has worried about the difficulty of assessing what we really want students to know and be able to do in science, I am encouraged by this report. At the same time,

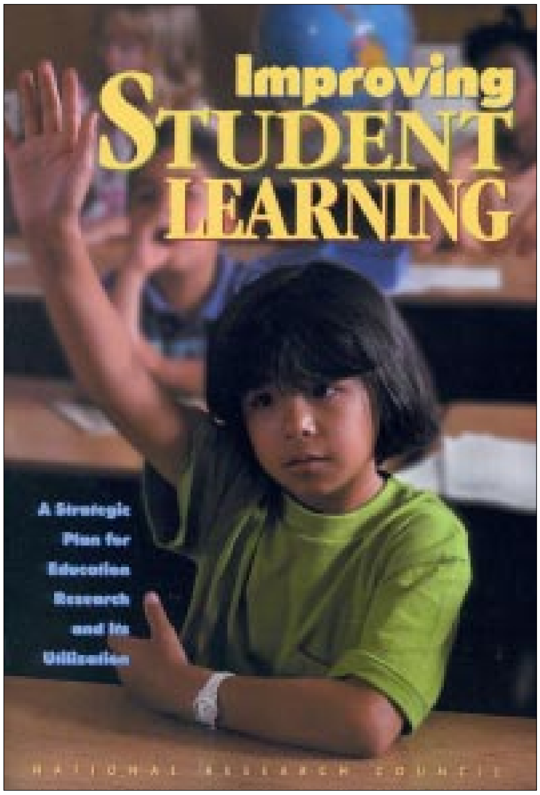


FIGURE 3

the report emphasizes that now is the time for a greatly intensified, well-focused investment in modern test development, something that our nation currently lacks. Perhaps one of the proposed SERP research networks can be directed to this critical issue.

Changing the nature of science education

Our Academy has a very special role in defining and promoting good science education. Our major report, the *National Science Education Standards* (Figure 4), has given the nation a roadmap for a revolutionary change in the nature and extent of science teaching in our schools. Our partnership with the American Association for the Advancement of Science (AAAS) in this endeavor has helped to create a strong consensus movement, focused on providing a new type of science education for all Americans.

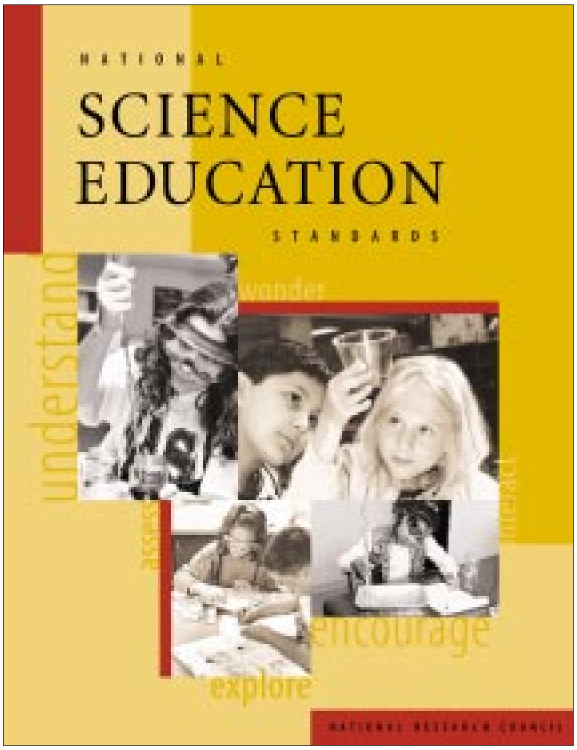


FIGURE 4

The Standards call for science to be taught to all students in the form of "science as inquiry." In this form of science teaching, students are encouraged to struggle with a problem and to discuss it with their classmates before being told the answer. The emphasis is on using evidence to make logical arguments, which requires the development of both analytical and communication skills. The aim is not to "cover the material," but to empower students with the abilities they will need to be able to learn on their own. These are not simply the skills that one needs to become a scientist or engineer. In our complex society, these are skills that everyone needs in order to become an effective citizen — and/or a productive employee in today's ever-changing world of work.

In this view, science education becomes a centerpiece in everyone's education, fully equal in importance to reading, writing, and mathematics. To quote from experts on workforce issues:

> While most descriptions of necessary skills for children do not list 'learning to learn,' this should be the capstone skill upon which all others depend. Memorized facts, which are the basis for most testing done in schools today, are of little use in the age in which information is doubling every two or three years. We have expert systems in computers and the Internet that can provide the facts we need when we need them. Our work force needs to utilize facts to assist in developing solutions to problems.
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> *Robert Galvin and Edward Bales, Motorola, 1996*

I must admit that many of us who worked on the National Science Education Standards have been frustrated by the relatively slow pace of change in our schools. Surveys show that the vast majority of K–12 science teaching today — perhaps 90 percent — continues to be carried out through textbooks that seem to encourage the rote memorization of information. In fact, a recent evaluation of both middle school and high school biology textbooks, carried out by Project 2061 of the AAAS, found great deficiencies in all of them.

As someone who writes textbooks at the college level, I sympathize with anyone who tries to write a high school or middle school textbook. Because of the nature of the commercial textbook market, one is forced to include a huge amount of knowledge in far too few pages. This leads to textbooks that are "a mile wide and an inch deep" — a terrible characteristic of U.S. science texts that stands out dramatically in the international comparisons of the Third International Mathematics and Science Study.

What can the Academy do about this serious issue? In 1985 we established a partnership with the Smithsonian Institution called the National Science Resources Center to produce a different kind of science curricula. Over the course of its first 10 years, the center produced 24 elementary science kits that emphasize hands-on, inquiry-based science for children. More recently, the center has begun to produce similar curriculum materials for middle schools (Figure 5). Curriculum materials of comparable quality are also being generated by the Lawrence Hall of Science in Berkeley, California, as well as by a few other groups. But all in all, we estimate that this kind of science is being taught today to no more than 10 percent of American students.

To further liberate teachers from their one-size-fits-all science textbooks, we have been speculating about a way in which the World Wide Web could serve as a rich resource for supporting our nation's science teachers. In principle, one can visualize a very different world in which a large set of outstanding text-based curriculum modules are available for free on the Web, each being continuously improved by an open-source process. In conceptualizing how such a system might be developed, a small group of Academy members consulted with outstanding teachers at a special workshop last summer. We have generated some promising ideas, but this is still very much a work in progress.

It is important to emphasize that there are major problems that extend beyond the curriculum. We now recognize that most Ameri-

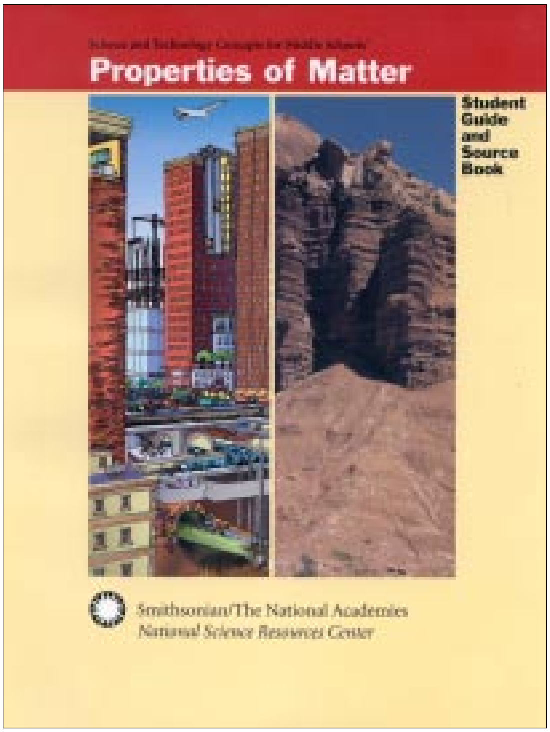

FIGURE 5

can teachers have never experienced scientific inquiry themselves, which makes it nearly impossible for them to change their way of teaching without a major investment in further professional development. Somehow, we need to do a much better job of developing, showcasing, and replicating outstanding examples of science teaching using inquiry at the college level, focusing on courses designed to serve large numbers of students. This continues to be an important task for the Academies.

As emphasized in the recent report of a national commission that I served on, chaired by Senator John Glenn, everything that we want to accomplish in U.S. education today depends on recruiting, retaining, and supporting large numbers of outstanding teachers. We need to recruit many more scientifically

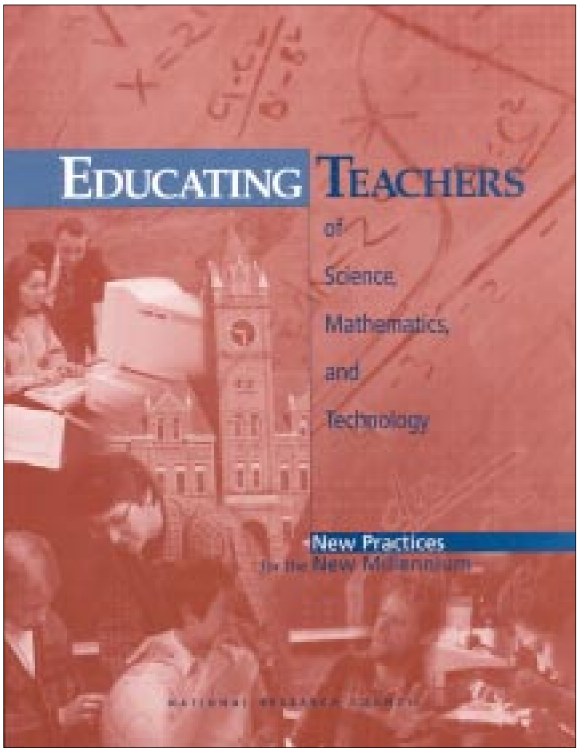

FIGURE 6

trained people into teaching careers. To do so, our introductory college courses must incorporate inquiry, so as to excite many more young people about both science and science teaching. And we absolutely must raise teachers' salaries. Today's beginning teachers earn an average of only $26,000 per year, and work an average of 49 hours a week. In fact, the standard of living for U.S. teachers is at its lowest level in four decades. This is an appalling situation for a wealthy nation that says it wants to make education its number one priority.

Some of the actions that need to be taken are in our direct control. This past year, the Academies issued a major report titled *Educating Teachers of Science, Mathematics, and Technology* (Figure 6). This report emphasizes a critical need for close partnerships between school districts and institutions of higher education, and it urges our faculty colleagues to share in the responsibility for both science and math teacher preparation and the ongoing professional development of teachers.

There are nearly 17,000 school districts in our nation. Over the next 10 years, their middle and high schools will need to hire an estimated 170,000 new science and math teachers. Therefore the partnerships we need between colleges and school districts must involve all kinds of higher education institutions — from community colleges to research universities. Traditionally, the science and mathematics departments of our major universities have felt that the education and support of precollege teachers is a problem for somebody else to solve. But business as usual has left the United States with boring, fact-laden textbooks. And it certainly helps to explain why so many of our young people have a tragic distaste for science, as well as for science and engineering careers.

How can it be that the nation that leads the world in science and technology still graduates a high school class that, in international comparisons, ranks very near the bottom in science and mathematics accomplishments? How can it be that the United States ranks 15 out of 17 among major nations in the proportion of national income devoted to teachers' salaries? It is time to admit that a great deal of the problem lies with those of us in higher education and industry. We can continue our isolation from everything at the precollege level — including even the most heroic science and math teachers in our neighboring school districts. But this detachment will guarantee that science teachers remain unsupported by our strong scientific community, largely invisible to the power structure, and badly underpaid.

In ending, I return to where I began — to the critical importance of institutions in general, and of the National Academy of Sciences specifically. Our institution has earned the great respect and importance it enjoys because of a record of providing high-quality, unbiased science and technology advice to the U.S. government for more than 100 years. Adding to this reputation are your own reputations as the nation's 2,000 most outstanding scientists. Our collective and individual prestige will be wasted if we do not try to make a difference in every way that we can: to the world, through the InterAcademy Council and our interactions with the 76 other Academies around the globe; and to our nation, not only through policy advice, but also by lending the full weight of our reputations — both individual and institutional — to the major changes needed in both science education and education research.

As emphasized by the great British statesman Benjamin Disraeli, "Individuals may form communities, but it is institutions alone that can create a nation." We will need your help, and that of the many universities and organizations you represent, to meet today's greatest challenge: the unprecedented new opportunities we now have to spread the benefits of science throughout the nation and the world.

NOTE: The text of this speech, with direct links to cited reports, is available on the Academy's Web site at <national-academies.org/nas/2001address>.