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The following article is an edited transcript of Dr. Schwartz's remarks to the annual meeting of the Minnesota Academy of Science in April 1988.

Introduction

In 1983 the National Commission on Excellence in Education (1) issued its report which identified America as a nation "at risk." Five years later the nation is still at risk. A number of recent surveys, many of them funded by the National Science Foundation (NSF), clearly indicate that the problems are particularly acute in science and mathematics education. I will summarize the nature and magnitude of some of these problems, describe the role of NSF in funding various efforts to address these problems and suggest ways in which members of the Minnesota Academy of Science can personally participate in improving science education in this country.

The Crisis in Science Education

The national needs are staggering. Jon Miller of Northern Illinois University has concluded, on the basis of extensive surveys, that 95% of Americans are "scientifically illiterate." By this he means that they cannot define or explain terms like "molecule" or "DNA." Moreover, many of our fellow citizens—some of them in high places—believe in astrology or a literal six-day creation. There is little wonder that this is the case, because only 33 percent of American high school students take chemistry, 17 percent take physics, and 3 percent take calculus. In the Soviet Union, the corresponding percentages are all 100.

Compared to children in other developed and developing countries our own children perform at an abysmally and embarrassingly low level. Unfortunately, some of the most incriminating evidence comes from Minnesota. Harold W. Stevenson, Shin-Ying Lee, and James W. Stigler recently published a study entitled "Mathematics Achievement of Chinese, Japanese and American Children (2)." The American children came from Minneapolis—a city chosen because of its cultural, ethnic, and racial homogeneity. Compared to other American cities, Minneapolis has few non-native English speakers in the school system, and its families enjoy relatively high socioeconomic status. By these criteria Minneapolis should have one of the best school systems in the nation. Indeed, in Minnesota we are proud of the quality of our state's education system. However, when Minneapolis students were compared with children from Sendai, Japan, and Taipai, Taiwan, they did not fare well. Identical tests were administered at the kindergarten, first grade and fifth grade levels. Our children started out slightly below Japanese children at the kindergarten level. By the first grade that gap had widened considerably and by the fifth, it was so wide that the average score of the highest ranked American class was below that of the Japanese class with the lowest ranking. The disparity becomes even greater at higher grades. The upper one percent of American 12th grade mathematics students perform at about the average level of Japanese high school students in advanced courses (3). Clearly there is something seriously wrong!

Another recent study (4) assessed the science achievement of students in a diverse group of countries. American ten-year olds ranked eighth when compared with similarly aged students from fourteen other nations. Our fourteen-year olds, in grades eight and nine, ranked fourteenth out of seventeen countries. Our twelfth grade science students who have had at least two years of chemistry, physics, or biology—in other words, our very best students—ranked thirteenth in biology, eleventh in chemistry, and ninth in physics out of thirteen nations. The performance of students from other countries reveal some interesting insights into educational systems, priorities, and values. Ten and fourteen-year olds do particularly well in Japan. Twelfth graders excel in England and in Hong Kong, perhaps reflecting the fact that the limited number of students who continue their education to that point already start to specialize. What I find particularly troubling about these results is the fact that the scores of American students range widely. There are some who score very well and many who score very poorly. This kind of extreme dichotomy is characteristic of a developing or third world country, where an elite few enjoy excellent education and the great majority receives inadequate training. The sobering implication is that our democratic ideal of a quality education for all has failed miserably.

A number of hypotheses have been advanced to account for these disgraceful statistics. No doubt, one of the problems is curricular. While French seventh graders are learning geometry and Japanese seventh graders are studying algebra, American seventh graders are doing long division for the fifth year. For all their paper and pencil drill, American students are worse at long division and other simple computations than students from other countries. Stimulated by such observations, the Mathematical Sciences Education Board, funded by the National Science Foundation, has launched a program to study mathematics education at all levels—kindergarten through college. Project 2061 of the American Association for the Advancement of Science is trying to do the same thing for science education at the precollege level, and the AAAS Project on Liberal Education and Science is addressing the college and university years. Unfortunately, these are massive and complex undertakings, and I am not terribly sanguine about their changes for success. Ultimately, curricular reform must originate in the classroom, not the committee room.

There is ample evidence that curriculum is not the only problem. Stevenson and his coworkers—the team that studied the Minneapolis, Sendai, and Taipai schools—emphasize the international differences in teaching style and in parent and student attitudes. Students in Oriental classrooms are better organized, better disciplined, and spend more time on task. An important factor is not just the number of hours spent in school, but the way in which those hours are spent, for example, the amount of time the teacher is engaged in a teaching mode. Children in Japan and Taiwan do much more homework than their American counterparts, and say they enjoy doing it.

Differences in attitude become apparent when mothers are asked to identify the most important factors leading to success in the study of mathematics. American mothers most frequently select "natural ability;" Japanese mothers give greatest weight to "hard work." In spite of the statistics just cited Japanese mothers are severe critics of their children's achievements and the effectiveness of the educational system. American mothers are more likely to be satisfied with the performance of their children and the quality of instruction. It would seem that the admirable American tendency to look on the bright side is simply national self-delusion. Furthermore, our work ethic appears to have disappeared with Horatio Alger novels. It may be revealing that mothers and not fathers were questioned in this survey because Japanese fathers were at work until late in the evening.

One can facetiously argue that time is on our side. The good news is that if we wait long enough, the American Way may ultimately triumph. After about three generations in the United States, Asian-Americans do not perform any better than the rest of us. Perhaps if we keep exporting Coca-Cola, golf, baseball, televison, and other examples of Americaan know-how to Japan, we may not only improve the balance of payments, but also induce the rapid intellectual Americanization of the Japanese people. This is sure to restore economic and productive parity.

The economic argument that I have just ridiculed is one of two popular justifications for supporting technical education. The other is the military preparedness argument. Both play pretty well in Washington. They may even be true. The United States will experience an estimated shortfall of 692,000 bachelor level scientists between now and the year 2011, if our rate of productivity remains constant at the 1983 level of 4.8% of 22-year olds. As it is, we are growing more and more dependent upon other nations to provide us with scientific and engineering personnel.

Pragmatic arguments can be persuasive, but I am old-fashioned enough to think that there are better reasons for supporting science education than its impact on a healthy GNP or a reliable SDI. Scientific literacy is a rather important commodity in a democracy and a technical age. Moreover, it is of great intrinsic worth. A study of science can encourage and reward curiosity; reveal and illuminate the beauties of nature; develop insight and imagination; promote tolerance for ambiguity; create a willingness to take intellectual risks; help discriminate between signal and noise; enable young people to learn for and by themselves; demonstrate the benefits of hard work; and develop a sense of responsibility.

I have already mentioned some of the barriers to realizing these benefits. To that list I could add an insufficient number of adequately prepared teachers, poor working conditions and inadequate compensation for teachers, outmoded curricula, poorly equipped laboratories, a widespread lack of understanding—often fear—of science, student hostility, parental indifference, and the anti-intellectualism of society. Indeed, the American public may have a better education system than it deserves, given the low priority it places on education.

When one realizes that there are 40 million students in 16,000 school systems across this country, the enormity of the problem becomes mind-boggling. It has been estimated that by 1992, more than 200,000 college graduates—23 percent of the graduating class—will have to go into teaching each year just to fill the vacancies. Faced with problems of this magnitude, what can any individual, any state science organization, or even the Federal government possibly hope to do? Obviously there are no easy answers. But I can describe some things that have already been done, make some suggestions about what each of us might be able to accomplish, and ask your support in trying to achieve some of these goals.

The Role of the National Science Foundation

I am going to focus on the National Science Foundation because it is the major Federal force in science education and an agency I know firsthand. NSF was established as an independent agency by President Harry Truman in 1952. A major impetus for its creation was a book by Vannevar Bush entitled "Science: the Endless Frontier." Bush was an MIT engineer who played an important role in the application of science and technology during World War II. The policy-making body of the National Science Foundation is the National Science Board, a group of very distinguished scientists; the chief administrator of the agency is its director, currently Erich Bloch, a former IBM engineer.

The major function of NSF is to support research and education in science, mathematics, and engineering and to exert national leadership in these areas. Funding for these activities is provided by Congressional appropriation. Although "government efficiency" may be an oxymoron, the operating expenses of the Foundation represent only about 5 percent of its total budget. The remaining 95 percent is invested in projects proposed by investigators and judged meritorious and worthy of support by peer reviewers and staff. Program officers negotiate the details of the grant and often make useful suggestions for improving the project. The staff of about one thousand is a mixture of permanent civil service employees and "rotators" on temporary assignment.

Figure 1 is the NSF organization chart. The majority of the eight directorates are discipline-based and chiefly involved with the support of fundamental research. These research directorates indirectly fund graduate education through grants for research assistants, but the Directorate for Science and Engineering Education (SEE) directly supports science education at all levels and in all disciplines.

Money is the stuff that fuels the Foundation, and Table 1 summarizes some recent budgetary history. The activities identified in the five rows are separate authorization and appropriation line items in the NSF budget. Note that one of these is Science and Engineering Education. The fact that SEE has a separate budget line gives it special visibility and provides Congresss the opportunity to exert direct control over its funding.

The numbers in the table make it clear that Congress does indeed get involved. In fiscal 1987, NSF had $1,623 million to invest. Of this total, $99 million (6.1%) was earmarked for the Education Directorate. The budget request for fiscal 1988, as prepared by the Office of Management and Budget and proposed by the Administration, called for a 16.3 percent overall increase, with a similar percentage increase for SEE. However, Congress increased the total NSF appropriation by only 5.5 percent to $1,717 million—$176 million less than the proposed budget. By contrast, the appropriation for the Directorate for Science and Engineering education went from $99 million to $139 million, an increase of 40.7 percent instead of the requested 16.2 percent raise. For fiscal 89, the appropriation for SEE increased by $32 million (23 percent), again exceeding the administration's request. This generous response suggests that Congress is probably the best friend science education has in Washington.

If any of you share my belief that tax money spent for science education is money very wisely spent, I urge you to communicate that position to your senators and representatives. Those members of Congress who have supported SEE in the past should be thanked; those who have not should be encouraged to do so. It is particularly important to write to members of the cognizant committees who oversee the authorization and appropriation process for NSF: the House Science, Space, and Technology Committee and its Subcommittee on Science, Research and Technology; the Senate Appropriations Committee and its Subcommittee on HUD-Independent Agencies; and the House Appropriations Committee and its Subcommittee on HUD-Independent Agencies. Descriptions of positive personal experiences with NSF educational programs are especially effective.

Lest readers conclude that the current legislative largess is more than enough to solve the problems of scientific education, let me remind you that the 1989 appropriation of $171 million represents about 70¢ per American or $4.25 per pupil. It is also instructive to note that about 50 percent of proposals submitted to SEE are judged by reviewers and staff to be worthy of support. Typically, the money available is only

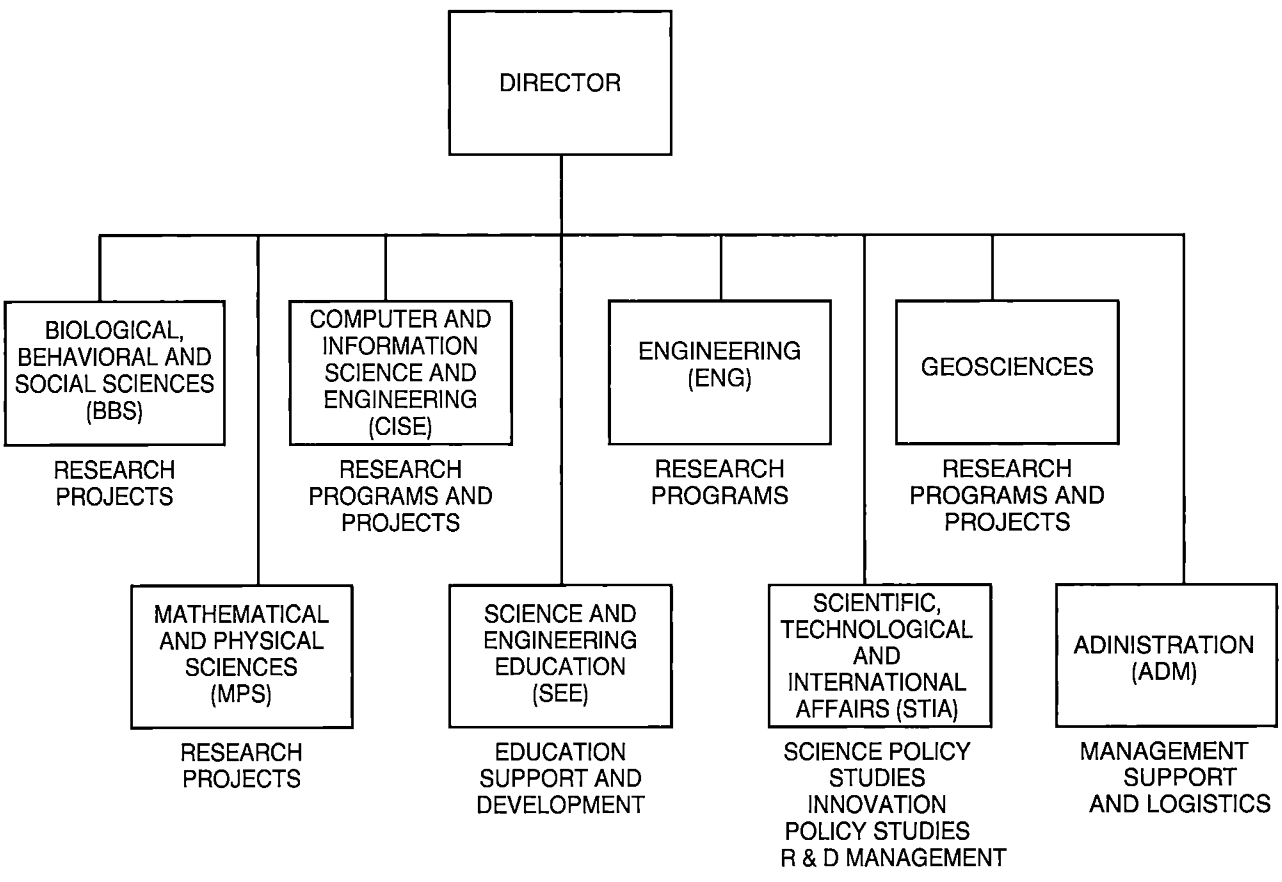

Figure 1. Organizational Chart for National Science Foundation

Table 1. NSF budget information for fiscal years 1987-89

(dollars in millions)

	FY87 Actual	FY88 Request	Percent Change Requested	FY88 Cong Action	Percent Change Actual	FY89 Request	Percent Change Requested	FY89 Cong Action	Percent Change Actual
Research and Related	1,406	1,635	15.9%	1,453	3.0%	1,603	10.3%	1,583	8.9%
U.S. Antarctic Program	117	143	21.9%	125	6.4%	141	13.0%	131	4.8%
Science & Engin. Education	99	115	16.2%	139	40.7%	156	12.1%	171	23.0%
Special Foreign Currency	0.73	—	-100.0%	—	-100.0%	—	N/A	—	N/A
Science & Tech. Centers	—	—	N/A	—	N/A	150	N/A	—	N/A
NSF Total	1,623	1,893	16.3%	1,717	5.5%	2,050	19.%	1,885	9.8%

sufficient to fund about one half of these—25 percent of all proposals received. Even if there were no increase in the number of proposals submitted, budgets for science education could be doubled without compromising the quality of the projects funded.

It is also important not to lose sight of the fact that the recent rapid increase in the NSF education budget is a phenomenon of only brief duration. Funding for science education has fluctuated widely since the establishment of the Foundation as evidenced by a plot of money spent by NSF (in constant 1988 dollars) from 1952 through 1988, (Figure 2). The graph also depicts the budgets for Research and Related activities and for Science and Engineering Education. It is painfully obvious that the SEE budget is only now recovering from a 26-year low—a $16 million appropriation in fiscal 1983.

When Bassam Z. Shakhashiri left the Chemistry department of the University of Wisconsin in 1984 to become assistant director for Science and Engineering Education, he inherited a demoralized, decimated, and nearly destitute operation. Under Shakhashiri's aggressive leadership, the Directorate has experienced a spectacular growth in funding and influence. However, the purchasing power represented by the fiscal year 1989 appropriation for SEE is well below that of the mid 60's. Moreover, the percentage of NSF funds committed to SEE, currently 9.1, compares unfavorably with the high of 40.9 percent in 1956-60. Other fluctuations in the size of education's piece of the Foundation pie are depicted in Figure 3.

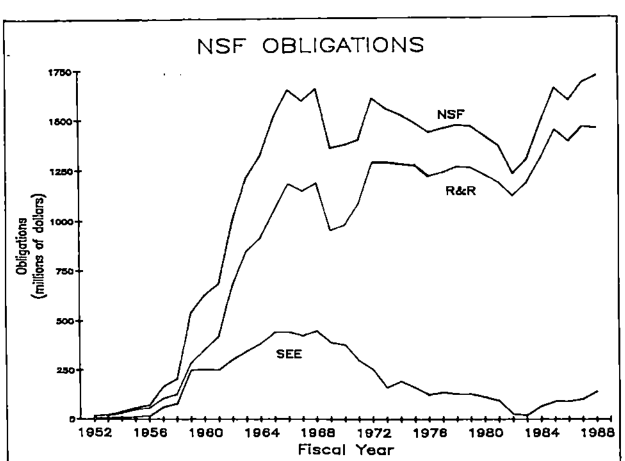

Figure 2. NSF obligations 1952-88 in constant FY 88 dollars.

The Directorate for Science and Engineering Education has, for most of its existence, funded educational programs at the graduate, undergraduate, and precollege levels. The details of the distribution of dollars among these categories are displayed in Figure 4. Actual budget figures appear in Table 2. The largest financial commitment continues to be at the precollege level, but appropriations for undergraduate science education are the fastest growing. This is at least partly a response to the 1986 report of a Task Committee of the National Science Board chaired by Homer Neal (5).

The funds appropriated to SEE are awarded through five divisions or offices. Figure 5 identifies these subunits and some of the major programs they administer. The largest division, in terms of budget, is that of Teacher Preparation and Enhancement. Many of the projects funded in the Teacher Enhancement Program are summer and/or academic year workshops or institutes for faculty teaching in elementary, middle, and senior high school. Typically, the instruction is by college faculty and the emphasis is more on content than on educational methodology. Recent grants from this program have gone to the University of Minnesota, Macalester College, and St. Mary's College.

The current crop of Teacher Enhancement projects differs in several significant ways from the post-Sputnik NSF initiatives which served so many teachers in the 1960's. Those projects were typically created by college and university faculty, with little or no consultation with their precollege colleagues. Today such collaboration is required in the

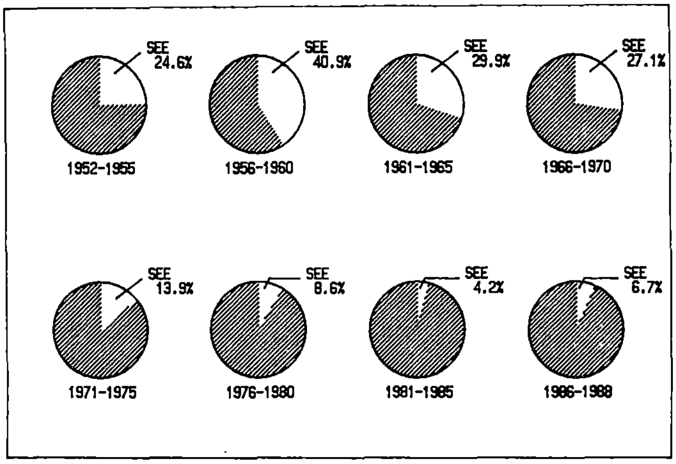

Figure 3. Obligations for Science and Engineering Education as Percent of Total NSF Budget.

Table 2. NSF-SEE Obligations by Level of Education — Fiscal Years 1987-89.

Education Level	FY 1987 Actuals	FY 1988 Actuals	FY 1989 Request
		(millions of dollars)	
Precollege	$ 62.2	$ 89.8	$ 108.5
(Percent Change)		44.4%	20.6%
Undergraduate	9.5	19.0	23.5
(Percent Change)		100.0%	23.7%
Graduate	27.3	30.4	24.0
(Percent Change)		11.4%	-21.0%
Total SEE	99.0	$ 139.2	$ 156.0
(Percent Change)		40.6%	12.1%

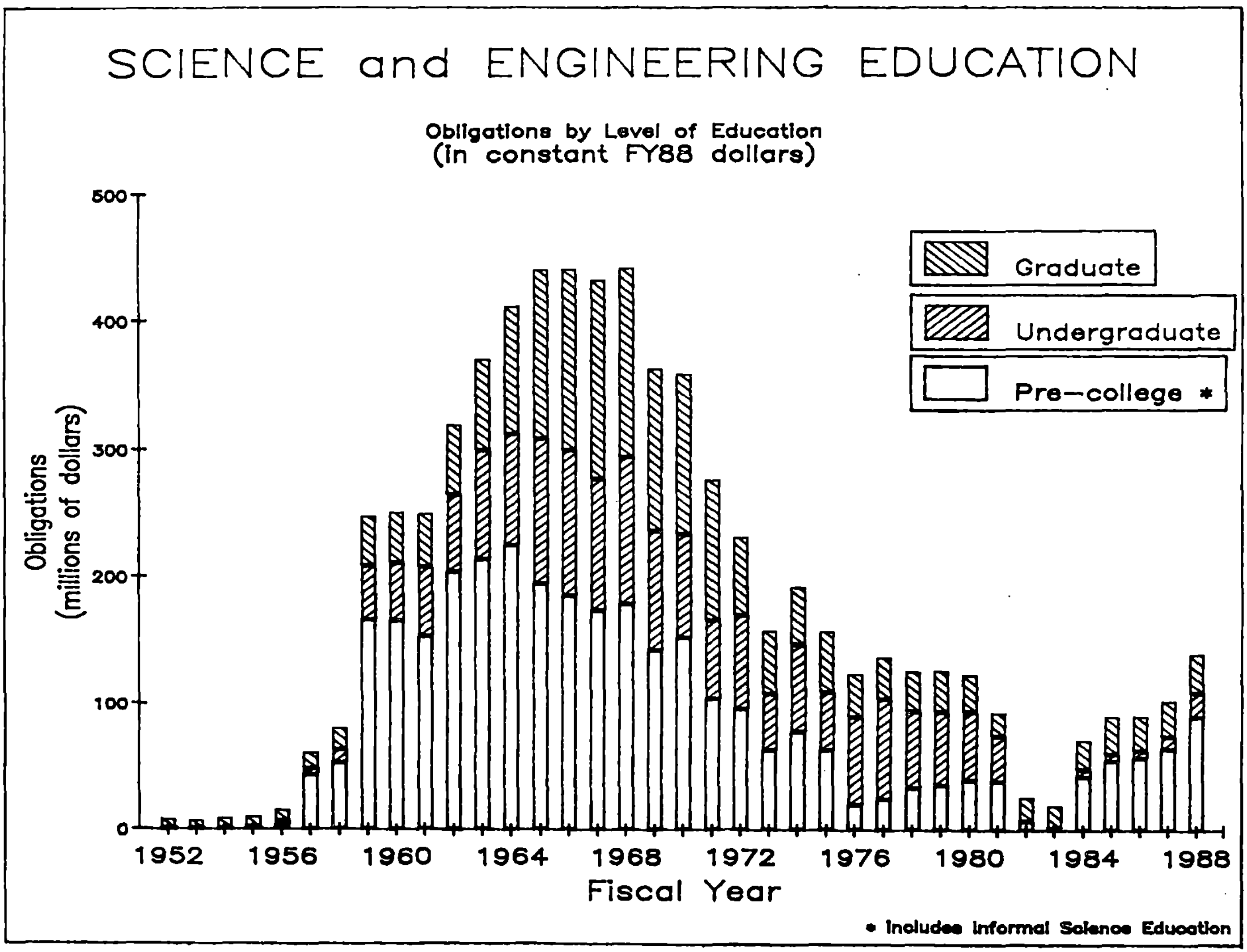

Figure 4. Directorate for Science and Engineering Education — Obligations by Level of Education.

planning phase and is very common in the implementation phase as well. As a result, the projects better serve the needs of the target teacher population.

Another important difference is the fact that follow-up, implementation, and dissemination activities are now expected. This reinforces the institute or workshop experience and makes it available to colleagues. In many cases, the participants become dissemination agents. The resulting catalytic effect greatly increases the number of teachers and students benefiting from the grant. For example, in fiscal 1987, about 6,000 teachers were direct participants in Teacher Enhancement programs. They, in turn, taught approximately 600,000 students and provided inservice instruction for 100,000 of their fellow teachers, each of whom teach an average of 100 students.

As the name implies, Teacher Preparation programs focus on the preservice education of teachers—an especially important undertaking because of the anticipated teacher shortage mentioned earlier. The Presidential Awards for Excellence in Science and Mathematics Teaching are particularly noteworthy because they annually recognize and reward the accomplishments of two outstanding teachers from each state. The 1987 Minnesota awardees were Steve Ethan, a physics teacher at Burnsville High School, and Edwin Andersen, a mathematics teacher at Southwest Secondary School in Minneapolis.

The Division of Materials Development Research and Informal Science Education funds the creation of instructional materials for precollege students. NSF has long been a patron and sponsor of innovative curricular materials. The 1960's marked the era of the Chemical Bond Approach, ChemStudy, the Physical Science Committee, and the Biological Sciences Curriculum Study. A modern project is a new high school chemistry curriculum called Chemistry in the Community (CHEMCOM). Unlike many of the post-Sputnik teaching materials, CHEMCOM uses a problem-oriented mode to present the content and methodology of science. This approach, which also stresses the societal implications of chemistry, has proved especially interesting to students with limited initial motivation for the study of science.

This concern with the needs of students who may not contemplate careers in science or technology is another characteristic of SEE initiatives for the 80's. There is a recognition that the health of science and society demands a scientifically literate population. It is not sufficient to concentrate exclusively on cloning more scientists. Excellent science instruction is essential for all our children and all our

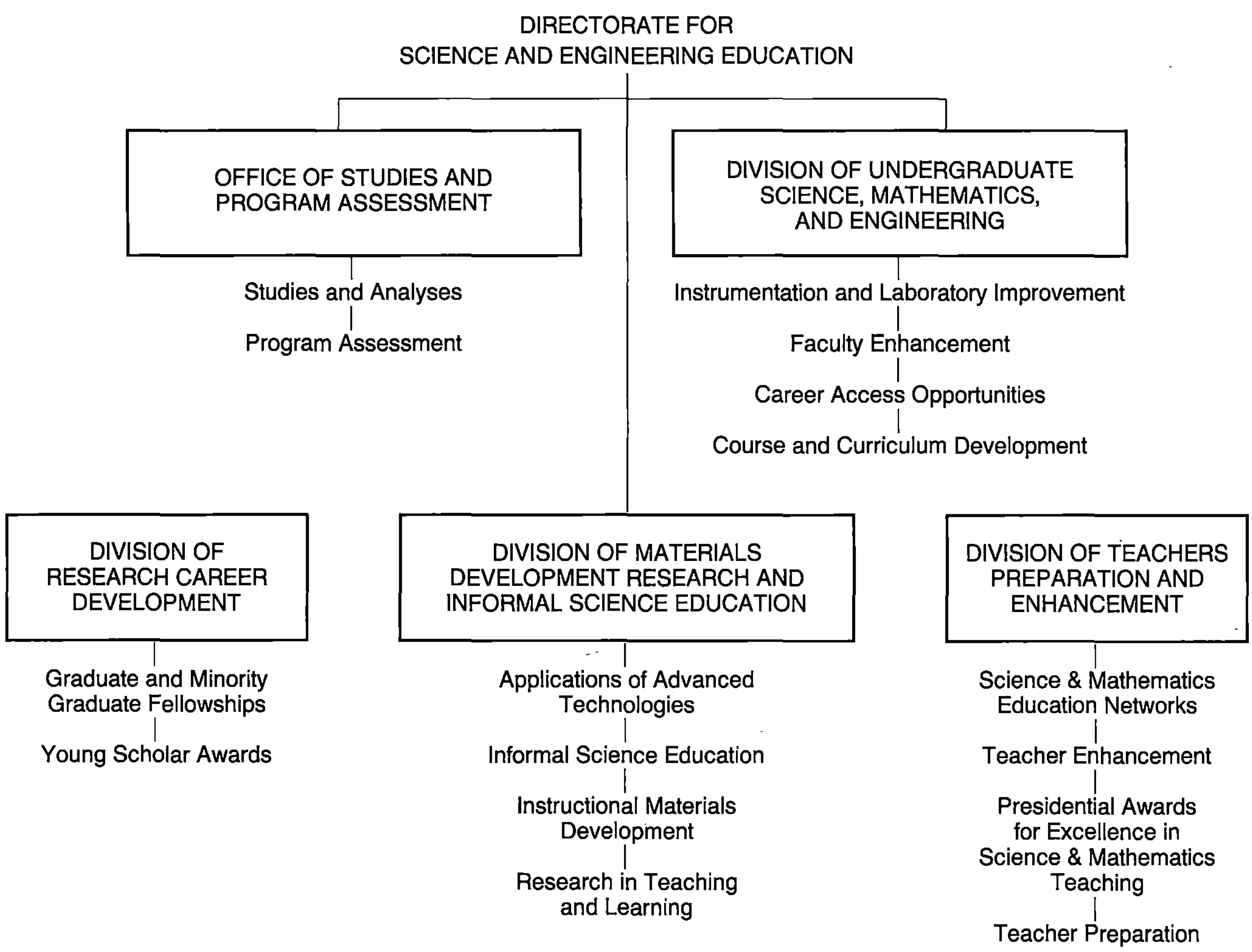

Figure 5. Organization chart for Directorate for Science and Engineering Education.

citizens. It must begin early, continue throughout the educational system, and even extend beyond formal schooling. The Program in Informal Science Education steps outside the classroom. Television is the medium of instruction in "3-2-1-Contact," "Square One TV," and "Ring of Truth." Other grants support educational programs at science museums, zoological parks, and aquaria.

Of course, the preparation of future scientists is not neglected by NSF. Many of the programs of the newly created Office of Undergraduate Science, Mathematics, and Engineering—one of the fastest growing units in SEE—are designed to benefit science majors in colleges and universities. Support is available for scientific instrumentation, undergraduate research, course and curriculum development, and college faculty enhancement. The prestigious NSF Graduate and Minority Graduate Fellowships are administered by the Division of Research Career Development.

The remaining unit of SEE, the Office of Studies and Program Assessment, analyzes national and international needs and trends in science education and assesses the effectiveness of various programs and innovations.

Embedded in all NSF-SEE programs is a commitment to attract more members of currently underrepresented groups to courses and careers in science, mathematics, and engineering. Too few women, members of ethnic minority groups, and physically handicapped persons have become scientists. The barriers to the full utilization of this human resource pool must be broken down.

What Can Individuals Do?

Much of value has already been accomplished by NSF-supported projects in science education. Much more remains to be done. While a federal role is essential, it is not sufficient. The great national need for major improvement in science education demands that all of us—but especially those of us who are scientists—become involved. If nothing else, self-preservation requires it! Therefore, in conclusion I would like to suggest some ways in which individual members of the Minnesota Academy of Science can contribute. My suggestions require no elaboration, so let me present them as bureaucratic "bullets."

- Give guest lectures in schools, to scout troops, etc.
- Serve as a tutor for elementary, middle or secondary students
- Serve as a resource person to a teacher
- Serve as a safety consultant to a teacher or school
- Help with chemical waste disposal problems
- Arrange for laboratory/plant tours by teachers/students
- Employ teachers/students during summer vacations
- Help with the Chemistry Olympiad, the Science Olympiad, the Junior Science and Humanities Symposium or science fairs
- Volunteer at the Science Museum of Minnesota
- Organize and teach in teacher workshops
- Attend Twin Cities Science Teachers' meetings
- Join the educational division of your professional society or the National Science Teachers Association
- Provide teachers with gift memberships in the Minnesota Academy of Science, the Science Museum of Minnesota, MSTA, NSTA, professional societies, etc.
- Provide teachers, schools and/or students with gift subscriptions to science-related publications
- Donate books, journals, magazines to schools
- Donate equipment and chemicals to schools
- Vote
- Lobby
- Run for School Board
- Become a teacher

The list could easily be lengthened; it is essential that it be implemented!

The current status of science education in the United States is a crisis of major proportion. Because of this crisis, we have the opportunity to become participants in an enterprise of great consequence. But we have more than an opportunity—as scientists we have a special obligation. As individuals who care about the future of our disciplines, our nation, and our youth, we have a solemn responsibility to do all we can to make the quality and quantity of American science education as good as it is anywhere on the globe. I invite you to meet this challenge.

Acknowledgement

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