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ABSTRACT

Presented is a detailed plan of action directed toward the Nation's achieving world educational leadership (as measured by student achievement, participation levels, and other non-subjective criteria) in mathematics, science, and technology in elementary/secondary schools by the year 1995. Sweeping and drastic changes are proposed in the breadth of student participation, methods and quality of teaching, student preparation/motivation, course content, and achievement standards. These changes will be accomplished by: building a strong and lasting national commitment to quality mathematics, science, and technology education for all students; providing earlier/increased exposure to these fields; providing a system for measuring student achievement/participation; retraining current teachers, retaining excellent teachers, and attracting new teachers of the highest quality and commitment; improving the quality/usefulness of courses taught; establishing exemplary programs; utilizing available resources, including new information technologies and informal education; and establishing a procedure to determine costs of required improvements and how to pay for them. Each of these areas is discussed in this report. In addition, the following information is provided in appendices (exhibits): brief descriptions of program/activities reviewed during the preparation of the report, suggested course topics and criteria for their selection, costs of recommended federal initiatives, imaginative ways to enhance teacher compensation, and computer uses in schools. (JN)

EDUCATING AMERICANS FOR THE 21st CENTURY:

A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995

A REPORT TO THE AMERICAN PEOPLE AND THE NATIONAL SCIENCE BOARD

THE NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

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NATIONAL SCIENCE BOARD
NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

NSB COMMISSION ON PRECOLLEGE EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

September 12, 1983

Dr. Lewis M. Branscomb
Chairman
National Science Board
National Science Foundation
Washington, D.C. 20550

Dear Dr. Branscomb:

It is a pleasure to transmit to you the Commission's final report. This Commission does not simply decry the present inadequate state of many of the Nation's schools. Rather, we spell out a detailed plan of action for all sectors of society to address the very serious problems facing America's elementary and secondary educational systems in mathematics, science and technology. Many of our recommendations focus primarily on these fields; however, many apply equally well to other areas of study—literature, foreign languages, social science, history, art, etc. Thus, we hope this Report is disseminated widely.

The plan of action in this Report is directed toward the Nation's achieving world educational leadership (as measured by student achievement and participation levels and other non-subjective criteria) in mathematics, science and technology in elementary and secondary schools by the year 1995. Moreover, in keeping with the goals the Commission adopted at its first meeting in July 1982, the recommendations are intended not only to increase opportunities for outstanding students in these fields, but also to enrich the educational experiences of the entire range of American students—those planning careers as professional mathematicians, scientists, engineers and teachers in these fields, those who will pursue technical careers, and those who will be the Nation's future political leaders, managers, laborers, parents, consumers and voters. The Commission believes America's educational systems must provide opportunities and high standards of excellence for all our youth because the Nation's national security, economic strength and quality of life depend on the mathematics, science and technology literacy of all its citizens.

The Commission has visited and analyzed acknowledged examples of successful programs and received testimony from a very wide range of individuals and groups. The exhibits in this volume summarize much of the Commission's work. In addition, the volume of source materials accompanying this Report reproduces many of the reports commissioned explicity to inform our deliberations.

The Report estimates the costs to the Federal government of the new programs we suggest it should adopt. The Federal cost recommended is $1.51 billion for the first year the Commission's recommendations are in effect (but Federal disbursement would not exceed $956 million in any year). The Report also suggests a procedure to ascertain the other, additional costs for the Nation—at Federal, state and local levels—to provide the kind and quality of education which the Commission deems necessary for successful living in the 21st century. The Commission believes the serious problems facing America's elementary and secondary educational systems in mathematics, science and technology can be solved. The job can be done. There are now numerous pockets of academic excellence throughout the United States. But raising the entire system to a new standard of excellence will require that these exceptions become the norm. This can only be accomplished through leadership from the President, Governors and leaders of local school boards, and by concerted and sustained actions throughout the Nation. We hope our Report will provide some guidance and inspiration to those who will lead the effort and those who must carry it to fruition.

The members of the Commission thank you for the opportunity to serve.

Sincerely,

William T. Coleman, Jr.
Co-Chair

Cecily Cannan Selby
Co-Chair

EXECUTIVE SUMMARY

September 12, 1983

AN URGENT MESSAGE TO PARENTS, DECISION MAKERS AND ALL OTHER AMERICANS

The Nation that dramatically and boldly led the world into the age of technology is failing to provide its own children with the intellectual tools needed for the 21st century.

We continue to lead because our best students are still unsurpassed. We continue to lead because our universities, industries, resources and affluence attract the finest talent from throughout the world. But this is a precarious advantage. The world is changing fast. Technological know-how is spreading throughout the world—along with the knowledge that such skills and sophistication are the basic capital of tomorrow's society.

Already the quality of our manufactured products, the viability of our trade, our leadership in research and development, and our standards of living are strongly challenged. Our children could be stragglers in a world of technology. We must not let this happen; America must not become an industrial dinosaur. We must not provide our children a 1960s education for a 21st century world.

We must return to basics, but the "basics" of the 21st century are not only reading, writing and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy—the *thinking* tools that allow us to understand the technological world around us.

These new basics are needed by *all* students—not only tomorrow's scientists—not only the talented and fortunate—not only the few for whom excellence is a social and economic tradition. All students need a firm grounding in mathematics, science and technology. What follows is a difficult and demanding plan to achieve this, but it must be accomplished. Our children are the most important asset of our country; they deserve at least the heritage that was passed to us.

- By 1995, the Nation must provide, for all its youth, a level of mathematics, science and technology education that is the finest in the world, without sacrificing the American birthright of personal choice, equity and opportunity.

This goal can be achieved. The best American students are the equal of any in the world. Indeed, the best schools in the world emulate the best of America. We have the know-how.

The Commission proposes sweeping and drastic change: in the breadth of student participation, in our methods and quality of teaching, in the preparation and motivation of our children, in the content of our courses, and in our standards of achievement. We propose to initiate this difficult change through a strategy of (1) building a strong and lasting national commitment to quality mathematics, science and technology education for all students; (2) providing earlier and increased exposure to these fields; (3) providing a system for measuring student achievement and participation; (4) retraining current teachers, retaining excellent teachers and attracting new teachers of the highest quality and the strongest commitment; (5) improving the quality and usefulness of the courses that are taught; (6) establishing exemplary programs—landmarks of excellence—in every community to foster a new standard of academic excellence; (7) utilizing all available resources, including the new information technologies and informal education; and (8) establishing a procedure to determine the costs of required improvements and how to pay for them.

In this Report we emphasize the teaching and learning of mathematics, science and technology in elementary and secondary schools; that is the Commission's charge. We recognize, however, that this area cannot be separated from the teaching and learning of many other important subjects, such as English, foreign languages and history. We hope that glaring deficiencies in these other areas will be met with the same sense of urgency. (pp. 6, 10)

Leadership

Reaching a new standard of academic excellence by 1995 requires clear educational objectives, strong leadership and firm commitment at all levels. Goals must be set and progress toward those goals assessed. We must recognize the necessary investment, assess the cost, and accept the responsibility for participation at Federal, state and local levels, in both the public and private sectors. We call upon our national leaders to begin and maintain the process. (pp. 9–12)

- The President should immediately appoint a National Education Council, reporting directly to him, to identify national educational goals, to recommend and monitor the plan of action, to ensure that participation and progress are measured, and to report regularly to the American people on the standards and achievements of their schools.
- The States should establish Governors' Councils to stimulate change, develop state educational goals, and monitor progress.
- Local school boards should foster partnerships with business, government and academia to encourage, aid and support in solving the academic and financial problems of their schools.
- The Federal government should finance and maintain a national mechanism for measuring student achievement and participation in a manner that allows national, state and local evaluation and comparison of educational progress.

Focus on All Students

This Commission's plan is not only for the affluent or gifted. While it provides the quality and intensity of education needed to continue their development, it also addresses the needs and potential of all other students. It recognizes that

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substantial portions of our population still suffer from the consequences of racial, social and economic discrimination, compounded by watered standards, "social promotion," poor guidance and token efforts. The Commission has found that virtually every child can develop an understanding of mathematics, science and technology if appropriately and skillfully introduced at the elementary, middle and secondary levels. (pp. 12–14)

- The Nation should reaffirm its commitment to full opportunity and full achievement by all. Discrimination, and the lingering effects thereof, due to race, gender and other such irrelevant factors must be eradicated completely from the American educational system. "Excellence and elitism are not synonymous."

Quality Teaching and Earlier and Increased Exposure

Here and in other countries, programs that produce excellence and high achievement have similar characteristics. Education in mathematics, science and technology begins early, is taught by qualified, committed teachers, and provides a consistent course of study, beginning before elementary school and continuing in a coherent pattern through high school. (pp. 17–23).

This "vertical" curriculum emphasizes early "hands-on" experience, disciplined and rigorous study, and a substantial amount of time-on-task and homework at all levels. Above all, it includes strong motivation and commitment. Parents, students and the system are all dedicated to high achievement from every student. Finally, successful systems have skilled and well trained teachers who are supported by skilled administrators, good facilities and specialized assistance. (pp. 17–25)

This is true of major competitors like Japan, and it is true of America's scattered but equally impressive model programs. Unfortunately, it is not true of most of our schools. (pp. 17–21)

- Top priority must be placed on retraining, obtaining and retaining teachers of high quality in mathematics, science and technology, and providing them with a work environment in which they can be effective.
- Top priority must be placed on providing earlier, increased and more effective instruction in mathematics, science and technology in grades K-6.
- Considerably more time should be devoted to mathematics, science and technology throughout the elementary and secondary grades. This will require that the school day, week and/or year be substantially lengthened.

Models for Change

The potential of exemplary or model programs has been demonstrated in cities and localities throughout the country. Typically, they exhibit high achievement from students of every background, have strong links to local resources, and set an example that should be emulated and replicated in every school. As a first step toward change we recommend that such landmarks of excellence for mathematics, science and technology education be established in every community. (pp. 23–25)

- The Federal government should encourage and finance, in part, the establishment of exemplary programs in mathematics, science and technology in every community, which would serve as examples and catalysts for upgrading all schools.
- State governments should promote and local school districts should establish such programs as a major strategy toward upgrading all schools.

We recommend that initially 1,000 such secondary schools and 1,000 such elementary schools be established throughout the country. The Commission estimates the cost to the Federal government to do so is $829 million disbursed at the rate of $276 million per year over a three year period. (p. 25 and Exhibit C, p. 109)

Solutions to the Teaching Dilemma

Ultimately, quality begins in the classroom; the teacher is the key. Unfortunately, we currently have severe shortages of qualified mathematics, science and technology teachers throughout the Nation, and many of today's teachers in these fields badly need retraining.

Many of the teachers in elementary schools are not qualified to teach mathematics and science for even 30 minutes a day. A significant fraction of our secondary school teachers are called upon to work in subjects for which they were never trained. Even the most seasoned and experienced veterans must deal with subjects that are in a state of constant change; no one can remain knowledgeable in science without constant refreshing. (pp. 27–31)

- State governments should develop teacher training and retraining programs in cooperation with colleges and universities. The potential of science museums as sites for such programs should be recognized, encouraged and supported.
- It is a Federal responsibility to assure that, in the present crisis, appropriate retraining is available. In-service and summer training programs should be established with Federal support. The Commission estimates the cost to the Federal government of initiatives for retraining mathematics, science and technology teachers to be $349 million per year for five years. (Exhibit C, p. 110)
- For the long term, teacher training by the States should continue as an ongoing process.
- Every State should establish at least one regional training and resource center where teachers can obtain supporting services such as computer instruction and software and curriculum evaluation.
- The National Science Foundation should provide seed money to develop training programs using the new information technologies.

At the same time that we improve the quality of current teaching, we must raise our standards for new teachers. We must attract and retain superior talent, and must provide better training, better working conditions, and better compensation for high quality teachers, together with more demanding standards. (pp. 31–33)

- States should adopt rigorous certification standards, but not standards which create artificial bars to entry of qualified individuals into teaching.
- Elementary mathematics and science teachers should have a strong liberal arts background, college training in mathematics and the biological and physical sciences, a limited number of effective education courses, and practice teaching under a qualified teacher.
- Secondary school mathematics and science teachers should have a full major in college mathematics and science, a limited number of effective education courses, and practice teaching under a qualified teacher.
- Both elementary and secondary teachers should be computer literate. Teacher training should incorporate the use of calculators and computers in mathematics and science instruction.
- Liberal arts colleges and academic departments need to assume a much greater role in training elementary and secondary teachers. Basic education courses should be revised to incorporate current findings in the behavioral and social sciences.

In the short run, the pool of those presently qualified and teaching must be enlarged.

- State and local school systems should draw upon the staffs of industry, universities, the military and other government departments, and retired scientists to provide sources of qualified teaching assistance. Local systems should take actions to facilitate the entry and classroom training of such special teachers.

Compensation for mathematics, science and technology teachers must be appropriate to their important role in "academic excellence," their small numbers, and their alternatives for employment. Highly qualified and competent mathematics, science and technology teachers should receive overall rewards that are fair and relatively competitive with those received by comparable professionals in other sectors. Ultimately, the public will get what it pays for. At the same time, many teachers and teacher unions will have to reexamine their views about differential salaries in areas of shortage and systems of pay based on factors other than merely years of service and credits for "staff development." (pp. 33–35) Examples of imaginative ways to enhance teacher compensation are provided in Exhibit D.

- School systems should explore means to adjust compensation in order to compete for and retain high quality teachers in fields like mathematics, science and technology. Compensation calculations must include consideration of intangible benefits such as the length of the work year, promotion potential, and similar factors.

- State and local governments should provide means for teachers to move up a salary and status ladder without leaving the classroom.
- Local school systems, military and other governmental entities, and the private sector should all explore ways to extend the employment year while providing supplementary income and revitalizing experience.
- Professional societies, schools, States and the Nation should find ways to recognize the performance and value of the excellent teacher.

Finally, we must take action to make the classroom a place where teachers can teach and children can learn—an exciting place with more opportunity for student-teacher interaction. We must build a professional environment that will attract and hold talented and well trained teachers, despite the allure of the private sector. (pp. 35–37)

- State and local governments should work to improve the teaching environment. This includes greater administrative and parental support of discipline and attendance, fewer classroom interruptions, and higher academic standards, as well as the provision of needed equipment, materials and specialized support staff.

Improving What is Taught and Learned

We have too long regarded mathematics and science as the exclusive domain of a talented elite—a preserve for only the gifted. By focusing on education of the well-prepared, we have both ignored and discouraged large numbers with potential talent and widened the gap between the sciences and the public they serve. There is no excuse for citizens in our technological society to say "I don't really know anything about science!"

While increasing our concern for the most talented, we must now also attend to the need for early and sustained stimulation and preparation of *all* students so that we do not unwittingly exclude potential talent and so that we produce citizens, political leaders, teachers, managers, workers and other decision makers who are prepared to deal with the age of technology. Significant, immediate progress can be made by simply increasing the amount of exposure students get to mathematics, science and technology—although more persistent change will require a more elaborate process of review and revision of educational objectives. (pp. 39–41)

- Local school districts should revise their elementary school schedules to provide consistent and sustained attention to mathematics, science and technology: a minimum of 60 minutes per day of mathematics and 30 minutes per day of science in grades K-6; a full year of mathematics and science in grades 7 and 8.
- Every State should establish rigorous standards for high school graduation, and local school districts should provide rigorous standards for grade promotion. We should curtail the process of social promotion.

- All secondary school students should be required to take at least three years of mathematics and of science and technology, including one year of algebra and one semester of computer science. All secondary schools should offer advanced mathematics and science courses. This requirement should be in place by September 1, 1985.
- Colleges and universities should phase in higher mathematics and science entrance requirements, including four years of high school mathematics, including a second year of algebra, coursework covering probability and statistics, four years of high school science, including physics and chemistry, and one semester of computer science.
- Specific school personnel should be obligated to inform students of these rigorous requirements. School districts and community colleges should cooperate in assisting students whose preparation is inadequate to allow them to take the next steps in their education.

For the long term, we must establish a pattern of education that will develop familiarity, skills and understanding consistently and coherently throughout the years of elementary and secondary education. This does not imply either a lockstep or "national" curriculum; local diversity and variation is a key strength of American education. Rather, we call for a consensus on new educational objectives and a coherent national *pattern*—a framework for consistent education within which alternative curricula and materials and local interpretation are encouraged. (pp. 45–48)

- The National Science Foundation should take a leadership role in promoting curriculum evaluation and development for mathematics, science and technology. It should work closely with classroom teachers, technical experts from business and government, school boards and educational researchers, as well as with professional societies. Representatives of publishers and higher education associations should become involved as the work proceeds, to encourage development and transfer of these ideas to actual material for the classroom.
- The Federal government should support research into the processes of teaching and learning at both the basic level and the level of classroom application.

In the body of this Report, we provide a broad and preliminary outline of the content that should be included in this new pattern of education for all students. More importantly, we indicate the kinds of problem solving *insight* and *skills* that must be provided. We offer this not as a conclusion, but as a beginning—a place to start the long process of defining and developing programs that prepare students for a wide range of roles and needs. (pp. 41–45 and Exhibit B)

New Information Technologies

Computers are revolutionizing many areas of our lives; they may well do the same for education. They and other new technologies offer the potential to work patiently with every student, regardless of level or sophistication. They also offer a means to relieve teachers of much of the drudgery of routine exercise and record keeping. Furthermore, computers offer a wealth of interactive learning resources, including access to word processing, data bases, graphic capabilities and a host of related means to expand students' learning potential.

If this promise is fulfilled, computers could simultaneously provide a new standard of achievement and lower the cost of education. (pp. 51–56)

- The National Science Foundation should lead in evaluating progress in the application of new technologies, supporting prototype demonstrations, disseminating information, and supporting research on integration of educational technologies with the curriculum. These plans should not interfere with private initiatives now underway.
- States should establish regional computer centers for teacher education and encourage the use of computers in the classroom for both teaching and administration.
- Top executives in the computer, communication, and information retrieval and transfer industries should develop plans which, in a good, economical and quick way, enable school systems to use the technology.
- The national and state education councils and school boards should work with school districts and schools to develop plans for implementing these technologies in the classroom.

Informal Education

A great deal of education takes place outside the classroom. The most fortunate students receive experiences in museums, clubs and independent activities. All children are strongly conditioned and motivated by their early experiences and impressions. The child who has regularly visited zoos, planetaria and science museums, hiked along nature trails and built model airplanes and telescopes is infinitely better prepared for, and more receptive to, the mathematics and science of the classroom.

Formal education should be preceded and supplemented by a wide range of such informal learning experiences. (pp. 59–61)

- Youth organizations, museums, broadcasters and other agents of informal education should endeavor to make the environment for informal learning as rich as possible.
- Science broadcasts warrant continued and substantial Federal support as well as corporate and other private support. Federal regulation of commercial stations should include a required period of educational programming for children.
- The Federal government should provide supplementary support to encourage a full spectrum of community and educational activities by science museums.
- Businesses and broadcasters should help to promote and publicize the efforts of institutions like science museums and public broadcasting.

- Local business groups and organizations with related interests should work with museums to supplement and encourage their activities and to create new programs that let children see science and technology in the real world.

Finance

This Commission has not avoided the difficult issue of cost. Change requires investment. In the end, it may well be that a better educational system will yield greater efficiency, long-term economies and a more valuable output. But in the near future, our recommendations require substantial net investment at all levels.

In particular, as the leader and driving force to encourage change, we believe that the Federal government should anticipate an initial investment of approximately $1.51 billion for the first full year the recommended Federal initiatives are in place (pp. 63–66, and Exhibit C) ($829 million of this amount will be disbursed over three years at the rate of $276 million per year.) During succeeding years the Federal appropriation will decline—to approximately $680 million in the second year and $331 million in the sixth year. We do not consider this an excessive investment in our Nation's human capital. In fact, the cost is small compared to the much larger efforts and investments of local school systems, which ultimately carry most of the burden, responsibility and authority for the quality of our children's education. The Federal government should study ways to protect the States and local communities from any anti-competitive effects on the States and local communities of increasing taxes for educational purposes. (p. 66)

Before we shrink from our responsibility, consider the heritage that was passed to us. We must not do less for our children and future generations.

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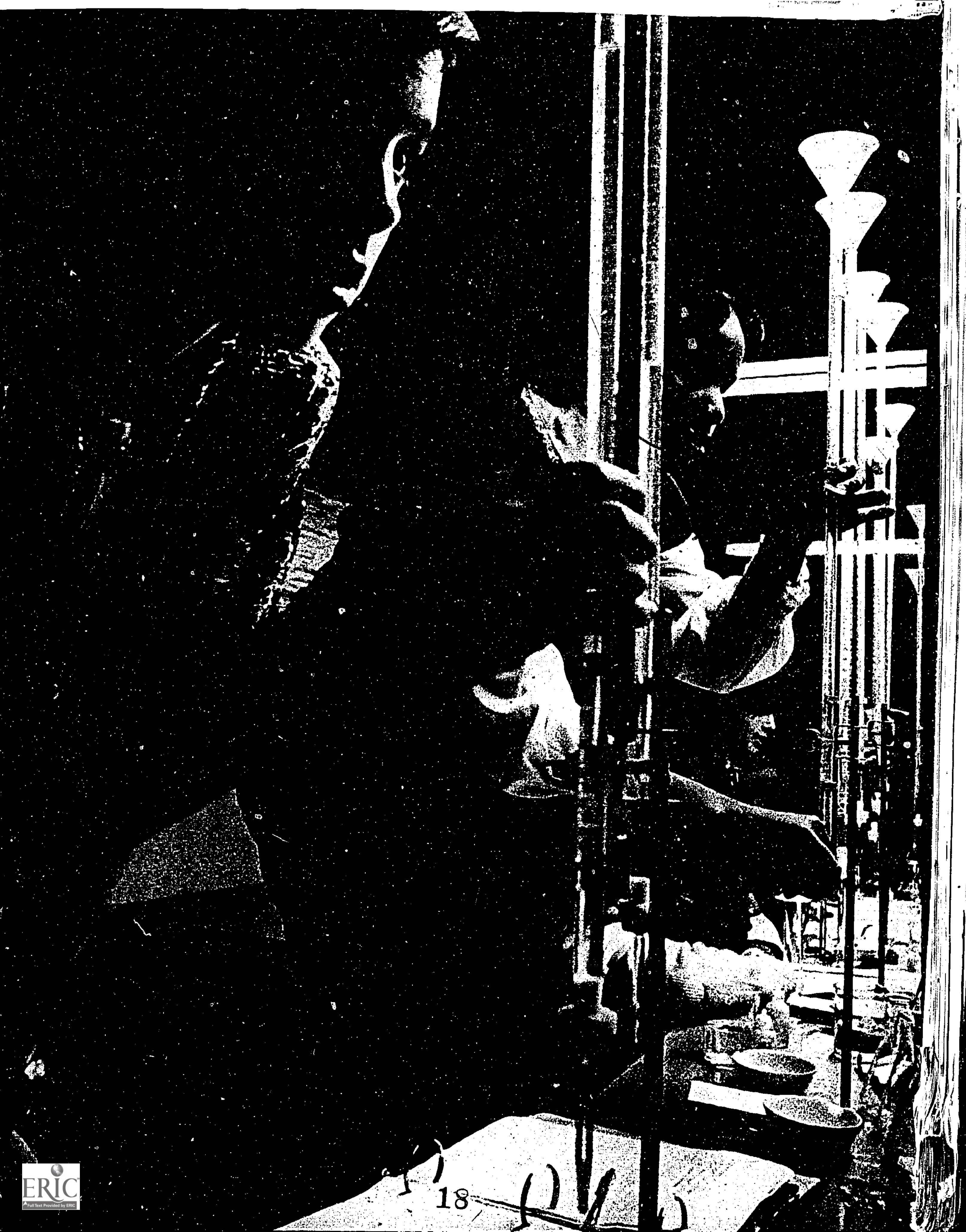
Exhibits



INTRODUCTION

Alarming numbers of young Americans are ill-equipped to work in, contribute to, profit from and enjoy our increasingly technological society. Far too many emerge from the Nation's elementary and secondary schools with an inadequate grounding in mathematics, science and technology. As a result, they lack sufficient knowledge to acquire the training, skills and understanding that are needed today and will be even more critically needed in the 21st century. This situation must not continue—improved preparation of all students in the fields of mathematics, science and technology is essential to the maintenance and development of our Nation's economic strength, to its military security, to its continued commitment to the democratic ideal of an informed and participating citizenry and to fulfilling personal lives for its people.

The problems facing elementary and secondary education, particularly in mathematics, science and technology, are well known and well documented. Simply put, students in our Nation's schools are learning less mathematics, science and technology, particularly in the areas of abstract thinking and problem solving. Since the late 1960s, most students have taken fewer mathematics and science courses.[1] Mathematics and science achievement scores of 17 year-olds have dropped steadily and dramatically during the same period.[2]

Indeed, the problem is vastly more serious when the way education is distributed among students is examined. Twenty-five percent of our young people are not even graduating from high school.[3] A disproportionate number of

1. There were declines in the percentages of high school students completing Algebra I (76-64%), Geometry (51-44%), Algebra II (35-31%), Biology (80-77%), Chemistry (34-32%) and General Science (61-37%). Source: Clifford Adelman, "Devaluation, Diffusion and the College Connection: A Study of High School Transcripts, 1964–81," Washington, DC: National Institute of Education, March 1983. (Available through the ERIC Document Reproduction Service, P.O. Box 190, Arlington, Virginia 22210.)

2. Between the 1973 and 1982 National Assessments of Mathematics, mean achievement scores of 17-year-olds declined 3.2%. Between 1970 and 1983, the National Assessments of Science mean achievement scores of 17-year-olds declined 6.7%. Source: National Assessment of Educational Progress, Education Commission of the States, Denver, Colorado.

3. Percentages of high school graduates increased in the United States reaching a peak of 76.3% in 1969. The percentage declined to 74.5% in 1981. Source: National Center for Education Statistics *Digest of Education Statistics 1983*, Washington, DC: U.S. Government Printing Office, 1983.

these non-graduates are minority students, children from poor economic conditions, and students whose parents do not speak English at home.[4]

The Commission on Precollege Education in Mathematics, Science and Technology, established by the National Science Board in April 1982, was not formed to produce yet another report on the problem. Recently, there have been a number of dramatic descriptions and cries of alarm. These previous reports[5] have successfully focused national attention on the "rising tide of mediocrity [in education] that threatens our very future as a Nation and a people."[6] This Commission's responsibility is different. Its task is to recommend solutions.

From the outset, therefore, this Commission has concentrated on developing specific recommendations to move elementary and secondary education in the United States forward to a new standard of "excellence"[7] worthy of a world leader (the United States is still the physically richest Nation in the world and the one most often called upon to provide international leadership). This Report outlines a plan of action and, for the first time, addresses the all-important question of costs and proposes a procedure to determine the methods of financing such a plan (see pp. 63–66, and Exhibit C).

During the last years of this century, the position of mathematics, science and technology, historically at the periphery of learning for all but a few American students, must shift to center stage for all. Americans must acquire a greatly increased understanding of the physical and biological world. This goal can be achieved. This Commission has seen convincing evidence that all students (except those with insurmountable learning disabilities) can develop a useful understanding of mathematics, science and technology if these subjects are appropriately introduced and skillfully taught at the elementary and secondary school levels.

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4. A report of the Bureau of the Census estimates that 15.9% of white, 21.3% of black and 36.3% of Hispanic youths aged 18 to 21 have not graduated from high school or obtained a high school equivalency degree. (Source: U.S. Department of Commerce *School Enrollment-Social and Economic Characteristics of Students: October 1981* (Advance Report), Washington, DC: Bureau of the Census, Series P-20, no. 373, February 1983, pp 8–9.) The lack of achievement is not based upon a difference in ability due to race or ethnicity. It results, in part, from inadequate pre-school and after school exposure, sometimes from differences in the opportunities to obtain high quality education and from societal attitudes toward some of its people. See pp. 12–14 below.

5. For examples, see: National Science Foundation and the U.S. Department of Education, *Science and Engineering Education for the 1980's and Beyond*, Washington, DC: U.S. Government Printing Office, 1980; U.S. Department of Education, *A Nation At Risk: The Imperative for Educational Reform*, Report of The National Commission on Excellence in Education, Washington, DC: U.S. Government Printing Office, April 1983; Education Commission of the States, *Action for Excellence: A Comprehensive Plan to Improve Our Nation's Schools*, Report of the Task Force on Education for Economic Growth, June 1983 (Copies available from Education Commission of the States, 1860 Lincoln St., Suite 300, Denver, CO 80295).

6. See footnote 5, *A Nation at Risk: The Imperative for Educational Reform*, p. 5.

7. When speaking of "academic or educational excellence," this Commission does not mean the provision of high quality education to only a small group of highly talented youth. As used in this Report, "academic or educational excellence" refers to educational offerings and teaching techniques and commitments that will not only enlarge the pool of students of highest potential but also will encourage and enable *all* students to achieve at a level equal to their full capability.

Promoting this learning of mathematics, science and technology will require fundamental changes in both what is learned and how it is taught. Effective leadership will be required at all levels of government in order to build a new national commitment to providing quality mathematics, science and technology education for all American students, while at the same time continually improving what we are now doing for the present set of outstanding students in these fields. Practices and attitudes in the present educational system must be significantly revised. Substantially more time must be devoted to the study of mathematics, science and technology. The quality of teaching in these subjects must be greatly improved, and increased numbers of qualified and committed teachers must be found. The substance of mathematics and science courses must be reviewed and improved, and technology must become an integral part of the study of science, mathematics and other subjects. Finally, improved methods of education, utilizing all available resources,[8] must be developed.

Each generation of Americans has the responsibility to prepare future generations for the world that will confront them. Our forefathers prepared us to cope with the complicated world we live in, and we, as the current adult generations, must fulfill our responsibility for preparing our children for the increasingly technological world of the future. We must heed H. G. Wells' warning that "human history becomes more and more a race between education and catastrophe." Action is required now to ensure that America's people are prepared for the 21st century.

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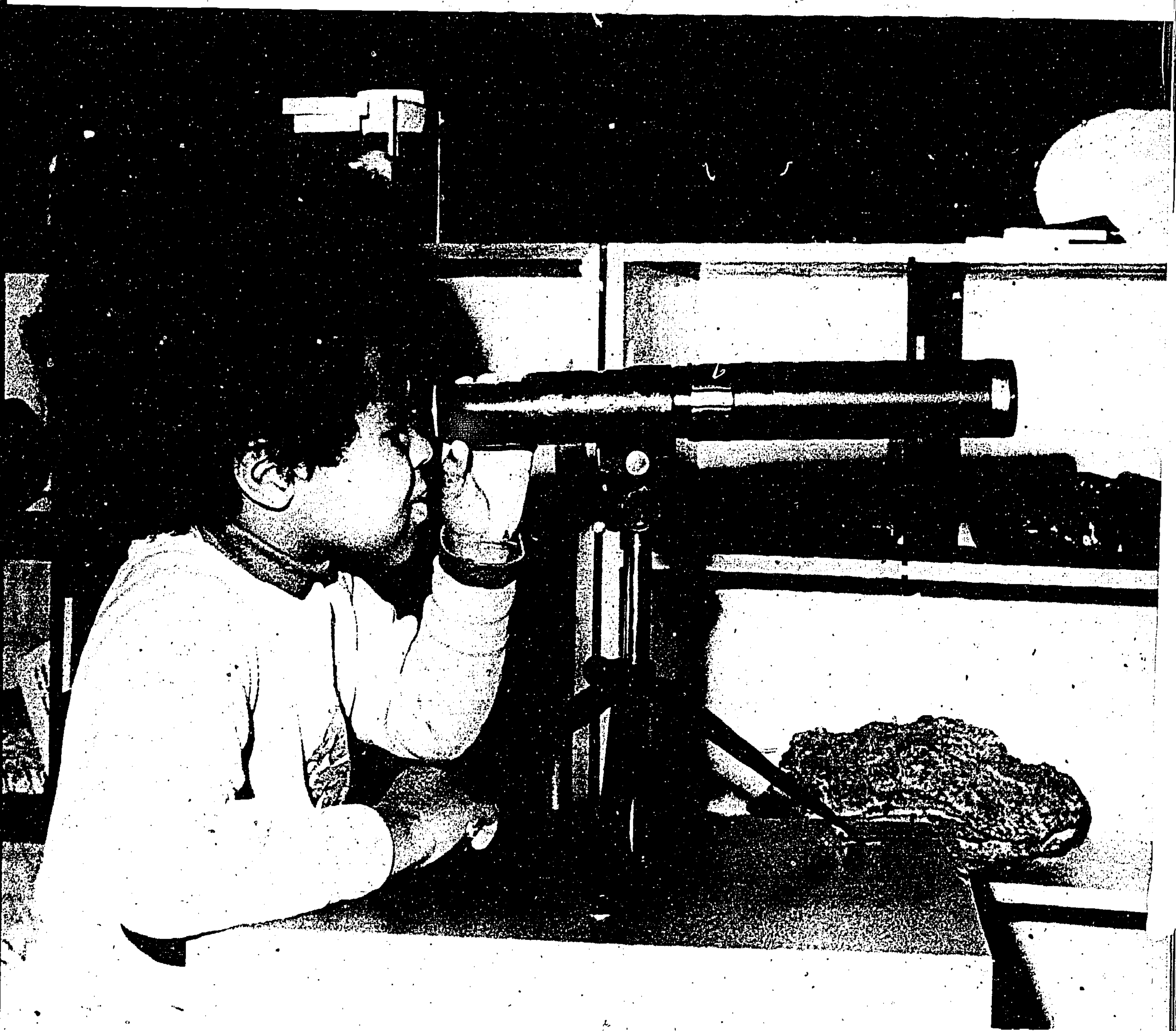
8. These resources are mentioned throughout this Report (e.g., technology, pp. 51–56; educational research, pp. 29–30, 48; museums, pp. 30, 59–61; business; pp. 11, 24, 32, 46–47, 56, 61.)



THE BASIC OBJECTIVE

Underlying every Commission recommendation is one basic objective:

THE IMPROVEMENT AND SUPPORT OF ELEMENTARY AND SECONDARY SCHOOL SYSTEMS THROUGHOUT AMERICA SO THAT, BY THE YEAR 1995, THEY WILL PROVIDE ALL THE NATION'S YOUTH WITH A LEVEL OF EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY, AS MEASURED BY ACHIEVEMENT SCORES AND PARTICIPATION LEVELS (AS WELL AS OTHER NON-SUBJECTIVE CRITERIA), THAT IS NOT ONLY THE HIGHEST QUALITY ATTAINED ANYWHERE IN THE WORLD BUT ALSO REFLECTS THE PARTICULAR AND PECULIAR NEEDS OF OUR NATION.

When the Supreme Court in *Brown vs. Board of Education* II, 349 U.S. 294 (1955) addressed the timing of the end of segregation in the public schools, the Court used the majestic words that racial segregation should end with "all deliberate speed." Despite this sound of urgency, some 28 years later, racial segregation continues in many school districts. This Commission, therefore, concluded that a specific date should be set for accomplishing what it recommends in this Report. It selected the date of December 31, 1995, 12 years from now, because this represents one complete education cycle for a generation of school children. This date provides adequate time to retrain present teachers, to find and train new teachers, to develop the necessary measurement procedures and core curricula, for governments to raise the needed funds, and for teachers, parents and students to accept and adjust to the massive changes. If this goal is achieved, then whoever is President of the United States can, in his or her State of the Union Address in 1996, tell the American public that their elementary and secondary schools are providing the kind of education in mathematics, science and technology that is the best in the world, that will meet the Nation's human resources requirements and, more importantly, that will provide all of its students a fair opportunity to realize their full potential in the technological environment of the next century.

To achieve this basic objective by 1995, the Commission first recommends a series of major strategic actions. They are aimed at building a new national commitment which will initiate major changes in American education and provide a system to measure the results. Such actions involve firm and continuing national leadership, state and local commitments to improved education, a popular commitment to "academic excellence," and the development of incentives and mechanisms to promote and bring about needed change. Such mechanisms include the establishment of deadlines by which certain parts of the process must be completed, a system to measure progress, both for the Nation as a whole and for its component school districts, and the creation of prestigious councils (at various levels) to guide the process.

After summarizing the factors which experience has shown to be critical to the delivery of high quality education in mathematics, science and technology, this Report sets forth a detailed plan to accomplish the basic objective by 1995. The plan outlines specific steps to increase the numbers, quality and status of teachers and suggests mechanisms for reaching new educational objectives in mathematics, science and technology. This plan also includes earlier and increased study of mathematics, science and technology for all students and the establishment of a series of exemplary programs to facilitate change and set examples for others to follow.

Consistent with this Commission's charge from the National Science Board, this Report's emphasis is on elementary and secondary school instruction and learning in mathematics, science and technology. The Commission recognizes, however, the interrelationships among all areas of learning, and that there are also glaring deficiencies in the teaching and learning of English and foreign languages, history, political science, the classics, art, music and other areas of study important for life in the 21st century. Plans and programs to meet these problems are vital. The Commission hopes such plans and programs will be developed with the same time schedule in mind.[9]

The Nation must not underestimate either the importance or the difficulty of achieving the basic objective set forth in this Report. The objective of "educational excellence" in mathematics, science and technology ranks high on the Nation's formidable agenda of complex public policy issues. Indeed, in importance it is light years beyond most other issues on that agenda. At stake is the quality of life of the next generations of Americans.

Correcting the problems of American elementary and secondary education will not, however, be quick or easy. Our educational system has, in many cases, suffered from shocking past neglect, misdirection, and deeply entrenched practices that are difficult to alter. Inertia, as well as often sincere opposition to many needed reforms, must also be overcome. Great change is required.[10]

9. Many of the recommendations set out in this Report could have significant value in developing education in areas of study other than mathematics, science and technology. The application of those recommendations to other aspects of America's elementary and secondary education systems should be seriously considered.

10. See National Science Board, *Today's Problems, Tomorrow's Crises*. Report of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, Washington, DC: National Science Foundation, October 1982. Change will not come easily in a highly pluralistic educational system such as ours. It is difficult to build a strong national consensus when major control is at the local, grass-roots level, and when there are complex local, state and national interest groups that have developed constituencies, programs, and sources of financial support over the years. Local school boards, teachers, school administrators, vocational

Funding needed changes is also a critical consideration. Some of the money now being spent at the Federal, state and local levels for elementary and secondary education might, of course, be directed more efficiently and effectively, and some of the reforms recommended in this Report should result in further economies in the long term.[11] In the near term, however, the necessary changes may require increased net investment at the national, state and local levels.

Determining the size of the required short term investment, the appropriate level of government (Federal, state or local) to fund such investments, and the appropriate source of, or methods for, raising required funds are all difficult public policy questions which must be addressed immediately with candor and determination. The Commission believes that in order to accomplish its objective by 1995 it is imperative that a process be established to address these critical questions. This Report deals with these essential and pressing fiscal issues on pages 63–66 and in Exhibit C. The public in a democratic society, if it is aroused, is willing to commit its limited resources to get what it considers important.[12] Americans will accept added costs if they are convinced that the money is being spent wisely, fairly, and efficiently, if the blueprint for improvement is clear, and if they begin to see significant results within a reasonable period of time. The Commission is confident, therefore, that citizens will accept additional costs for mathematics, science and technology education if the importance of such education to our Nation is supported by its leaders and is recognized by its people.

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education officials, state legislators, chief state school officers, state boards and departments of education and governors, as well as many other groups and individuals, are all involved in this complex balancing of interests, expertise and control. Resistance to change can range from reflexive avoidance of the untried, through sincere disagreement with the proposed course of action, to deep-seated opposition on the part of the politically entrenched. At the same time, this very diversity constitutes the system's strength—its innovativeness, its adaptability to local needs, and its stability. Once mobilized, it can be a powerful force.

11. These long-term economies will be widespread even if some may be subtle to detect. Not only would educational reform result in the delivery of better education at lower unit costs, but it would relieve governments of the public expenses connected with aid to those who cannot hold a meaningful job, relieve private and public employers of some of the costs to train their employees, create greater productivity, and relieve the military of some expenses connected with training ill-prepared recruits.

12. See footnote 10. In outlining the dimensions of the elementary and secondary school problem, the Commission identified several areas of particular concern which included the need to increase public awareness of the problem and to involve the public in fashioning the solution. But, as stated there, and after further deliberation, we are even more convinced that if there is a dominant focus of responsibility it is the public itself, whose values determine as much as they reflect the conditions of the schools.

BUILDING A NEW NATIONAL COMMITMENT

A continuous process to increase and then maintain America's interest, support and involvement in elementary and secondary education is essential. In order to stimulate widespread support for excellence in mathematics, science and technology education, the Commission finds that *four* national efforts are required.

A. National Leadership is Essential

One of the most important roles of national leaders is to call attention to national problems and to impress upon the public the need for constructive change. The President and leaders of Congress, therefore, must endeavor to make the public aware of the need to improve mathematics, science and technology education in the Nation's elementary and secondary school systems. It is essential that the President and other national political leaders continue to direct the attention of the American people to the problems, performance and potential of elementary and secondary mathematics, science and technology education. Members of Congress, the Secretary of Education, the President's Science Advisor, the Director of the National Science Foundation, Governors, Mayors and other state and local officials must assist in this vital effort. These efforts should emphasize that all students have the ability to learn mathematics, science and technology, that all Americans must be provided with the opportunity to develop their abilities in these fields, and that such skills will be a fundamental prerequisite to successful living in the coming century. It is critical that our leaders also encourage a commitment to "educational excellence" among students, teachers, parents, local school board members, business executives, military leaders, labor leaders and other influential people.

B. Prestigious Councils Are Needed to Guide the Process

Neither a series of Presidential, Cabinet or Congressional speeches nor a significant increase in Federal, state and local expenditures can, by themselves, achieve the objective called for by this Report. Nor can all the necessary changes be implemented at once. Rather, the goal will require a continuous process over the next 12 years (and thereafter). Achievement of the 1995 goal will require the establishment of a highly visible, viable process to identify and preserve what is excellent in our present structure while encouraging constructive change throughout the entire American educational system. National, state and local priorities must be set to accomplish the most critical and workable tasks first. Many sectors of American society must work together in order to implement the fundamental changes needed to achieve our basic goal. The first major recommendation of this Commission, therefore, is that Education Councils be established without delay at the national and state levels to provide focus, coordination, direction and mid-course corrections (as necessary) to achieve constructive change, and that local communities take appropriate steps to form partnerships with institutions and individuals who can aid in the educational process. Thus, the Commission recommends:

- The President should immediately appoint a National Education Council[13] made up of representatives from a cross-section of national interests. This Council should report regularly to the President. It should provide leadership in developing, coordinating and implementing plans to improve and maintain the quality of the Nation's elementary and secondary education in mathematics, science and technology. The President's National Education Council should, on a continuing basis, (1) identify national educational goals and recommend the changes needed[14] in the form and content of education to achieve them; (2) ensure that the assessment mechanism described below is developed and maintained for measuring and comparing student achievement, participation and progress toward these goals in every State, school district and school; and (3) monitor and report annually to the American people on the status of American education and progress toward achieving the new educational goals. It should also facilitate the sharing of information about successful mathematics, science and technology educational programs. Finally, the President's National Education Council should recommend incentives to encourage state, local and private investment in education.
- At the state level, the Commission recognizes and endorses the establishment of Governors' Councils as recently recommended by the Education Commission of the States' Task Force on Education for Economic Growth. Many States are already taking steps of this nature, and the Commission recommends that each Governor should immediately form such a Council with representation from key sectors with interests in elementary and secondary education (for example, government officials, educators, school board members, professional scientists and engineers, business, labor and industry leaders and parents).

13. The Commission strongly emphasizes that all academic areas are important to an educated citizenry. For this reason, we recommend a National Education Council that will consider the overall quality of education. This Commission's recommendation is, however, limited to a delineation of the National Education Council's responsibilities with respect to mathematics, science and technology education. If the National Education Council's activities are so limited, a more appropriate designation might be the President's Council on Mathematics, Science and Technology Education.

14. As stated on page 41 below, the Commission is not recommending a centrally controlled educational system or that a national curriculum be developed. In fact, the Commission recognizes that many important developments occur at the state and local level. What the Commission seeks is a process to get these developments widely disseminated.

These Governors' Council should develop educational goals for their States, monitor progress toward those goals, and make recommendations for the improvement of education—particularly in mathematics, science and technology. They should help generate public support for necessary improvements. They should encourage local boards of education to set higher standards and to monitor and evaluate progress, and they should facilitate the exchange of information among school districts, with the President's National Education Council, and with the Governors' Councils in other States.

- Due to the variety and diversity of American communities, it is neither desirable nor possible to be specific as to the appropriate mechanism for inducing change at the local level. However, the Commission strongly recommends that local school boards foster partnerships between the school board, school administrators, local officials, business and industry, labor leaders and parents in order to facilitate constructive change. They should encourage business and other institutions not primarily involved in education to become active participants and lend fiscal, political and other support to the local education system. They should help to further plans for improving educational offerings that stress mathematics, science and technology, rigorous curricula, and high standards of student and teacher commitment and performance. They should encourage parental involvement in all these efforts. One mechanism which might, in certain situations, be appropriate is the establishment of local councils on mathematics, science and technology education.

C. Periodic Objective Measurement of Achievement and Participation is Essential to Determine Progress

In order to evaluate how far the Nation has progressed toward meeting the Commission's educational goal, we must know where the Nation stands now and at each step on the way. Today, the Nation's best students rank equally with those of any other nation. But it is clear that average American student achievement and participation levels in mathematics and science rank low among advanced countries of the world. There are, moreover, few national benchmarks with which to make comparisons among the various States and school districts.

Clearly, therefore, an improved national assessment mechanism is needed to enable local communities, States and the Nation to monitor their progress toward improving mathematics, science and technology skills among elementary and secondary students and to incorporate such information into their program development activities. These regular assessments should build on the present work of the National Assessment of Educational Progress[15] and allow

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15. The National Assessment of Educational Progress (NAEP), begun in 1968, was originally conceived as a comprehensive measure of the results of American education. Goals, objectives and subsequent banks of specific test items were developed to cover the range of subjects taught in elementary and secondary schools. These activities were initially supported by the Department of Health, Education and Welfare and then, after its creation, by the Department of Education.

for the direct measurement of student achievement and participation against the Commission's primary objective—the highest quality education and highest participation level in the world by the year 1995.

Such a national assessment mechanism, if it is to provide a true benchmark against which Americans can evaluate the effectiveness of their schools, must cover knowledge and competencies which all students should possess. These include the ability to write for a purpose, apply higher-level problem-solving skills, and analyze and draw conclusions, rather than minimal basic skills such as the rote memorization of facts. The content covered should reflect the most up-to-date knowledge in mathematics, science and technology, and the tests should use the most up-to-date testing techniques.

The mechanism should also provide for the widespread dissemination of results and promote the recognition that "excellence in education" should be the standard for *all* students. The Commission firmly believes that achieving its educational objective requires regular monitoring of educational progress, and that such monitoring will itself increase the speed of change.

Thus, the Commission's second major recommendation is that:

- The Federal government should finance and maintain a national mechanism to measure student achievement and participation in a manner that allows national, state and local evaluation and comparison of educational progress. This assessment mechanism should be overseen by the President's National Education Council. The actual assessment, however, should be performed by the groups responsible for the National Assessment of Educational Progress or other such entities experienced in testing procedures and techniques.

D. A Strengthened Commitment At All Levels of Government to Ensuring Quality Education for All American Students is Required

The plan of action recommended in this Report is intended to keep the achievement level high for the students already performing at a superior level, but at the same time, to improve the quality of education provided to *all* students. Thus, incentives and opportunities must be offered for enrichment and acceleration of the education of our most talented youth. The system must also, and at the same time, raise the mathematics, science and technology skills of students who will pursue technical careers, and increase the general level of understanding of future managers, workers and consumers. In short, the educational system must provide opportunity and high standards of excellence for all students—wherever they live, whatever their race, gender, or economic condition, whatever their immigration status or whatever language is spoken at home by their parents, and whatever their career goals.

This focus on all students reflects the Commission's view that America's security, economic health and quality of life are directly related to the mathematics, science and technology literacy of all its citizens. The opportunity to learn mathematics, science and technology is at present not fairly and evenly provided to all students. Students of high potential are too often deprived of the opportunity to utilize their abilities fully. In the past, such inequalities have resulted from a failure to recognize and develop potential talent, from inadequate educational programs in some communities or for certain groups of students, and from the erroneous belief that many students lacked the ability to learn mathematics and science.

Although progress has been made in recent years, unacceptable disparities in achievement, participation and opportunity still exist. For example, black and Hispanic 17-year-olds scored significantly lower than their white counterparts on the national mathematics assessment in 1982. The national norm was 60.2%. White students scored 63.1%, blacks scored 45.0% and Hispanics scored 49.4%.[16] In addition, although the differences are diminishing, there are still fewer females choosing to take advanced mathematics and physical science courses than males.

By 1995, there will be almost 30 percent fewer college-age students for the work force.[17] Furthermore, upwards of 40 percent of these young people will be black or Hispanic, the very groups who, for no reason related to inherent ability, are now at the bottom of the educational and economic ladder. Such disparities mean that the Nation continues to suffer from the inadequate development and utilization of its human resource potential. The Nation cannot afford educational casualties.

All of the evidence reviewed by the Commission demonstrates that disparities in test results are not based on the fact that students of different races, students whose parents do not speak English in the home, or students from disadvantaged socioeconomic backgrounds have inherently different potentials. Indeed, the low achievement scores of a significant proportion of such students can be traced directly to both blatant and subtle racial discrimination (including stereotyped racial attitudes), extreme poverty, and, in some cases, unsatisfactory rural or urban conditions.

The Commission finds that there is a striking relationship between achievement in mathematics, science and technology and the early exposure of students to stimulating teaching and good learning habits in these fields and enrichment by regular exposure to informal educational activities. The skillful and early introduction of mathematics, science and technology in the elementary schools, therefore, is critical.

These experiences, for societal reasons, are frequently unavailable to many racial minorities, those whose parents do not speak English at home, and those who are economically disadvantaged. The Commission found, however, that when they are exposed to a good learning environment, these students perform as well as any. Low achievement norms do not reflect ability; they reflect a lack of preparation and early exposure.

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16. Education Commission of the States, *The Third National Mathematics Assessments: Results, Trends and Issues*, Denver, CO: National Assessment of Educational Progress, Education Commission of the States, April 1983, pp. 33-36.

17. U.S. Department of Commerce, *Projections of the Population of the United States: 1982-2050* (Advance Report), Washington, DC: U.S. Department of Commerce, Bureau of the Census, Series P-25, No. 922, October 1982.

The Commission believes that in any achievement testing program minorities and other disadvantaged youth should be judged on the same basis and held to the same standard as other students. The creation of a different set of standards for special groups should be avoided. All students should be encouraged to achieve a higher standard rather than have standards reduced to enable some schools to avoid the challenge altogether.[18] The true test as to whether a school, a school district, or a State is doing a good job of educating its students is not only achievement, but also the distribution of that achievement—whether progress is being made without regard to race, economic condition, immigration status or language spoken at home.

Discrimination and other disadvantages due to race, gender, ethnic background, language spoken in the home or socioeconomic status and the lingering effects thereof must be eradicated completely from the American educational system. Our Nation needs full participation by all of its citizens in education and employment to address the problems it faces and to carry out the constitutional commitment that race and other irrelevant factors, such as gender or poverty, have no place in education. Thus, the Commission's third major recommendation is:

- Each school district should adopt and carry out programs which will identify and eliminate those barriers to full educational opportunity which discriminate against or otherwise place at a disadvantage elementary and secondary students on the basis of race, gender, ethnic background, language spoken in the home or socioeconomic status. Programs are needed in mathematics, science and technology that reach all students and stimulate each to achieve an understanding of these subjects that is limited only by his or her talent and temperament. The unique national role of the Federal government (including important Department of Education and National Science Foundation programs) in ensuring access in its broadest sense to educational opportunity must continue.

The emphasis in the past few pages on equality of educational opportunity is absolutely essential to the Nation's commitment to excellence. It is crucial that programs for minority and economically disadvantaged students and for students whose parents do not speak English at home continue to strive for the same level of excellence as other programs. As Commissioner John B. Slaughter said in his inaugural address as Chancellor of the University of Maryland at College Park: "Excellence and elitism are *not* synonymous. Too often we equate the notions of affirmative action, nontraditional student, or continuous education with mediocrity. We must open our doors to create educational opportunities for a wide variety of students, and we must recognize the potential for excellence in a diverse student body. Equality and quality are not mutually exclusive!"

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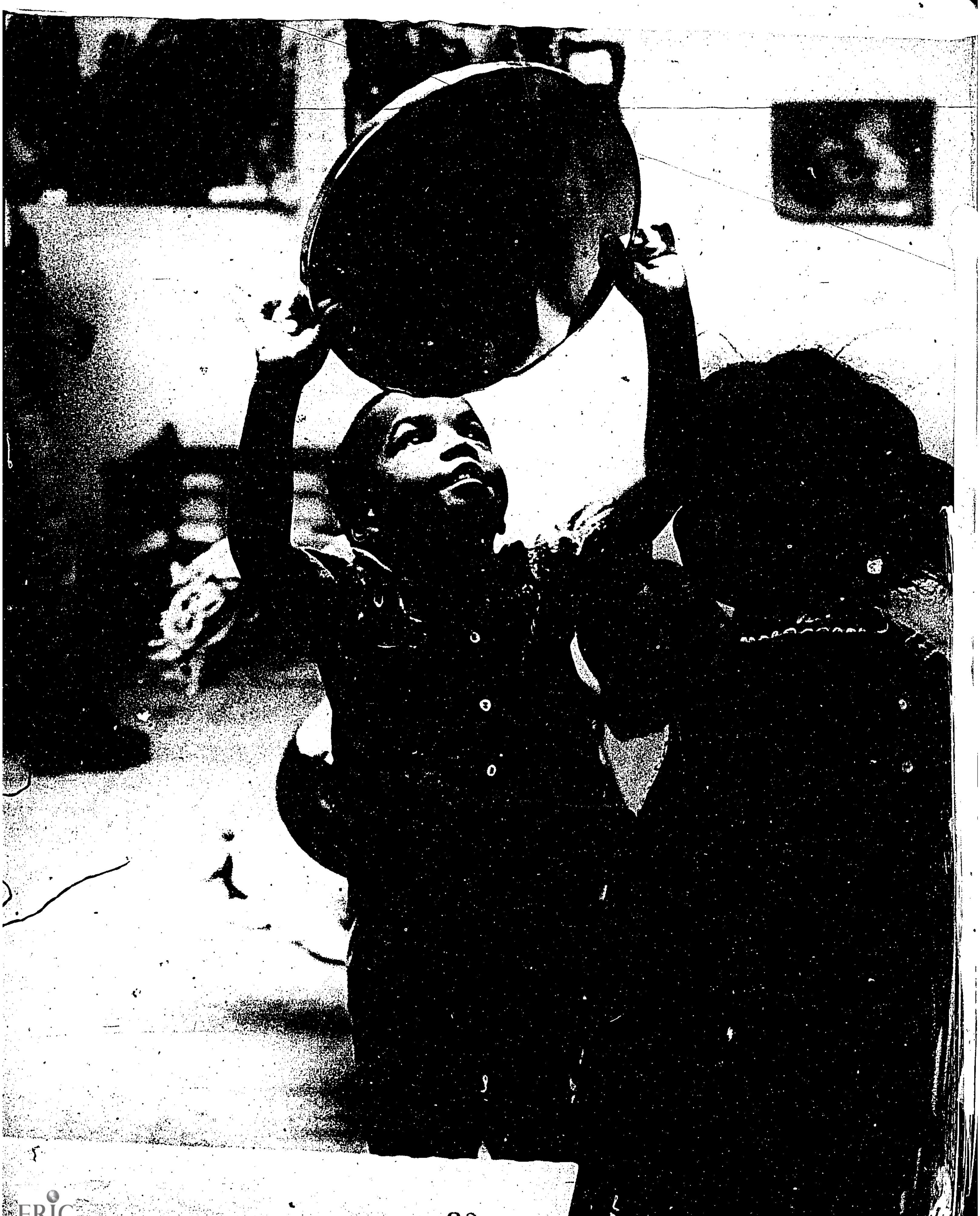
18. Over the past decades, there has been increasing discussion of the need to address differing student backgrounds, experiences and abilities. Those artificial disadvantages which handicap the child just entering school must be eliminated so that such a child has an equal opportunity to benefit from good teaching and appropriate curricula.



POINTING THE DIRECTION FOR WIDESPREAD DRAMATIC CHANGE.

The problems of American education can be solved. The job can be done within the American system—and without sacrificing either our goals or our standards. The successful practices and performance of other countries have been reviewed and valuable lessons have been learned. This Commission also has learned a great deal from testimony received, studies commissioned, research conducted, discussions held and visits to programs and schools.

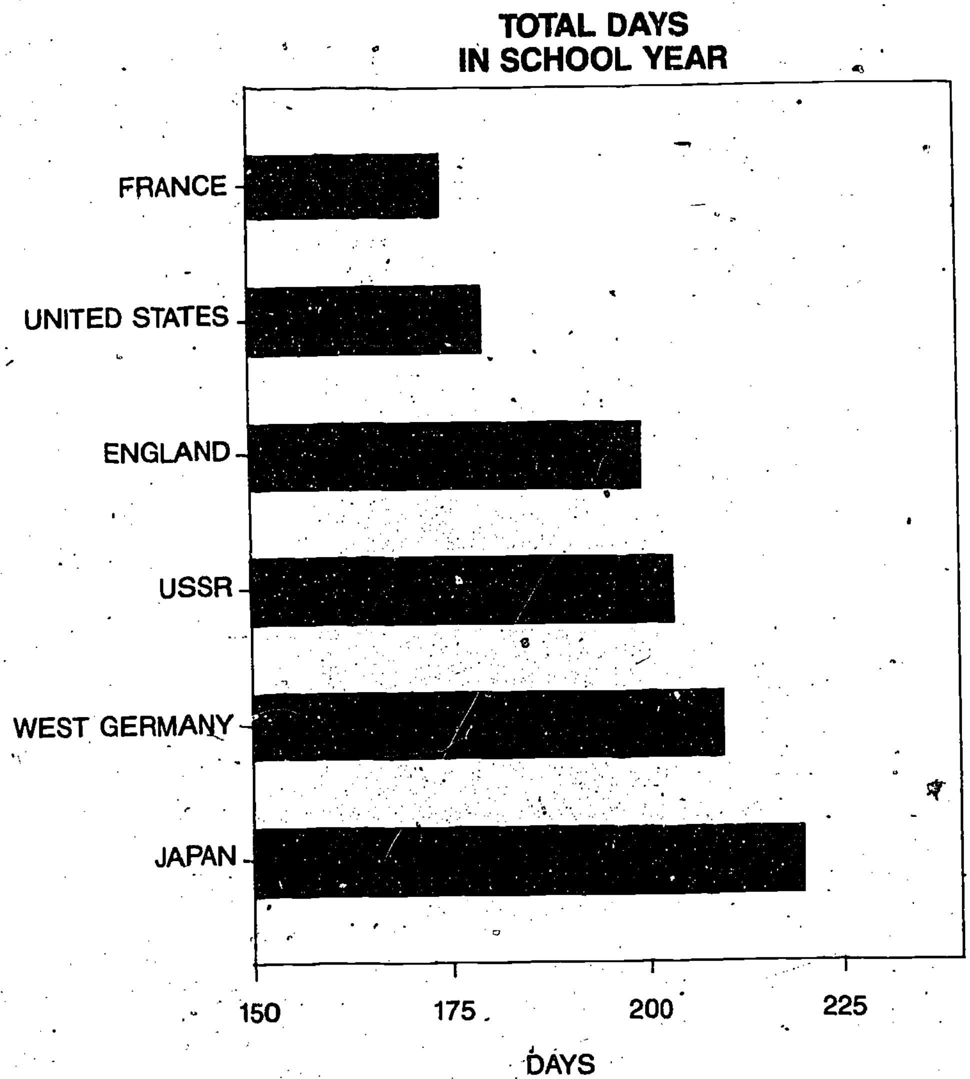
Importantly, successful American programs demonstrate that students from every background can reach high levels of participation, skill and achievement. The problem is that these highly successful programs are isolated pockets of "educational excellence" and not the norm. The Commission believes that a close look at these successful programs points the direction for constructive change. Widespread adoption of the elements responsible for the successs of these programs will be a key step toward achieving world leadership in mathematics, science and technology education by 1995.

A. Lessons From Other Countries

An obvious comparison to make is with Japan, because it is often viewed as a major international competitor and shares many of America's educational goals. Similar conclusions, however, can be drawn from other highly developed countries (see charts below). In the first international mathematics survey in 1964 and the first international science survey in 1970–1971, the achievement scores of U.S. students tended to be the lowest in both mathematics and science, at least as far as 18-year-olds were concerned.[19] The results of the Second International Mathematics Study are expected to be similar and will be published in the summer of 1984; those of the Second International Science Study will not be published until 1985.

Japan, like America, pursues the goal of universal education. The top students in both nations score equally well in mathematics and science achievement tests. But the remaining 90 percent of Japanese pupils do far better than their American counterparts. The variation in mathematics and science achievement scores among Japanese students in the same grade is said to be relatively

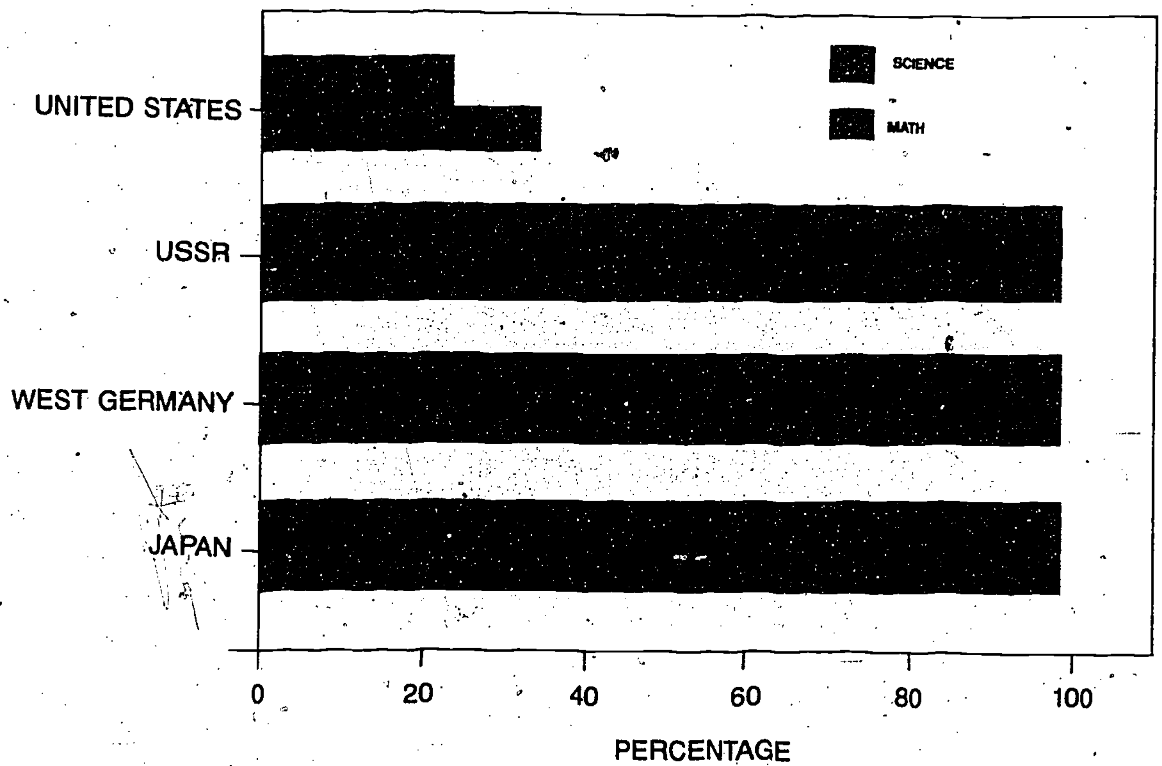
19. The achievement tests referred to here were part of the International Assessment for the Evaluation of Educational Achievement. For a summary, see Torsten Husen, "Are Standards in U.S. Schools Really Lagging Behind Those in Other Countries?", *Phi Delta Kappan*, March 1983, pp. 455-461.



Note: The average length of the school day in the U.S. is 5½ hours, whereas it ranges from 6 to 8 hours in the other countries. In Japan, more time is spent with after school tutoring and homework than in the U.S. 36% of Japanese high school seniors report spending more than 10 hours per week on homework contrasted with only 6% of U.S. seniors. In the U.S., 52% of seniors report spending less than 5 hours per week, in Japan only 8% of seniors report spending less than 5 hours per week. (Source: William B. Fetters, Jeffery A. Owings, Larry E. Suter and Ricky T. Takai, "Schooling Experiences in Japan and the U.S.: A Cross-National Comparison of High School Students," a paper presented at the 1983 Annual Meeting of the American Educational Research Association in Montreal, Canada, 13 April 1983.)

Source: *A Challenge for American Precollege Education: Scientific Literacy in Japan, China, the Germanies and the Soviet Union*. edited by Margarete Klien and F. James Rutherford. New York: the Macmillan Company (in press). Data on school year also provided by the Embassy of France and The British Embassy, washington, DC, August 1983.

PERCENTAGE OF "HIGH SCHOOL" STUDENTS TAKING 3 YEARS OF SCIENCE AND MATHEMATICS



Note: While all students study mathematics and science (at least one course) each year in the upper secondary school in Japan, West Germany and the U.S.S.R., the most recent NAEP data (1983) indicate 84% of U.S. students *do not* take physics, 65% *do not* take chemistry, 62% *do not* take Algebra II, 48% *do not* take geometry and 23% *do not* take biology.

Source: National Center of Educational Statistics, *High School and Beyond*, Washington, DC: National Center for Educational Statistics (NCES 81-244), April, 1981 and *A Challenge for American Precollege Education: Scientific Literacy in Japan, China, the Germanies and the Soviet Union*, edited by Margrete Klein and F. James Rutherford, New York: The Macmillan Company (in press).

narrow. For American students the variation at the same grade level is much wider.

These results strongly suggest that Japan is doing much better than the United States in realizing the goal of having *all* students learn science and mathematics. This is ironic, since the Japanese school system, reconstructed in 1945, was closely modeled on our own.

What accounts for the great disparities in performance? Two key answers, the Commission finds, are *time-on-task* and *motivation*. Japanese students attend school 220 days a year. American students go to school 180 days a year (and are absent more often than the Japanese) During the school day, Japanese children spend two-thirds or more of their time on academic subjects. Over 12 years of schooling they average 26 percent of their time on mathematics and science. Their American counterparts spend far less time on these subjects from the first grade on. For example, in the primary grades, U.S. students average less than 20 minutes a day on science. In terms of class hours, a typical Japanese secondary school graduate will spend three times the number of hours in science than even those U.S. students who elect four years of science in high school.

The premise in Japan is that all children can and must do well in mathematics, science and other academic areas. This expectation of excellence stands in sharp contrast to what is demanded from students and teachers in many American schools.[20]

Reflecting this commitment, Japanese school systems put a high priority on mathematics and science education from the earliest grades. Their mathematics and science curricula are structured vertically—beginning very early and continuing through most of secondary school. In the United States, mathematics and science are rarely taught in a coordinated manner or in an organized sequence at the elementary school level. At the secondary level, science courses usually lack coordination and continuity from one course to another. Japanese expenditures on supplies and instructional materials are far greater than ours.

Teachers and outside tutors are considered highly important in Japanese society. In contrast to the United States, the status and salaries of teachers in Japan are higher than many other public servants. Japan has established more than 200 science teaching centers, where teachers continue their professional development.

In making such comparisons, it is important to recognize that the Japanese educational system, like those in most other developed countries, is centrally directed and is characterized by basically a culturally homogeneous student population. This has significant disadvantages as well as advantages. While 94 percent of Japanese students currently graduate from high school (compared to 74.5 percent in the United States in 1981), only those who pass an all-important rigorous examination in grade 12 are admitted to a university. Consequently, opportunities for higher education and upward social mobility are limited. This

20. Kay Michael Troost, "Society and Science Education in Contemporary Japan," *A Challenge for American Precollege Education: Scientific Literacy in Japan, China, The Germanies and the Soviet Union*, edited by Margrete Klein and F. James Rutherford, New York: The Macmillian Company, (in press).

is especially true for females who are less than a third as likely to obtain a college degree as males.

The American system provides enormous and unique mobility. The exceptionally high proportion of our youth who attend college (60 percent of high school graduates, equivalent numbers of males and females, half of whom complete college) are able to pick and choose among areas of study, switch their interests, and shift careers quite late in life. There are few irretrievable decisions. Given the fast-changing occupational and human resource demands of our evolving economy, this flexibility provides the Nation great strength and resilience.

Equally important, America's students and its educational system are much less culturally homogeneous than those of other countries. Our schools reflect a broad diversity of racial, national, cultural and economic backgrounds that characterizes the Nation as a whole.

This Nation's unique educational system seeks to promote independent thought and judgment, analytical capacity, and the maximum development of each individual's potential. American scientists and mathematicians excel in theoretical and experimental science and mathematics and gain world-wide recognition as original thinkers and leaders in their fields. America also leads in the application of such knowledge to original and breakthrough technology. We are respected throughout the world for our commitment and contributions to the generation of new knowledge. Americans can take pride in this; our educators continue to produce the best in the world despite difficult and demanding problems.

Thus, foreign examples do not offer a simple and unmitigated formula for our Nation. Rather they reaffirm the value of traditional American virtues: *commitment, motivation* and *hard work*. The challenge facing the United States is to find ways of matching the participation, achievement and other positive aspects of monolithic educational systems, while preserving the unique strengths of America's diverse educational system.

B. American Successes

Most characteristics of foreign success are not unique. A significant number of American schools already meet the challenge of "academic excellence," and many of the Commission's recommended steps for improvement have already been demonstrated in this country. Some examples are discussed in this Report; others are set forth in Exhibit A. These impressively successful programs are marked by common characteristics similar to those found in successful foreign programs. These characteristics are:

—agreed upon, clearly defined educational goals

—dynamic and knowledgeable leadership

—committed, motivated, knowledgeable and resourceful principals and teachers

—administrative flexibility

—opportunities for, and willingness of, teachers to interact and exchange ideas.

—a specific student commitment

—programs and instructional techniques which motivate the students

—sufficient time-on-task

—demanding standards of participation and achievement

—a coherent course of study in mathematics and science, with early "hands-on" experience

—early exposure to good teaching in elementary school

—adequate resources

—innovative use of available facilities

—extensive homework

Committed teachers, administrators and students, in an environment that values and rewards achievement, that makes optimum use of available resources and that fosters a sense of trust and community, are essential to educational success. Three overriding lessons can be learned from such successful programs and their learning environments that form the basis for most of the specific recommendations for improvement found in this Report.

(1) Quality Teaching is Critical

If mathematics, science and technology are to be successfully learned, it is clear that the teachers must be of high talent, high motivation and must be allowed to function in a setting in which effective teaching is possible. So important is the quality of teaching to the success of America's educational system that the Commission sets forth the outline of a comprehensive plan to retrain elementary and secondary school teachers in relevant aspects of mathematics, science and technology (see pp. 29–32 and Exhibit C, p. 110). Properly managed, this plan would provide the needed retraining of the Nation's 1.17 million elementary and 200,000 secondary school mathematics and science teachers within five years. Therefore, the Commission recommends:

- Top priority must be placed on retraining present teachers and recruiting and retaining teachers in mathematics, science and technology so that they all will be of high quality. Such teachers must be provided with a work environment in which they can be effective.

(2) Early Exposure is Critical

Early and substantial exposure to mathematical and scientific concepts and processes is critical to later achievement. Early creative and stimulating experience is essential to truly equal opportunity and to effective and continuing study in these fields (see pp. 39, 41–47). Thus, the Commission recommends:

- Top priority must be placed on providing increased and more effective instruction in mathematics, science and technology in grades K-6.

(3) Increased Time for Teaching of Mathematics, Science and Technology is Required

The Commission finds that our students spend too little time in the course of their schooling in the study of academic subjects (particularly mathematics, science and technology), and devote too little time to "hands-on" experiences. To remedy this situation, schedules must be changed, more time must be devoted to the teaching of mathematics, science and technology, and ways must be found to use time more efficiently and effectively. Schools must become more efficient in the use of their academic day. Many nonacademic courses now offered may have to be reduced or eliminated, or ways found to teach them more efficiently and effectively, or not within the normal school day.[21] The school day, week and/or year must be lengthened to provide the required time. These important and necessary changes are discussed in greater detail below (see pp. 39–48.)

The Commission recommends:

- Considerably more time should be devoted to the study of mathematics, science and technology throughout the elementary and secondary grades. Consequently, the school day, week and/or year must be substantially lengthened.

C. Exemplary Programs—Catalysts for Change

The Commission has observed that innovative and exemplary programs (some types of which are sometimes referred to as "magnet" or "model" programs[22]) often provide dramatic examples of excellence and can be a powerful tool for educational change. Communities such as New York, Chicago, Atlanta, Houston, and States like North Carolina and Louisiana have multiplied or leveraged the effects of their limited financial resources by establishing "magnet" schools or "model" programs. They have combined quality teachers, committed and promising students, committed parents, innovative use of facilities, demanding standards and increased time-on-task. The result: impressive gains in student academic achievements.

Contemporary "magnet" schools have been designed to maintain the American emphasis on open access while stressing motivation, commitment and discipline—all crucial aspects of education. Some have moved from the original concept that they were only for the highly talented. These programs, based on a philosophy of inclusion rather than exclusion, are now open to any student sufficiently motivated and willing to meet the requirements of the school. In such a setting, the likelihood of academic success is substantial since students become willing—even eager—participants.

21. The Commission is not urging the dropping of sports or such important training as automobile driver education. But such activities should not be at the expense of school time which is required for mathematics, science, technology and other important academic courses like English, foreign languages, history, etc.

22. Early "magnet" schools like Boston Latin, Philadelphia's Central High School, Washington's Dunbar, San Francisco's Lowell and the Bronx High School of Science were based on intellectual achievement measured in the eighth grade. However, more recent exemplary schools, as stated in the text, have been based on student and parental commitment—commitment to work harder for a better education.

Such programs have taken various forms to fill varied needs.[23] Some versions utilize a local school, with specialized equipment, facilities and programs. Others are weekend programs. Still others commit students to begin school before the normal starting time or continue after the end of the normal school day. Some programs select students on the basis of talent, some on the basis of commitment. The objective is an exemplary educational program. In many cases, a new environment must be created through a strategy such as starting a school afresh as a "magnet" or "model" school, whereas in other cases school leadership is such that the optimum environment can be developed within existing structures. When visited by the Commission, leaders at these successful contemporary schools uniformly reported that their programs are neither divisive nor solely for the affluent. More specifically, the most important findings are that the most effective of such exemplary schools generally:

—have better academic achievement, better attendance, and usually fewer behavior problems;

—provide quality education for average as well as above average students;

—have strong leadership and support from the superintendent and school board;

—can have strong links to other community resources, such as universities, businesses, hospitals, and theaters;

—are, wherever possible, racially and ethnically integrated and usually reflect the larger population they serve. They often operate in an environment of reduced racial tension, as parents and students identify special programs that appeal to them;

—succeed equally well in "good" and "bad" neighborhoods, as long as they provide a quality learning environment;

—can be created, organized, and managed well within the administrative capabilities of all but perhaps extremely small school districts.

Some problems can be more realistically addressed within school systems by creating islands of excellence rather than by attempting immediate system-wide changes. When multiplied over time, such exemplary programs have the potential of building to a critical mass and transforming American education. Thus, ultimately the exemplary school can become the norm.

Moreover, such exemplary schools in science, mathematics and technology can also serve as laboratories for the development of curricula, teacher training, pilot materials, and instructional strategies for dissemination to other schools. Special attention must, of course, be focused on forging linkages with other schools. New ways of sharing resources and linking faculties must be developed and implemented.

Therefore, the Commission's recommends:

- The Federal government should encourage and finance, in part, the establishment of exemplary schools or programs in mathematics, science and technology in each community throughout the Nation to serve as examples and catalysts for upgrading all schools.

23. A number of impressive examples are summarized in Exhibit A.

- The Federal government should evaluate current resource allocation policies, entertain redistribution[24] and, where necessary, appropriate funds to support the development of such programs.
- The Department of Education and the National Science Foundation should support and facilitate the dissemination of information to help build this national network of exemplary programs.
- State governments should study and promote, and local school districts should establish, such schools or programs in mathematics, science and technology in each community,[25] to serve as examples for upgrading all schools.
- The Commission estimates, based on differences in sizes of communities and on the number of existing exemplary schools, that, as an effective initial step, the Federal government should appropriate funds to aid the establishment by local communities of at least 1,000 such exemplary schools at the secondary level and at least 1,000 such schools at the elementary level throughout the country.

The Federal cost will require an appropriation of $829 million in the first year, but these funds will be disbursed at a rate of $276 million per year over a three year period. (Exhibit C, p. 109)[25a]

The Commission is not suggesting that establishing more such exemplary programs alone will accomplish the primary goal of this Commission: improving the academic performance, especially the mathematics, science and technology achievement, of the entire range of students by 1995. Indeed, we have seen many examples (listed in Exhibit A) where neighborhood schools are achieving excellent educational results within existing budgets. The Commission, moreover, would not like to see the majority of resources or all talented teachers move from regular schools into such schools.

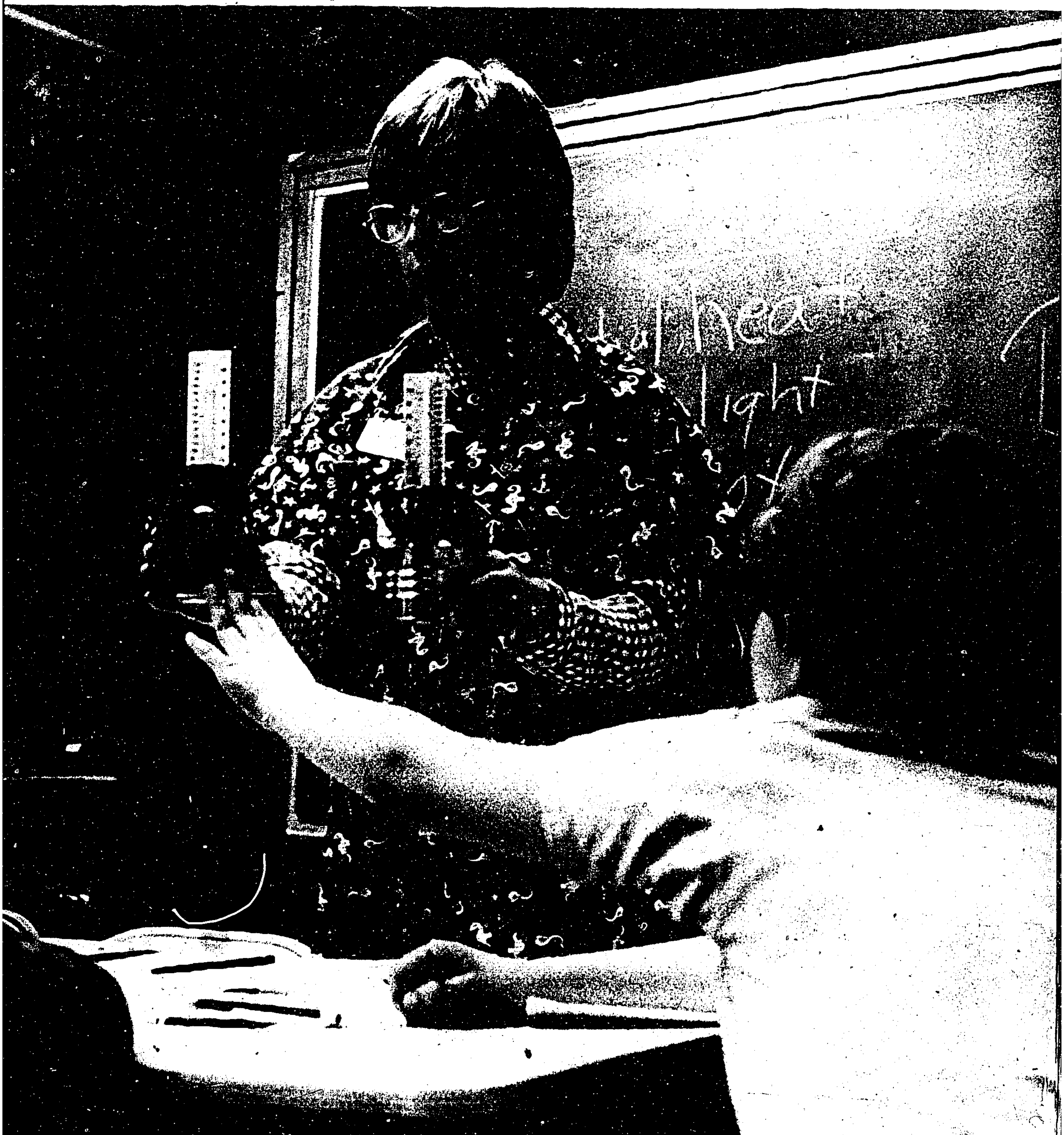
Most communities, however, lack sufficient resources of time, talent and money to restructure completely their mathematics, science and technology education programs at one time. In the meantime, exemplary programs can provide a substantial improvement for those students who are already motivated and ready to learn. Such programs, moreover, will provide a format for emulation by other schools in the school district or State—a major step toward a more general level of excellence.[26] By applying broadly the characteristics of the schools which use the approaches set forth above, these programs—especially the underlying philosophy—will, the Commission is confident, have a significant impact.

24. All Federal programs, whether or not dealing with education, should be evaluated.

25. Extremely small communities can benefit by having exemplary classes or, where distance allows, by having joint exemplary schools and programs.

25a One Commission member feels that the plan to create 1,000 exemplary secondary schools and 1,000 exemplary elementary schools is too ambitious. That member feels that the number should not exceed 1,000 of such schools and that the Federal costs per school should be $100,000.

26. These same exemplary schools and programs could also be vehicles through which teaching of other subjects, such as English and foreign languages, history, political science, the classics, art, music and other important disciplines can be conducted in the same innovative fashion.



SOLUTIONS TO THE TEACHING DILEMMA

The teacher is the key to education—the vital factor in motivating and maintaining student interest in mathematics, science and technology. This opportunity to have a direct impact in the course of students' lives has always been one of the important rewards of teaching. The Commission has seen and heard of many cases where the commitment and creativity of a particular teacher profoundly affected the lives of his or her students. As Justice Oliver Wendell Holmes, Jr. said, in another context, in explaining his ability to render superb public service to the Nation: "Through our great good fortune, in our youth our hearts were touched with fire." Public misperception of science and mathematics as cold subjects makes lighting such fires particularly difficult—yet precious.

More well-qualified teachers will be needed for U.S. students to spend more time studying mathematics, science and technology, a major recommendation of this Report. Moreover, teachers must be able to communicate in a positive way the most current and appropriate information (see pp. 41–45 below). This is the most pressing problem facing mathematics, science and technology education today. Our Nation's educational systems must attract and retain qualified mathematics, science and technology teachers.

Despite this critical need, all available evidence suggests that there are currently severe shortages of qualified[27] mathematics, science and technology teachers in many parts of the Nation.[28] Fewer college students are entering the

27. The Commission is not using the word "qualified" as necessarily embracing the term "certified." Some certified teachers are not qualified and some qualified teachers may not be certified. (See also footnote 32.)

28. A study of teacher demand in all subjects from 1976 through 1983 (James N. Akin, *Teacher Supply/Demand: 1983* Madison, WI: Association for School, College and University Staffing, 1983.) found the most severe teacher shortages in mathematics, physics and chemistry. Trevor Howe and Jack A. Gerlovitch found 42 states reporting problems in recruiting adequate secondary school mathematics, physics and chemistry teachers in 1982 (Trevor G. Howe and Jack A. Gerlovich, *National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers: 1980–1982*, Ames, Iowa: Iowa State University, November 1982). A National Science Teachers Association survey of college and university placement officers (James A. Shymansky and Bill G. Aldridge, "The Teacher Crisis in Secondary School Science and Mathematics," *Educational Leadership*, November, 1982, pp. 61–62) found that between 1971 and 1980, students enrolled in practice teaching courses in mathematics declined fourfold and science threefold, and only half of these student teachers ended up in teaching jobs. The survey also found that almost 25 percent of those currently teaching secondary school mathematics and science plan to leave in the next five years. The American Council on Education's longitudinal study of higher education (Alexander W. Astin, Margo King Hemond and Gerald T. Richardson, *The American Freshman: National Norms for Fall 1982*, Los Angeles, CA: University of California at Los Angeles, December 1982) reports that the 22 percent of entering college freshmen choosing education as a major field in 1966 dropped steadily to 4.7 percent by 1982.

teaching profession, particularly mathematics and science teaching, and increasing numbers of experienced teachers of mathematics and science are leaving. In 1980-81, four percent of these teachers left for more attractive careers, primarily in business and industry—a rate five times the loss due to teacher retirement.[29]

The declining interest in teaching has been accompanied by a decline during the 1970s in the academic potential, as measured by SAT scores, of students planning to major in education. By 1982, these scores were 80 points below the national average.[30] More striking, perhaps, is the fact that the Commission found virtually no examples of high- or even adequately-achieving students in mathematics and science who were being encouraged to enter elementary and secondary school teaching. In part, the decrease in the numbers of highly capable teachers is being adversely affected by salutary developments in American society. As the barriers of race and sex discrimination come down, those members of minorities and those women who earlier only had teaching careers open to them now are often hired by business, or enter other professions such as law, medicine and economics.[31]

Because of the serious shortages of mathematics and science teachers that exist throughout the Nation, school systems have often been forced to disregard state certification requirements and fill the gaps with unqualified[32] instructors hired on an emergency basis.[33] In addition, certification requirements have tended to become less rigorous in recent years so that even when certified, teachers often have not been adequately prepared (qualified) to teach mathematics and science.[34] Equally serious is the fact that many classroom veterans have not upgraded their skills and knowledge—a necessity in rapidly evolving fields like mathematics and science.

29. James A. Shymansky and Bill G. Aldridge, "The Teacher Crisis in Secondary School Science and Mathematics," *Educational Leadership*, November 1982.

30. This difference is approximately 15 percentile points. Source: College Entrance Examination Board, *National College-Bound Seniors, 1982*, New York: College Entrance Examination Board, 1982.

31. As the Governor of Utah, Scott M. Matheson, said this spring in explaining a 50 percent decline in the number of teachers trained in the state over the last ten years, "The truth is that bright, capable women have been the mainstay of public schools for years. We have simply escaped paying them what their talents might have been worth because few other professions were open to them." Remarks of Governor Matheson to the Utah Educational Seminar, Salt Lake City: University of Utah, March 17, 1983.

32. The terms "certified" and "qualified" cannot be, and in this Report are not, used interchangeably. A qualified teacher is one adequately prepared to teach the subject. A certified teacher is one licensed to teach the subject, even if unqualified and licensed on an emergency basis.

33. The National Science Teachers Association found that half of the teachers hired nationwide in 1981 to teach secondary mathematics and science were unqualified. Only 15 percent of the mathematics and science teachers hired in the Pacific states region in 1981–82 were qualified. (See footnote 29.)

34. See, for example, *Recommendations for Improving the Quality of Science and Mathematics Education in North Carolina's Public Schools*, Raleigh, NC, North Carolina Board of Science and Technology and the State Department of Public Instruction, July 1982, Raleigh, NC.

The reasons behind these declines in quality and numbers of teachers are complex. They include the perception of teaching as a low status profession, the working environment of the profession, frustration with the low levels of student interest, inadequate training and certification standards which are ineffectively enforced, insufficient financial rewards, and a failure to provide long-term opportunities for advancement and satisfaction in the classroom. In some cases, certification procedures and standards are inappropriate barriers that prevent a truly qualified person from teaching.

The problem of attracting able people to the teaching profession will continue well into the next decade. The key to its solution lies in improving the effectiveness, status and attractiveness of teaching. Public prestige, the opportunity for fair and just compensation for all qualified teachers and recognition for the superior teacher are vital.

Most of the responsibility for addressing the problem lies at the state and local level. Many States are already diligently seeking ways to upgrade the standards for teacher certification, improve teacher training and compensation, and attract more and better students into the profession (especially into mathematics and science teaching, where the shortage is currently most pronounced). These efforts include extensive retraining and upgrading of skills, forgivable loans, scholarships and summer stipends, and fair and just compensation for the qualified and superior person who wishes to teach. Such efforts are to be commended, especially given the great pressure on state and local budgets. Steps must be taken immediately to ensure that the Nation has a sufficient number of qualified mathematics, science and technology teachers available to accomplish the objectives set forth in this Report by 1995.

A. Improving the Quality of Teaching

In order to improve the quality of teaching, substantial efforts must be made at three levels: (1) the skills and understanding of many current teachers must be upgraded; (2) the training of incoming teachers must be improved; and (3) in the interim, persons who are qualified to teach mathematics, science and technology must be found from "non-traditional" sources.

1. Upgrading Skills and Knowledge of Current Teachers

The quality and style of elementary and secondary teaching constitute the most obvious and immediate source of the problems facing mathematics and science education. New measures must be developed and exemplary materials and models disseminated for in-service training of large numbers of teachers. A substantial number of our Nation's 1.17 million elementary school faculty members lack sufficient knowledge, training and, in many cases, interest to teach mathematics and science effectively. In the short term, the use of special instructors to teach mathematics and science at this level would reduce the number of teachers who must be retrained. But the number needing retraining is still expected to total hundreds of thousands. Most of the Nation's 200,000 secondary mathematics and science teachers also require additional training because of the rapid development of new knowledge in mathematics and science and in cognitive psychology. Traditional summer workshops or institutes cannot accommodate this large a number of both elementary and secondary teachers and retrain them at a reasonable cost.

The Commission has concluded that the Federal government must play an important role in helping to provide such teacher training. However, a significant part of such training is the responsibility of state government, local school boards and teachers themselves.

Thus, the Commission recommends a combination of programs to provide upgrading of teachers:

- State governments should develop teacher training programs in mathematics, science and technology in cooperation with colleges, universities and science museums, and provide for academic year and summer programs to meet the particular needs of that State. (A number of States have already begun to do this.) In establishing these programs, industry scientists and engineers and certain government personnel should be encouraged to participate as teacher trainers when they have particular, needed expertise.

- The Federal government has a responsibility to ensure that such training is available and should provide funding for these teacher training programs in mathematics, science and technology. Summer and in-service institutes, supported by the National Science Foundation, provide a proven model for the upgrading of teacher skills.

- The potential of science museums as a site for teacher training programs should be recognized, encouraged and supported.

- The entire retraining and upgrading program should be completed in five years. The Commission estimates that the Federal share for the cost of such training is $349 million per year (see Exhibit C, p. 110.)[34a]

- For the long term, states and local school districts should ensure that teacher training continues as an ongoing process.

In the near future, such upgrading efforts should be supplemented by new communications technologies such as closed circuit TV, cable TV and interactive telecommunications. The new information technologies can provide on-site instruction which could be widely available to all teachers within five years and could be provided at a substantially lower cost than university or conference-site instruction.

34a. One Commission member feels that the plan to retrain 1.16 million teachers in five years is not workable since, in that Commission member's judgment, there are not sufficient facilities to complete the plan within the recommended time period. In the Commission member's judgment, either the plan should be completed over a longer time period or fewer teachers should receive training.

Therefore, the Commission recommends:

- The National Science Foundation should provide seed money to develop and establish state-wide or regional on-site teacher training programs using the new information technologies.

2. Establishing Higher Standards for New Teachers

At the same time that the knowledge and skills of in-service teachers are being upgraded, steps must be taken to ensure that new teachers who enter the profession also provide high quality teaching. States are responsible for setting certification standards.

Therefore, the Commission recommends:

- States should adopt rigorous certification standards for incoming mathematics and science teachers. Such certification standards should not set up any artificial barriers to entry into the teaching profession, but should be only those which are relevant to ensuring high quality in the teaching of mathematics, science and technology.

The primary requirement for elementary school teaching should be a comprehensive liberal arts education supplemented by a limited number of effective education courses together with demonstrated teaching, including appropriate internships under a highly qualified teacher. The primary requirement for secondary school teaching should be a full major in the subject matter to be taught, supplemented by a limited number of effective education courses together with demonstrated teaching, including appropriate internships under a highly qualified teacher.

States should set timetables and establish a process to ensure that all secondary teachers are certified and teaching in their field of speciality. Out-of-field teaching should be permitted only under extreme and carefully restricted conditions. Finally, local school boards and administrators should uphold these modified standards through teacher evaluation and hiring practices.

Institutions of higher education also have a crucial role to play in improving the training of new teachers. Currently, such institutions, particularly the colleges of liberal arts and engineering, give little evidence of interest in training elementary and secondary teachers or encouraging able students to enter the teaching profession. One contributing factor is that incentives and rewards in colleges and universities are heavily weighted towards research.

The Federal government should examine current policies of support to colleges and universities in order to identify ways of providing additional incentives for teacher training without jeopardizing the research effort. Ultimately, however, the primary responsibility lies with the Nation's colleges and universities themselves. Therefore, the Commission recommends:

- Institutions of higher learning should take steps to improve the quality of mathematics and science teachers, including the establishment of higher admission, curriculum and graduation standards for such future teachers.

The process of change is already underway in a number of colleges and universities and other institutions of higher education are urged to follow. Substantial improvement will be realized if the following steps are taken:

—Liberal arts colleges need to assume a much greater role in training elementary and secondary mathematics and science teachers.

—Basic education courses required of prospective teachers should be thoroughly reviewed and revised to incorporate the findings of recent research in behavioral and social sciences.

—Elementary mathematics and science teachers should be required to have a strong liberal arts background, including college courses in mathematics and the biological and physical sciences. Student teaching, which acquaints the teaching candidate with children and classroom procedures, and proven methods courses should be emphasized.

—College courses for prospective elementary school mathematics teachers should provide sufficient background for an understanding of the relationships between algebra and geometry, functions, elementary probability and statistics.

—Secondary school mathematics and science teachers should have a full major in college mathematics or science, an appropriate number of effective education courses, and teaching experience under a highly qualified teacher.

—Future elementary and secondary teachers should be computer literate; teachers must be familiar with computers to promote literacy among their students. Teacher training should incorporate the use of calculators and computers in mathematics and science instruction.

3. Filling the Present Gaps

For the immediate future, the number and quality of students certified for careers in mathematics and science teaching will fall far short of meeting the demand. A curriculum which motivates and prepares students in mathematics, science and technology will help, among other factors, to alleviate the critical shortage of mathematics and science teachers in the long run. But in the short run, any intensification of mathematics and science education will make the shortage worse. It is necessary, therefore, to turn to other sources of talent for qualified people who can teach mathematics and science, particularly at the secondary level. Suitable mathematics and science majors without education credits must be given the opportunity to acquire a knowledge of classroom management and educational psychology. This could be accomplished through intensive training programs or by placing them under the direct supervision of a more experienced teacher. Obviously, hiring practices should first select those candidates with good common sense, good communication skills, and an interest in and understanding of children. In the secondary school, these new teachers should report to the principal or department head who would regularly observe the teacher and serve as a mentor.

Thus, the Commission recommends that the pool of potential mathematics and science teachers be enlarged immediately through the following actions:

- State and local school systems should draw on industry, universities and the military and other governmental bodies as well as on the ranks of retired scientists, engineers and teachers, as sources of teaching assistance where necessary and possible. States should modify certification requirements for special teachers who are qualified in the subject matter but lack certain education credits.

- Local school administrators should facilitate the use of special teachers who are qualified in the subject matter and should arrange for appropriate classroom supervision as necessary.

B. Making the Classroom a Rewarding Place to Work

If this Nation's educational systems are to attract and retain high quality mathematics and science teachers, it is critical that the classroom become a rewarding place to work. The Commission believes that it is absolutely essential for the public to recognize the vital role played by teachers. Financial rewards should be adequate to attract and hold well-qualified and excellent teachers of mathematics, science and technology. Equally important, however, classroom conditions must be improved, so that such teachers have the opportunity to teach effectively.

1. Teacher Compensation

Teacher compensation is a difficult and complex issue that has long been a problem. It is affected, in part, by ingrained traditions and practices and by the fact that any changes in teacher compensation have a direct and substantial effect on public finances. Objective comparison, moreover, is complicated by differences between the length of the school year—generally 180 days or 36 weeks—and the length of the work year elsewhere in our society—generally 240 days or 48 weeks. Additional factors include the decline in the qualifications of teachers and the tradition of lockstep pay increases based on seniority and training experiences that may have little to do with performance in the classroom.

Public perceptions of teaching also complicate the problem. There is often a failure to recognize that many teachers work long hours,[35] that in terms of purchasing power teacher salaries today are 15 percent below the level they were in 1970-71,[36] and that many teachers must supplement their teaching salaries by additionally working part-time during the school year and full-time during the summer if they are to support their families.

At the same time, teachers must reexamine their long-held views with respect to increased pay for areas where there is a shortage and with respect to a system of pay based on years of service and credits for "staff development." Many teachers have expressed concern that salaries based more on performance would be impossible to administer in a non-prejudicial or non-preferential way. However, many teachers have also expressed frustration at the absence of opportunities to advance in salary without leaving the classroom. Many States are already seeking ways to improve teacher compensation, and to attract more and better students into the profession, especially into mathematics and science teaching where the shortage is currently most pronounced. These efforts, which include relatively competitive compensation for the qualified and superior person who wishes to teach, forgivable loans, scholarships and summer stipends, are to be encouraged. (See Exhibit D)

The Commission believes that once qualifications, work time, and other factors can be placed on a comparable basis with other sectors of the economy, the public will support adjustments in compensation for highly qualified and highly competent teachers, particularly in fields where shortages exist. Some States and communities have already begun to tackle this problem. Highly qualified and competent mathematics, science and technology teachers should receive overall rewards that are fair and relatively competitive with those received by comparable professionals in other sectors. Thus, the Commission recommends:

- School systems should explore means to adjust compensation in order to compete for and retain high quality teachers in fields where shortages exist, such as mathematics, science and technology. States, together with teacher unions when they are the bargaining agents, school boards and industry representatives, should carefully examine current working conditions, salary levels, issues of comparability, length of the work day/week/year, tenure provisions, promotion procedures and other factors that are important aspects of teacher compensation.

- State and local governments should reward excellence in teaching and should provide opportunities for high quality teachers to move up a salary and status ladder without leaving the classroom.

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35. According to the National Education Association, (*Status of the American Public School Teacher, 1980–81*, Washington, DC: National Education Association, 1982), the average number of hours per week spent on all teaching duties of public school teachers was 46 in 1981.

36. National Center for Education Statistics, *The Condition of Education, 1982, Statistical Report*, Washington, DC: U.S. Government Printing Office, 1982, pp. 86–87.

- Local school systems should explore ways to extend the employment year for mathematics, science and technology teachers by providing reimbursement for in-service teacher education, curriculum development, student workshops and other ancillary activities, and by lengthening the school year.

- Industry, the military and other governmental entities should furnish some summer or year-round, part-time employment for mathematics, science and technology teachers.

- Professional societies, schools, school districts, States and the Nation should find ways to recognize, through publicity and special financial rewards, the excellent teacher.

2. Improving Classroom Conditions—Enabling Teachers to be Effective

Teachers of mathematics, science and technology must be enabled to devote the time they have with their students to teaching the subject. They should be given the time to teach and be relieved of other tasks now often thrust upon them or their students during the class period. Moreover, a working environment must be provided that supports teachers with the best tools, materials and methods of instruction. One innovative method for incorporating new equipment and other resources into the classroom would be the development of regional training and resource centers. The Commission recommends:

- Every state should develop at least one regional training and resource center to provide a variety of supporting services for mathematics and science teachers (including computer instruction and software evaluation). These centers could also serve as a local focus for the participation of business, educators and government, and would include equipment for assistance in technology instruction.

In addition to providing adequate facilities, action must be taken to address the deterioration of the school environment which results in teachers spending less and less time on academic matters. Discipline must be maintained, administrators must work with and be supportive of teachers, and student involvement and interest in learning must be better activated and harnessed.

a. *Discipline*. Breakdown of order in the classroom is one of the more disturbing manifestations of today's educational crisis. Discipline and, therefore, the ability on the part of students to concentrate is too often absent in classrooms across the Nation. Such problems make it difficult for even knowledgeable, creative teachers to teach. The lack of disciplinary codes and the interpretation of the law often limit administrators and teachers from effectively dealing with discipline problems. Actions that should be taken to maintain a classroom environment that is conducive to teaching and learning include:

—The adoption by schools and school districts of rigorous discipline policies which reflect goals and expectations.

—Clear, written statements of the rules. These statements should be distributed to students and parents at the beginning of the year. All rules should be applied consistently, fairly and impartially.

—Modification, where necessary, of state laws[37] to permit effective discipline in the schools.

—Greater support by parents of discipline in the school and classroom.

b. *Administration of the Schools*. Most, if not all, successful schools boast a principal who is highly accessible to teachers, who involves them in the planning and decisionmaking process, and who is a knowledgeable educator. The principal's effective organization of the staff and the school's priorities can greatly improve teacher working conditions.

In the administrative process, teachers, principals and superintendents need to be supportive of each other and accountable for activities in their classrooms, schools and school districts. This requires:

—An objective evaluation of administrators and teachers which relates to salary, advancement and retention of their current position in the school system.

—Greater administrative support for better discipline, attendance, fewer classroom interruptions, and higher academic expectations in the classroom (as discussed previously).

—Reasonable and manageable class sizes.

—Support from local school systems and school administrators for teachers to obtain necessary equipment and classroom materials.

—Up-to-date textbooks and curriculum materials.

c. *Increasing Student Involvement, Interest and Achievement*. The decline of student interest also makes it more difficult for good teachers to teach. According to a recent report, 61 percent of American students were enrolled in general science in 1969 in contrast to only 37 percent in 1981. Algebra I enrollments fell to 64 percent in 1981 from 76 percent in 1969. Conversely, student enrollments in driver education skyrocketed to 59 percent in 1981 from a mere 0.3 percent in 1969.[38]

Many of today's students do not focus on academics, do not apply themselves to difficult subjects and, for the most part, have lost respect for a quality education and an understanding of the importance of the time spent in the classroom. Some suggestions for alleviating these problems are:

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37. State law may play a major role in determining such conditions as permissible disciplinary action. In addition, States and/or school boards can control attendance requirements and, for instance, provide that if a student does not spend a certain number of hours in the classroom, that student, except in rare circumstances, does not receive full credit.

38. Report by Clifford Adelman to the Department of Education's National Commission on Excellence in Education. (See footnote 1.)

—Normed achievement measures should be used effectively. Intelligently used, they provide an objective, constructive measure of student and teacher performance, contribute a sense of purpose and direction to academic activities and encourage responsibility for achieving measured progress.

—Every effort should be made to fill the available hours with purposeful, substantive content. This can be encouraged through procedural changes such as eliminating interruptions for public affairs announcements during class time, immediately beginning work when the class period starts and freeing teachers and students of other tasks often thrust upon them during class. In addition, at the secondary school level, providing the students with course outlines so they know what they are to do, when they are to do it and why they are doing it will promote achievement.

—Specific homework assignments should be required of all students on a regular basis. Such assignments should be suitably evaluated by the teacher.

—A clear attendance policy with sanctions should be adopted.

—Social promotions should be curtailed.

In addition to improving the quality of mathematics, science and technology teaching, efforts must be made to improve what and how students learn about those subjects. Immediate and significant progress can be made by increasing the amount of time students spend learning mathematics, science and technology. Persistent improvements, however, require redesigning educational objectives and related curricula and instruction to conform to those new educational objectives.

A. Raising Requirements for Mathematics, Science and Technology Education

This Commission is convinced that increased time-on-task is a crucial element to improving mathematics, science and technology education in our Nation. Short-term improvements will result from increasing the amount of time spent studying these subjects in the elementary school and by increasing the requirements for high school graduation and college entrance.

1. Raising Requirements in K-8

Mathematics, science and technology education must begin at an early age. Knowledge and skills in specific subject areas must be developed in incremental steps, and equally important, good habits of study—the ability to apply oneself to more difficult tasks—must be nurtured and reinforced over time. Therefore, the Commission recommends:

- Local school districts should revise their elementary school schedules to provide more time-on-task for the study of mathematics, science and technology. In grades K-6,[39] a minimal daily allocation of 60 minutes per day for mathematics and 30 minutes for science should be required.
- A full year of mathematics and of science and technology should be required each year in grades 7 and 8 (high school requirements are discussed in the next section).

39. When kindergarten is taught for only one-half day, these requirements would, of course, be halved for kindergarten.

2. Raising Requirements for High School Graduation and College Entrance

The trend in the 1960s toward reduced high school graduation requirements in many school systems and reduced admissions criteria in many college systems is frequently blamed for producing a decreased emphasis on academic standards and achievement in secondary schools. In fact, many students graduate from high school with only one year of mathematics and one year of science. Lessening rigor in secondary schools directly affects priorities in elementary schools. The Commission believes that high school graduation and college entrance requirements in mathematics and science, which in many school systems now amount to only a bare minimum, should be significantly increased and this should be done forthwith. This is already occurring in a number of school and university settings.

The Commission is aware that education must meet the needs of all students, and that not all will pursue similar careers. To recommend equally demanding courses of study in mathematics, the sciences and technology for each secondary school student may not be sound. This is not to say that high expectations should not drive all of our educational endeavors. But, rather, reality suggests that we prepare the academically talented for further study in our colleges and universities in a rigorous manner and perhaps in areas different from those who will not choose to continue formal education in institutions of higher learning.

Thus, the Commission further recommends:

- Each state should institute statewide performance standards and strict high school graduation requirements, and each local school district should institute more stringent grade promotion requisites.
- All secondary school students should be required to take at least three years of high school mathematics including one year of algebra (see Exhibit B for suggested course content), and at least three years of science and technology, including one semester of computer science, prior to high school graduation. This requirement should be mandated at the state and/or local level to take effect no later than September 1, 1985.[40]
- All schools should provide opportunities for their students to develop their mathematical and scientific skills to the limits of their abilities and should offer appropriate sequences of courses for students at various levels of ability.
- Steps should be taken to phase in higher mathematics and science entrance requirements for all colleges and universities (a development now underway in many institutions of higher education). Such college requirements should include four years of high school science, includ-

40. Requirements should be instituted forthwith, but the Commission recognizes these requirements must be phased in so as to avoid penalizing current students who do not have sufficient time remaining before graduation to meet all of these new requirements; those students should have to fulfill as many of these requirements as possible.

ing physics, chemistry and one semester of computer science, four years of mathematics, including a second year of algebra and coursework covering probability and statistics.

- Every school district and each middle and secondary school should establish mechanisms and procedures which obligate specific school personnel to inform, in time for such courses to be taken, all students of these college entrance requirements.
- Guidance counselors play an important role in academic and career advising of students. School districts must give special consideration to the preparation and responsibilities of those persons who occupy such positions. In addition to competence in the technical areas of advising and counseling, guidance counselors should be selected and trained with appropriate emphasis on their sensitivity and understanding of the Nation's commitment to abolishing discrimination based on race, sex, ethnicity or socioeconomic circumstances.
- School districts and community colleges should cooperate in providing appropriate opportunities for students whose mathematics and/or science preparation is inadequate to allow them to take the next steps in their education.

B. New Educational Objectives

Throughout this Report, the Commission has asserted that American students require a substantially improved background in mathematics, science and technology. Many of the courses now taught in most American schools badly need revision and updating; better trained teachers must have more up-to-date courseware in order to teach effectively. These needs result from the explosion of knowledge in scientific and mathematical fields, the availability of new technologies for the communication of this knowledge, the recent results of cognitive and behavioral research about how students think and learn, and the failure of some teachers to keep their skills current. Some improvements can be made in the short term by increasing high school graduation and college entrance requirements (see discussion above, pp. 40–41). For the long term, however, a continuing process of planning and review must be established at all levels of America's educational systems. In the process, new educational objectives will have to be set and met. With this capacity, our educational system may be able to avoid periodic crises.

The Commission sets forth herein a suggested set of educational objectives. This should not be construed as a suggestion for the establishment of a national curriculum; rather these are guides that state and local officials might use in developing curricula for local use.

Factors that must now be considered in setting new educational objectives are:

—The need to expand the focus of mathematics, science and technology education from only the pre-professional to all students;

—The changes in what students should know about mathematics, science and technology;

—The availability of new communication and educational technologies;

—The promise for education resulting from recent work in the social and behavioral sciences;

—The tendency of the present system to motivate only the already motivated and pre-professional students to continue to study and enjoy the fields of mathematics and the sciences;

—The evidence that students entering primary school exhibit a natural curiosity about numbers and about the world around them, but are discouraged from consideration of serious study in these fields early in the elementary grades due to inadequate teaching or lack of motivation.[41]

In the Commission's discussions with a variety of groups, including the education, business and government communities, very few endorsed an emphasis on specific job-related skills. Rather, there was general agreement that our contemporary society requires youth who are "trainable," that is, who have the capability of continuing to learn as changes take place in our society, whether at work or elsewhere. Teaching specific job-related skills instead of providing a strong general education is deemed ill-advised because specific job skills might be needed only for a short span of time.

Suggestions for selection criteria, course topics and student outcomes are presented in Exhibit B and summarized below. Many of these suggestions were developed by conferences sponsored by the Commission. We are confident that these suggestions will move the Nation's educational systems in appropriate directions. They are presented to stimulate further discussion and debate. The Commission urges their careful review by organizations of scientists, mathematicians, teachers, technologists and educational researchers.

Objectives for Mathematics Education

Mathematics is a way of thinking that opens doors to new knowledge in virtually every field (e.g., art, music, social sciences) and is essential for understanding the sciences. The applications of various aspects of mathematics in the sciences and engineering are changing and will continue to change as computers and calculators become ever more pervasive. The skills listed below provide a base for the study of other disciplines and are considered essential for the use of current technology and for further study in the mathematical sciences.

Analysis of current student performance in mathematics—particularly the use of mathematical skills in unfamiliar areas—indicates that they are learning to be technicians but not problem solvers. Opportunities should be provided for

41. Paul DeHart Hurd, "State of Precollege Education in Mathematics and Science," paper prepared for the National Convocation on Precollege Education in Mathematics and Science, Washington, DC, May 12–13 1982, sponsored by the National Academy of Sciences and the National Academy of Engineering, Washington, DC.

the application of arithmetic and mathematics in a variety of areas—in the natural and social sciences, in consumer-related experiences and in other real-life situations where analysis through mathematics is possible. In this context, computers and calculators make it possible to present simulation as a problem-solving tool with important applications in virtually every aspect of elementary and secondary learning.

Mathematics instruction at the *elementary level* should be designed to produce the following outcomes:

—Comprehensive understanding of and facility with one-digit number facts, place values, decimals, percentages and exponential notations;

—Skill in informal mental arithmetic, estimation and approximation;

—Ability to use calculators and computers selectively;

—Basic understanding of elementary data analysis, simple statistics and probability, and fractions;

—Ability to use some algebraic symbolism and techniques;

—Thorough understanding of arithmetic operations and knowledge of when each should be used.

At the *secondary level* there is a need to examine the content, emphasis, and approaches of courses in algebra, geometry, precalculus methods and trigonometry. Some components in the traditional secondary school mathematics curriculum have little importance in the light of new technologies. The current sequence which isolates geometry in a year-long course, rather than integrating aspects of geometry over several years with other mathematics courses, must be seriously challenged. Some concepts of geometry are needed by all students. Other components can be streamlined, leaving room for important new topics.

—Discrete mathematics, elementary statistics and probability should now be considered fundamental for all high school students.

The development of computer science as well as computer technology suggests new approaches to the teaching of all mathematics in which emphasis should be on:

—Algorithmic thinking as an essential part of problem-solving;

—Student data-gathering and exploration of mathematical ideas in order to facilitate learning mathematics by discovery.

New computer technology allows not only the introduction of pertinent new material into the curriculum and new ways to teach traditional mathematics, but it also casts doubt on the importance of some of the traditional curriculum. Particularly noteworthy in this context at the secondary level are:

—Symbolic manipulation systems which even now, but certainly far more in the near future, will allow students to do symbolic algebra at a far more sophisticated level than they can be expected to do with pencil and paper;

—Computer graphics and the coming interactive videodisc systems which will enable the presentation and manipulation of geometric and numerical objects in ways which should be usable to enhance the presentation of much secondary school mathematical material.

We stress that the use of this technology and related software packages is not a substitute for the understanding of the essential elements of mathematics, but rather is a means to enhance understanding and stimulate creativity.

2. *Objectives for Science and Technology Education*

Science and technology are integral parts of today's world. Technology, which grows out of scientific discovery, has changed and will continue to change our society. Utilization of science in the solution of practical problems has resulted in complex social issues that must be intelligently addressed by all citizens. Students must be prepared to understand technological innovation, the productivity of technology, the impact of the products of technology on the quality of life, and the need for critical evaluation of societal matters involving the consequences of technology.

Further, the nature of scientific inquiry and observation presents frequent opportunities for experiencing success with original ideas. Such inquiry does not require unique answers. Students can rightly and successfully report what they have seen and found. This type of experience should be encouraged.

Businesses will require, to an increasing degree, people who are knowledgeable about science and technology. Science and technology instruction at the elementary and secondary levels should be designed to produce the following outcomes:

—Ability to formulate questions about nature and seek answers from observation and interpretation of natural phenomena;

—Development of students' capacities for problem-solving and critical thinking in all areas of learning;

—Development of particular talents for innovative and creative thinking;

—Awareness of the nature and scope of a wide variety of science- and technology-related careers open to students of varying aptitudes and interests;

—The basic academic knowledge necessary for advanced study by students who are likely to pursue science professionally;

—Scientific and technical knowledge needed to fulfill civic responsibilities, improve the student's own health and life and ability to cope with an increasingly technological world;

—Means for judging the worth of articles presenting scientific conclusions.

The materials for broadening science instruction to achieve these outcomes must be developed and tests must be devised that will effectively measure the degree to which these educational objectives are reached. It will take time, talent and funds to develop these materials and tests. These will not be forthcoming, however, unless top priority is given to effecting these changes and providing teachers and students with the needed new instructional experiences.

In summary, students who have progressed through the Nation's school systems should be able to use both the knowledge and products of science, mathematics and technology in their thinking, their lives and their work. They should be able to make informed choices regarding their own health and life-styles based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. They should also be prepared to make similarly informed choices in the social and political arenas.

C. Revamping the Curriculum

The Commission believes the schools will have to develop for all students new, coherent patterns of K-12 mathematics, science and technology courses that are explicitly designed to meet the new educational goals set forth in the previous section. New science curricula that incorporate appropriate scientific and technological knowledge and are oriented toward practical issues are needed. They also will provide an excellent way of fostering traditional basic skills. The introduction of practical problems which require the collection of data, the communication of results and ideas and the formulation and testing of solutions or improvements would: (1) improve the use and understanding of calculation and mathematical analysis; (2) sharpen the student's ability to communicate verbally and to write precisely; (3) develop problem-solving skills; (4) impart scientific concepts and facts that can be related to practical applications; (5) develop a respect for science and technology and more generally for quantitative observation and thinking; and (6) stimulate an interest in many to enter scientific, engineering and technical careers.

Curriculum content requires revision, not only to make the substance more meaningful to students and excite them, but also to incorporate new knowledge. For example, there is now a glaring absence of technology education in American schools—a lack of curricula, course materials, demonstrated teaching methods and qualified teachers. The greater the degree to which all the sciences and technology can be integrated in new curricular approaches, the broader understanding in these fields will be.

The Commission firmly believes that thorough review of curricula should not be a reaction to periodic crises. Rather, the Commission believes that a process of continuous curricular review and updating (kindergarten through 12th grade) should be established. It should incorporate developments in various disciplines, technology and the latest understanding of the learning process.

Curriculum selection and presentation are primarily a state and local responsibility--and often are very successful--but it is generally agreed that optimum results usually require the coordinated efforts of experts from many disciplines and fields. This effort is often difficult to mount at the local or even state level. Therefore, a process which includes national leadership must be established to evaluate present courses of study, propose new approaches and promote their implementation in the classrooms of the Nation.

- The National Science Foundation, which has recognized expertise in leading curriculum development, should again take the leadership role in promoting curriculum evaluation and development for mathematics, science and technology. The National Science Foundation should set up a process to evaluate existing curricula, identify good curricula, disseminate information, act as a clearinghouse and promote the development of guidelines for new curricula as necessary.

- The professional societies in mathematics, science, engineering and other technologies should play an active role in curriculum development, review and revision.

There are numerous ways in which the National Science Foundation might approach its part of this task. The Commission offers the following for serious consideration as one possible mechanism:

—A Mathematics, Science and Technology Curriculum Council might be established in the National Science Foundation. Within the next 12 months this Council would begin a continuing process to maintain a broad overview of instructional material for elementary and secondary education. To accomplish this, it would appoint and coordinate the activities of committees to address:

Elementary Mathematics	Elementary Science
Secondary Mathematics	Secondary Science and Technology

The responsibility for each committee would include:

—Recommendations regarding course content for its subject area;

—Recommendations regarding instructional design and methodologies, including software and new hands-on approaches;

—Critical review of the available texts and other teaching and resource materials;

—Publication of these recommendations and evaluations;

—Identification of the areas where improved and/or new course materials are needed and the exploration of new methodologies;

—Identification of the areas where future research is needed in the design of curricula and the processes of teaching and learning.

Membership on these committees would consist of experts in the subject matter, including classroom teachers, representatives of professional societies and school boards, technical experts from business and government and academic educational researchers and instructors. The Commission recognizes that some of these groups have already mounted efforts in curriculum development. They should be encouraged and given the opportunity for official consultation to facilitate implementation of new courses of study.[42]

As the work of the committees proceeds and areas for development and implementation are identified, the Curriculum Council would add members representing publishers and associations of higher education, as necessary, to encourage the development and transfer of these ideas to actual material for the classroom. The Council and committees might work with demonstration centers widely dispersed around the country to evaluate new approaches. In areas where magnet schools or other exemplary schools or programs have been established, these might serve as the test centers. These test centers could play a key role in the dissemination of information on good curricula and should serve as sites for the training of teachers to use these curricula.

Content development efforts must include participation of practicing scientists, engineers and teachers, who can be organized through their professional organizations, particularly those that have teachers and other academicians among their active members. These efforts should make use of educational technology and be closely correlated with software developers to find means to interest and excite students in mathematics, science and technology at the earliest grade possible. In considering appropriate curricula, the Commission strongly suggests that particular attention be paid to the new information and communication technologies which are revolutionizing our society. It is critical that all students gain an understanding of the operation and capabilities of computers, since this technology has become an integral part of our society and is becoming more important as time passes. States should require teachers to have computer skills. Students should have significant exposure to computers by the fourth grade and should have at least one semester of training in the use of computers by the tenth grade. Computer programming will become a tool for learning mathematics, science and technology, for learning autonomy and for learning the spirit of intellectual play. Thus, the Commission recommends:

- States should take steps to ensure that all teachers and all students have access to such training.
- School districts should develop explicit plans to achieve computer literacy, since these goals must ultimately be implemented at the local level.

42. As a bridge between professional mathematicians, scientists and teachers, the Nation's professional societies occupy a unique position. They should play an important role in any effort to improve our educational system in mathematics, science and technology. This Commission has encountered many outstanding programs which are currently being operated by professional societies to help teachers and to motivate students. For example, the programs of the American Association for the Advancement of Science, the American Association for Engineering Education, the American Association of Physics Teachers, the American Chemical Society, the American Society for Engineering Education, the Institute for Electrical and Electronics Engineers, the Mathematical Association of America, the National Association of Biology Teachers, the National Council of Teachers of Mathematics, the National Science Teachers Association and the National Society of Professional Engineers are all noteworthy. A summary of programs provided by the professional societies is presented in Exhibit A.

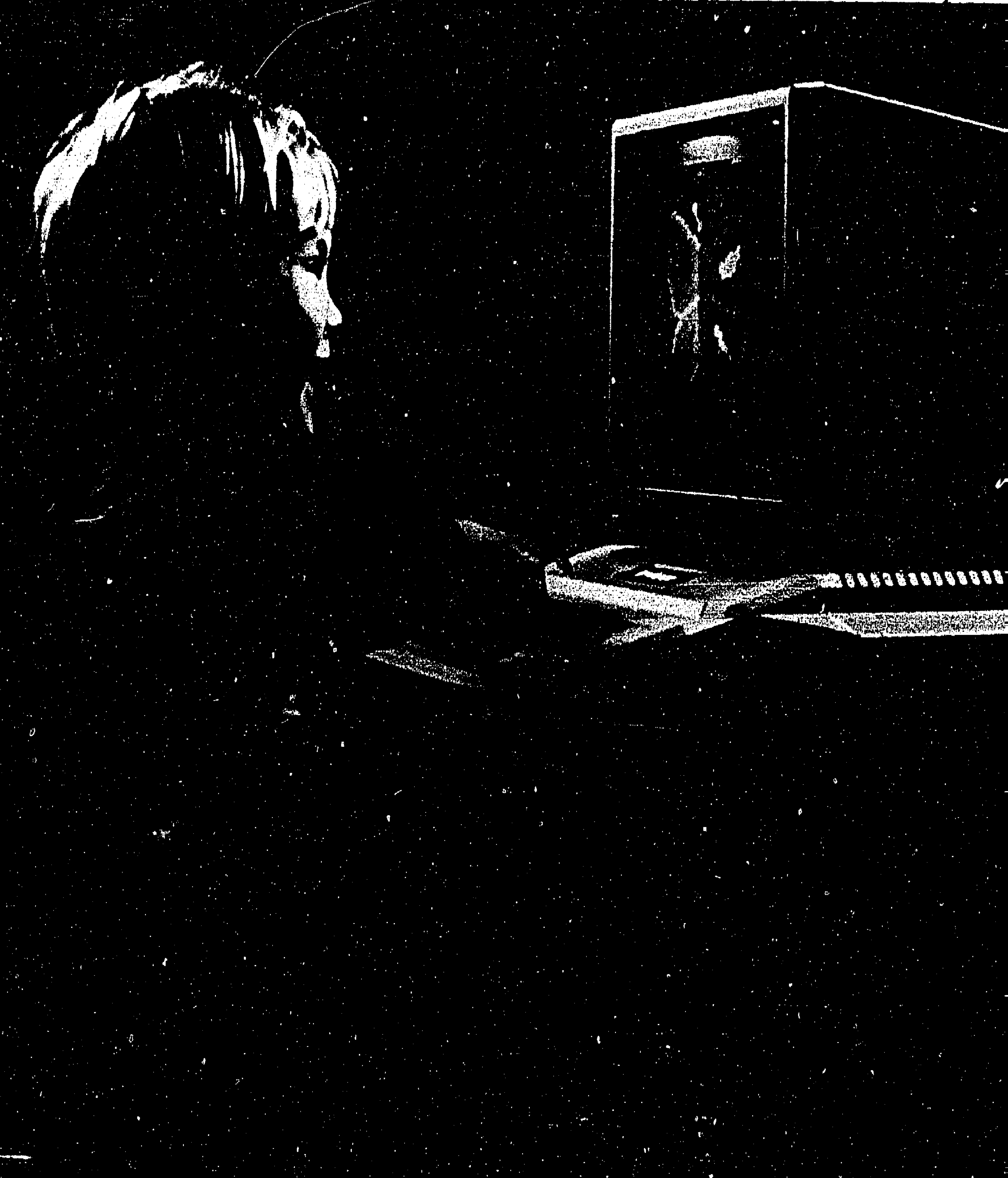
- Business should be invited to take part in cooperative programs which involve resource sharing and contributions of equipment.
- Individuals with expertise from business, government and the higher education community should take an active role in teaching both students and teachers about computers.

In addition, the Commission has found that curricula for separate technology courses are virtually nonexistent, and material about modern technology is generally poorly integrated into the science curriculum. Recent studies reported to the Commission have placed particular emphasis on the need for materials dealing with technology at grades 8 and 9. The Commission, therefore, recommends:

- The National Science Foundation should support the development of courses to meet this need, utilizing expertise from business both in determining course content and in formulating plans for using local technologists to assist in presenting the material.

Finally, in developing revised curricula, educators should strive to incorporate the latest information on the teaching and learning processes. The rapid growth of psychological knowledge holds some promise for improving instructional methods. Indeed, collaborative research between cognitive psychologists and researchers in mathematics and science education should be encouraged to test new concepts under classroom conditions. Consequently, the Commission recommends:

- Research into the processes of teaching and learning should be supported with Federal funds at both the basic level and the level of classroom application. This research should further the recent progress in the cognitive sciences, and particular research projects should investigate the integration of educational technologies into the processes of teaching and learning.



THE PROMISE OF THE NEW INFORMATION TECHNOLOGIES

Modern information technologies offer a tremendous potential for improving education and could revolutionize the education process. In the past decade, computers have become universal devices with applications in numerous areas. The microprocessor in particular is likely to affect education as dramatically as it has every other facet of our lives. Television, via satellite, cable and closed circuit, now provides unprecedented flexibility in the transmission of information to almost any location. Interactive communications, coupling television with microprocessors and videodiscs, and computer graphics are offering new and exciting possibilities for the improvement of teaching and learning. If the promise of these technologies becomes a reality, the scale of financial and human resources required for elementary and secondary education would be substantially reduced, while improving the effectiveness of the process.

The benefit of these new technologies is already being realized in other sectors. The military is pioneering the use of computer simulations, input-output devices and videodiscs for training. Industry, business and universities are using the technology for retrieval of data, transmission of information and training of personnel. In fact, developments are occurring so rapidly that it is difficult to assess the actual state of the art in many areas. Almost any statement made today will, therefore, be obsolete in a few years, if not months.

How, then, can new technologies best be used in elementary and secondary education? The computer is already being used in the classroom to develop computer literacy, improve student motivation, enhance rates of learning, provide assistance for teacher shortages and deficiencies, provide higher-level instructional opportunities for disadvantaged and isolated students, improve administrative efficiency and increase teacher efficiency. (Some examples of the effective use of these technologies in schools and classrooms are presented in Exhibit E.) The Commission found that interest is high and, as shown in the following table, use of this equipment is increasing rapidly.

School Use of Microcomputers for Instruction

Year	*No. of Schools*
October 1981	15,318
October 1982	24,696
October 1983	54,050 (estimated)

Note: The data for October 1983 are estimated on a sample of 29,880 out of a total of 82,884 schools (public, private and Catholic) reporting as of 23 August 1983. The estimated number of microcomputers (average) per school is 4.3 for elementary schools, 7.2 for junior high schools, 10.4 for senior high schools and 9.7 for combined K-12 schools. On this basis, approximately 350,000 microcomputers are estimated to be used for instruction (grades K-12) across the country.

Source: The data, generated by telephone survey, are provided by John F. Hood, Vice President of Market Data Retrieval, Westport, CT 06880.

A. Educational Uses of the Computer

Many technologies have been applied to education; however, the computer is unique because it permits a high degree of interaction with the user. The current educational uses of microcomputers fall into three general categories: learning about computers, through computers and with computers.

1. Learning About Computers

In a beginning stage, computer literacy is simply learning about computers —how to use them and how they benefit society. At a more advanced stage, computer literacy includes computer programming. Computer programming is important because it provides a marketable skill and encourages students to think algorithmically and develop problem-solving skills. A large number of time-consuming administrative tasks could be handled by computers.

2. Learning Through Computers

The major focus of research and development in educational computing—learning through computers—(measured in effort and dollars spent) has been on drill-and-practice, diagnostic testing, and question-and-answer tutorials. This mode of computer use has several attractions:

—There is a body of research attesting to the effectiveness of this mode of learning compared to conventional instruction.

—Teachers are able to develop their own learning materials with relative ease, with authoring languages, like PILOT, permitting them to tailor the material to the needs of their students and giving the students the feeling of control and "ownership."

—The cost of developing materials in this mode is moderate.

—This mode is well-suited to home-based learning, because it involves a one-on-one relation between the student and the computer and because there is little need for teacher intervention during a lesson.

—It permits each student to learn at his/her own pace.

3. Learning with Computers

The most promising use of computers in learning environments, both formal and informal, is the use of the computer as a tool of instruction and an environment within which learning can occur. Materials generated for this, mode generally are more expensive to produce because they require a wide range of talents and expertise not found in a single individual; however, they offer rich opportunities for learning of concepts and procedural skills, as well as development of the student's intellect.

This mode has several components including:

—Microworlds, which are cybernetic environments within which elements may be combined according to given rules;

—Educational games, including adventure games, which develop reading comprehension and problem-solving skills;

—Microcomputer-based instrumentation systems which permit explorations of real-world phenomena;

—Data bases to increase information available to students;

—Tools, including graph-plotting routines, word processing, spread-sheet programs, and general purpose problem-solvers;

—Special purpose computer languages, like LOGO, which permit creation of learning environments that foster development of the child's intellect;

—Simulations, which create flexible universes within which the student may experimentally discover properties of the real world;

—Discovery learning in mathematics, which provides a more active and self-directed learning environment within which the student can discover properties of mathematical functions and operations.

These applications of computers are exciting. However, four notes of caution are necessary. First, the Commission has observed a substantial gap in perception as to the utility of these systems between the producers and the teachers who must apply them. Producers must provide materials that are appropriate to teachers' needs, and teachers must be provided with the necessary training to apply this technology effectively.

Second, economically advantaged students often have access to computer systems at home or in schools, and thus learn to use the computer as an effective tool. This circumstance is seen as potentially increasing the gap between economically advantaged and disadvantaged students. Disadvantaged students may have only limited access to computers, and then only in school for drill and practice. Equal access for all segments of the student population to the best technology available is clearly an important issue.[43] Rapid growth in the number

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43. Schools in poorer districts were 25 percent less likely to own microcomputers than other districts. About 70 percent of schools in wealthy districts own microcomputers; 40 percent of poorer schools have the equipment. The number of microcomputers in homes doubled from 1982 to 1983, reaching about 4 million homes; no doubt the greatest percentage is in the more affluent homes. (Findings on computers in schools released by Market Data Retrieval, Inc., Westport, CT., Gallup and Roper surveys reported in *Time*, May 23, 1983, p. 61.)

of computers available in the schools may ameliorate such unequal distribution.

Third, computers are, at their current level of development, educational tools to assist teachers. They are not replacements for teachers.

Fourth, some currently available software is not of high quality and is difficult to integrate with the curriculum. Many teachers have had unsatisfactory experiences with inadequate software. Improved programs are becoming available and much better programs are expected.

B. Guiding the Development of Educational Technologies

The Commission finds that the new information technologies offer great potential for improving the classroom environment, particularly in mathematics, science and technology. These technologies can play an important role in short- and long-term efforts to resolve the crises facing K–12 education, including teacher retraining and the alleviation of teacher shortages. Therefore, the Commission recommends that policies promoting the use of educational technologies be encouraged by:

- The National Science Foundation, which has recognized expertise in supporting educational applications of new technologies,[44] should again take the leadership role in evaluating the status of developments in this area. This should include such action as determining needed initiatives, supporting prototype demonstrations, disseminating information on model materials and practices, and supporting research on integration of educational technologies with the curriculum.

There are numerous ways in which the National Science Foundation might approach its part of this task. The Commission offers the following for serious consideration as one possible mechanism:

—A Council for Technology Application in Education might be established by the National Science Foundation. The Council would consist of professionals drawn from authorities on the use of technology in education, including classroom teachers, representatives of professional societies, and experts from appropriate businesses, industries and universities.

This group would advise and oversee National Science Foundation initiatives in this area including:

—Initiatives to develop the most effective uses of these new technologies for teaching and learning. Research and development efforts should

44. During the 1960's and 1970's, the National Science Foundation supported a number of significant development efforts that facilitated the use of several of the information technologies for educational purposes. Among the developments resulting from such National Science Foundation support are: the computer languages BASIC and LOGO; CONDUIT as a clearinghouse for computer courseware; the PLATO hardware and software and authoring system; the Huntington II software to supplement existing high school courses; the prototype demonstration of the intelligent videodisc; and a range of software and courseware options in science and mathematics ranging from the pre-school to college levels.

The National Science Foundation has consistently been able to draw on leaders of the computer and communication industries, professional societies and the universities to participate in its short- and long-range planning formulations.

bring together teachers and curriculum experts, cognitive scientists, mathematicians, scientists, engineers and experts from business and industry. Federal resources should not preempt the initiatives currently being taken by the private sector in this area and should not duplicate or restrain such efforts. New approaches should be tested with students in school classrooms before extensive implementation is attempted.

—Research, which would otherwise not result in the near term from private efforts, to provide a solid base of knowledge to permit effective utilization of modern educational technology and integration into the curriculum of mathematics and science courses.

—The development of mathematics, science and technology curricula that can integrate computer systems and supporting materials effectively. Grants should be provided to support research and development in critical areas that private industry is not pursuing and for small business innovative research projects which are appropriate in these areas.

—Encouraging the private sector, science and technology centers, government agencies and colleges and universities to collaborate in training practicing teachers in the utilization of high technology systems. Special out-of-school training programs, in-service programs, computer conferences and other such training resources need to be developed. Training programs for schools of education and liberal arts colleges also need to be put in place for our future teachers.

—Encouraging and assisting school systems to acquire computers, software and instructional materials. Business should not only expand the many programs they are currently supporting, but also develop new approaches. The National Science Foundation and other Federal agencies should assist in making the highest quality software available on the broadest possible scale. States, too, have an important role to play. They should forge cooperative efforts with industry to provide equipment and training (especially in computer literacy) to local school systems, public institutions of higher learning and other programs. As part of these various efforts, special attention should be devoted to ensuring that students from all segments of society have equal access to the best technology available.

—Developing training materials for school administrators in the use and management of educational technology.

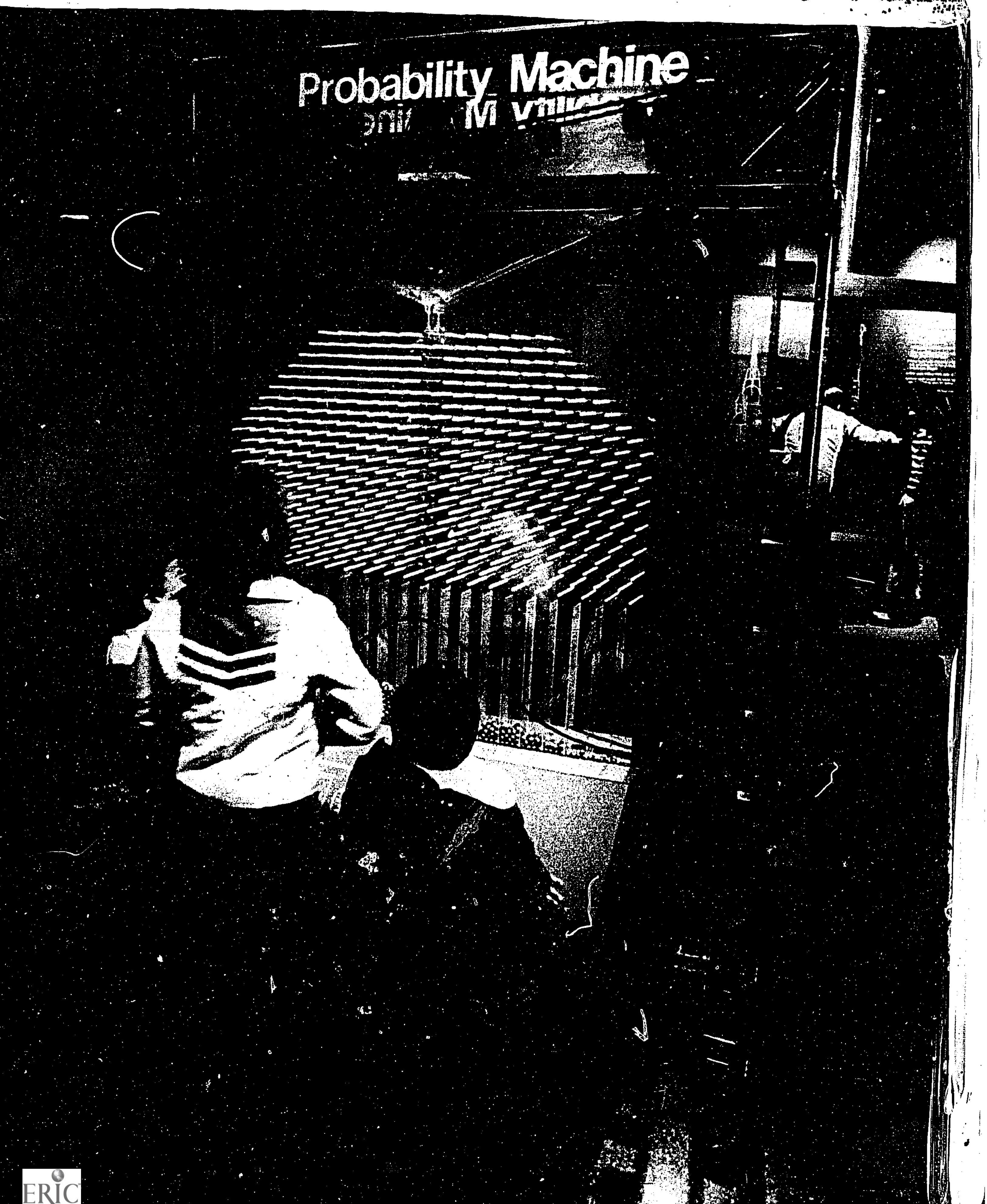
—Developing training materials for parents in the educational use of home computers.

C. Utilizing Information Technologies

A variety of steps can aid in effectively tapping the promise of the information technologies. Therefore, the Commission recommends:

- The States should consider establishing regional teacher education and computer centers for the demonstration of and training in new technologies. These centers could also coordinate the evaluation of hardware and software and make information available to teachers on what specific products are available.

- The use of computers and other high technology equipment in the classroom should be managed so that students receive both the benefits of the equipment and increased familiarity with this technology. In particular, courses in computer literacy should take into account the availability of this equipment for instructional purposes.
- The use of computer management techniques to relieve science and mathematics teachers of excessive administrative burdens and to make more of their time available for teaching should be pursued.
- Top executives in firms which make up the computer communication and information retrieval and transfer industries should develop plans which, in a good, economical and quick way, enable school systems to use the technology.
- The national and state education councils and local school boards should work with local school districts and individual schools in developing goals and plans for implementing computer managed instruction and other technologies in mathematics, science and other appropriate courses. These councils should make a particular effort to utilize the expertise of executives and technical specialists from the computer and communications industry and appropriate professional societies. In this manner, these new technologies can be directly applied to achieving the educational goals and objectives set forth in this Report by 1995.


Probability Machine

INFORMAL EDUCATION

Much that affects the quality of formal education occurs outside the classroom and beyond the control of the school—a great deal of learning takes place unintentionally and unconsciously through casual reading and experiences. The process has been referred to as informal or experiential learning and offers an important opportunity for improvement in our overall educational system. Such opportunities are particularly helpful for the sciences and technology.

There are children who have had little experience with tools and toys that develop problem-solving and manipulative skills, who have had little guided experience with physical and biological phenomena that are all around them, and who believe that science is extremely difficult and that scientists are strange people. Such children are poor candidates for mathematics or science in the classroom. Unfortunately, the great majority of American children today fit this description.

Thus, while out-of-school activities and informal learning provide a special enrichment value for the gifted and talented, they have an even greater significance for the average student. The child who has regularly attended zoos, planetaria and science museums, hiked along nature trails and built model airplanes and telescopes is infinitely better prepared for (and more receptive to) understanding the relevance of mathematics and learning about the physical and biological sciences.

Formal education must be supplemented by a wide range of activities that can reinforce the lessons of the classroom and lend meaning and relevance to the rigor and discipline of formal study. The Commission believes that all students need the best introduction to science through a wide variety of early experience and information. The environment for informal learning should be as rich as possible. Yet few children are exposed to enough of these stimulating and preparatory experiences. Many communities lack convenient access to science museums and hobbies, and even the best science museums are seriously limited by inadequate funds for their educational activities.

Therefore, the Commission recommends:

- Youth organizations, museums, broadcasters and other agents of informal education should cooperate with school districts and each other to provide a rich environment for early and continued learning and motivation outside of the schools.

Perhaps the most pervasive medium of informal learning today is through broadcasting; even young children watch almost four hours of television daily. Indeed, in an increasing number of homes both parents work and children return home each afternoon and are exposed to commercial television programs which often present a grossly distorted, and generally negative, picture of science. A few efforts to convey the facts and excitement of science by this media, however, have been successful.

One such example is "3-2-1 Contact," a daily science program for 8–12 year olds which is viewed in over 23 million homes. The series costs less than one cent per viewing and is used as a classroom supplement by roughly a half-million teachers. The Girl Scouts of the U.S.A. has begun a special science program based on the TV series and over 10,000 science badges were awarded in Washington, D.C. alone during the first year. Almost a million children read related magazines and books—entirely funded by private sources. Nonetheless, although corporate and public-television contributions total over $10 million per year, "3-2-1 Contact" and similar series are basically dependent upon Federal funding for their existence. The Commission also recommends:

- Science broadcasts are an important and cost-effective vehicle of informal learning and should continue to receive substantial Federal investment and support.
- Businesses, private foundations and others should increase their support for such programs in the commercial, as well as the public, broadcasting areas. They should particularly encourage programming of such material by local stations and promote appropriate educational objectives for this programming.
- Federal regulation of commercial stations should include, at a time convenient from the point-of-view of the student, a required period of educational programming for children.
- Cable and local TV stations should assist with teacher training and publicity to increase the public awareness of and attendance at science museums and technology centers.
- Corporations should provide special support to promote the efforts and audiences of institutions like public broadcasting and science museums.

Although broadcasting offers an exciting and cost-effective means to supplement the experience of large numbers of children, it remains a passive and vicarious activity—limited in its ultimate effect until complemented by direct, "hands-on" experiences. The background and stimulus of television should be matched by the direct "hands-on" activities of science museums and clubs. Recreational science activities, youth organizations, reading and personal experiences are the indispensable route to experiential learning.

Museums provide an especially important location for such activities. The attendance at science museums and related institutions totals roughly 150 million per year—almost as large as all other museums combined and more than the combined annual attendance at baseball, football and basketball games. Attendance at the Air and Space Museum is almost as large as Disney World, and attendances of several million people at large science museums are common.

In recent years, an increasing number of museums have seen education as their primary role and have developed a wide variety of entertaining, "hands-on" experiences that have helped to attract these enormous audiences. Many integrate science, technology, art and history in a manner that contributes to classroom education in a number of areas. Many science museums have established substantial teacher training activities and weekend and evening programs for all types of science hobbies.

Most museums are largely supported by private funds and they have consistently recruited exceptionally talented and well-trained teachers. Status and morale are generally high. The wide variety of innovative programs, the creative displays, the links to school activities, the large attendances and the large cadres of volunteers are the envy of other countries. American science museums are considered a model throughout the world and are copied assiduously.

Yet few museums offer more than a portion of the spectrum of programs and services that have been proven and demonstrated—largely because local funding has reached the limits of its ability. The Commission, therefore, recommends:

- Science museums should serve as a focus for community interest in informal learning about science and technology. Science museums, whenever possible, should offer a full range of activities and opportunities to pursue science hobbies, teacher-training programs, weekend and evening programs for parents and children, and opportunities for "hands-on" experience to complement the stimulus and background experience provided by such media as television and reading.
- The Federal government should provide supplementary support for museum education activities in mathematics, science and technology at a level that will encourage a rich spectrum of activities and options.
- Local business groups should work with museums to encourage, support and publicize their education activities.
- Institutions like libraries, voluntary youth organizations, the Boy Scouts and Girl Scouts, the Audubon Society and similar science and technology related groups should work with museums and schools to enrich the environment for informal learning.
- Private industry and businesses, the military and other governmental agencies should create programs and opportunities which let children see science and technology in actual operation in their plants and installations.

Finally, in broadcasting and museum activities—as well as journalism, magazines and other vehicles of informal education—it is important to recognize that "adult" and "children's" materials are inextricably interwoven. A substantial part of their value and impact reflects the fact that they are a *joint* learning experience, and a rich environment is valuable to both. If parents and adults understood more, and were more aware of science and technology, the problems of guidance and counseling in our schools would be far less difficult.


S·C·A·L·E
PURCHASING POWER
S·C·A·L·E
HOW GOOD WERE THE GOOD OLD DAYS?

HOW THE NATION SHOULD FINANCE NEEDED EDUCATIONAL IMPROVEMENTS IN ELEMENTARY AND SECONDARY SCHOOL MATHEMATICS, SCIENCE AND TECHNOLOGY

The Commission has not made a comprehensive analysis of the costs of elementary and secondary education in the United States. Educational finance in America is a complex matter, with support coming mainly from state and local governments, coupled with some assistance from the Federal government, industry, foundations and other sources. Total expenditures for public elementary and secondary education for the last four years are summarized in the following table:

TOTAL EXPENDITURES FOR PUBLIC ELEMENTARY AND SECONDARY EDUCATION[a]

	School Year[b] 1979–80		*School Year[c] 1980–81*		*School Year[b] 1981–82*		*School Year[c] 1982–83*	
	Billions	*%*	*Billions*	*%*	*Billions*	*%*	*Billions*	*%*
1. The Federal Government[d]	$ 9.5	9.8	$ 9.6	9.3	$ 9.7	8.6	$ 9.0	7.7
2. The States, including District of Columbia, and other territorial governments	$45.1	46.8	$ 48.8	47.4	$ 53.6	47.7	$ 57.6	49.0
3. All local political subdivisions and school districts below the state level	$41.5	43.1	$ 44.2	43.0	$ 48.8	43.4	$ 50.6	43.0
4. Other, including foundations, business, etc.	$ 0.3	0.3	$ 0.3	0.3	$ 0.3	0.3	$ 0.4	0.3
TOTAL:	$96.4	100%	$102.9	100%	$112.4	100%	117.6	100%

[a] The estimated amounts spent for *private* elementary and secondary school education for the school years 1979–80 and 1982–83 were $12.2 and $15.3 billion, respectively. Source: National Center for Education Statistics (NCES) (to be published in the 1983 *Digest of Education Statistics*.)

[b] *Source: Digest of Education Statistics 1982.* NCES.

[c] These are the latest figures available from NCES (to be published in the 1983 *Digest*).

[d] In addition to estimates for "regular" schools, data include estimates for "other" schools, such as subcollegiate departments of institutions of higher education, residential schools for exceptional children, Federal schools for Indians, and Federal schools on military posts and other Federal installations. For example, the Federal expenditures for 1979-80 were estimated to total $9.5 billion. Of that total, $3.4 billion came from the Elementary and Secondary Education Act (Title I—now referred to as Chapter I—allocates funds to school districts on the basis of the number of students from low income families; these monies are then spent to assist educationally deprived youngsters); $3.2 billion from the school lunch, milk and child feeding programs; $0.66 billion from school assistance in Federally affected areas; $0.36 billion from the vocational education acts; $0.13 billion from the Emergency School Assistance Act; and $1.8 billion from other Federal programs.

Consonant with its original mandate from the National Science Board, the Commission has formulated a set of recommendations that call for actions and initiatives at the Federal level. The estimated cost of the recommendations listed in Exhibit C is $1.51[45] billion in the first full year of their institution.[46] In total, the cost of these new Federal initiatives is modest in comparison to the $9.0 billion spent last year in Federal assistance to elementary and secondary education.

Inefficiencies, where found, elimination of unsuccessful and duplicative efforts and more effective expenditures of governmental funds might reduce (at the margins) present levels of Federal, state and local spending.[47] And many of the Commission's recommendations will result, in the long term, in a better quality of services being delivered at a lower overall net cost to society. It is mandatory that a search for all such savings and the elimination of unnecessary expenditures be undertaken immediately by each level of government (with help from the private sector).[48] The public will not tolerate waste if, at the same time, it is called upon to increase significantly its support for education. Any perception of waste, whether well founded or not, will reduce the public zeal for changes which require additional governmental outlays.

Even after such possible savings are realized, however, the Commission is certain that, at least in the short term, more public money must be spent to accomplish the goals and objectives set forth in this Report by 1995. In addition to determining the required overall net increase in spending, the difficult and equally crucial question of what portion should be borne by the Federal government must be addressed. The Federal government has an interest in the overall functioning of the elementary and secondary school system, and, in appropriate circumstances, this interest warrants Federal assistance to aid in the establishment, maintenance and support of such schools. This belief is based upon recognition that, *inter alia:*

45. During their initial year, the initiatives set forth in this plan will require a Federal appropriation of $1.51 billion. During succeeding years this figure will decline—to approximately $680 million in the second year and $331 million in the sixth year. The initial Federal appropriation of $1.51 billion includes $829 million to help state and local governments initiate some 2000 exemplary mathematics, science and technology programs in elementary and secondary schools. These funds would be distributed over a period of three years at a rate of about $276 million per year, but immediate authorizations and appropriations are required to establish the scale of the program and provide the necessary credibility and assurance to state and local governments.

46. Since this Report is limited to necessary improvements in mathematics, science and technology, it does not reflect additional costs, if any, which might be required to improve elementary and secondary education in other disciplines. Some of these costs, however, will not have to be incurred since certain of the Federal costs delineated in Exhibit C will undoubtedly result in system-wide improvements which will enhance education in all areas.

47. For example, there are reports that in certain States the population of students of K-12 age may decrease as much as 30 percent in the next five years. School administrators might be able to reduce operating costs as a result.

48. Such reviews, necessary recommendations and initial implementation of recommendations should be accomplished by August 31, 1984.

(a) Prepared citizens (especially in science, mathematics and technology as well as other basic academic and technical subjects) are required for the operation of the Nation's essential industries and services, the ability of those industries to compete internationally and for military security. Such preparation is also necessary to enable an informed public to consider, discuss and judge intelligently the major issues facing the Nation today, many of which have a mathematical, scientific and technological thrust.

(b) Some Federal activities and requirements place additional costs on the local school system (e.g., impacts created by the stationing of Federal facilities like military bases in the school district, Federal racial desegregation, anti-poverty and anti-handicap policies and regulations.)

(c) Federal involvement is necessary when certain critical skills are extremely short or when there is a great need for an urgent program to produce vital talent in the Nation (e.g., shortages of trained doctors or other medical personnel in wartime, or the national response to Sputnik.)

(d) Improperly or inadequately trained high school graduates increase the cost of training for those inducted into the defense forces.

Thus, the Federal government is perceived as having at least some responsibilities to ensure that its citizens are trained to meet the demands of the workplace and a society that increasingly require mathematical, scientific and technological skills and understanding.

This Commission does not believe, however, that these and other considerations lead to the conclusion that the Nation now expects the Federal government to assume the primary responsibility for supplying financial support for new educational activities at the elementary and secondary school level required to accomplish the 1995 objective. Americans live under a Federal Constitutional system which reserves certain powers and functions to the States. Throughout its history, the Nation has accepted and supported the premise that the principal responsibility for creating, maintaining and operating elementary and secondary school systems belongs to the States and local governments. The Commission believes, therefore, that there is a national consensus that (except in unusual circumstances) state and local governments should bear most of the expense of elementary and secondary education, including costs of buildings, textbooks, teachers and administrators.

The Commission also recognizes that it would not discharge its responsibility by merely recommending increased Federal expenditures, because, simply stated, it will never happen, and if it did, it would not completely solve the problem and might just result in the waste of some Federal dollars. The Federal government already has an enormous annual deficit. Federal allocations to the States and schools are often accompanied by paperwork and control which many school districts already claim are excessive. Most importantly, excessive Federal intrusion might deter or prevent the implementation of imaginative plans which the Commission knows local school districts are capable of developing.

The Commission does not recommend, therefore, that the Federal government supply *all* of the necessary new funds. As previously stated, however, the Commission does recommend Federal funding for certain specific programs as set forth in Exhibit C. In addition, new approaches must be stimulated by the Federal government to aid state and local districts in the discharge of their responsibilities.

In order to develop the financial approaches required and to make the determinations called for in deciding how the costs of public education should be shared by all sectors, the Commission recommends:

- The President should immediately establish a Council on Educational Financing, which would examine the methods through which the Nation could marshal the resources to implement the Commission's recommendations. The function of the Council would be (1) to determine which levels of government are responsible for providing the funds required to implement the recommendations, and (2) to suggest devices that will protect States and local governmental bodies which assume a share of the responsibility for implementing any or all of these recommendations from anti-competitive tax disadvantages.[49]

In order to do this, the Council would need to determine: (a) just how much funding is needed to implement all of the recommendations, (b) what part of these funds, if any, can be recouped through increased efficiency and the elimination of unnecessary present programs, (c) which levels of government should assume responsibility for the remaining financial shortfall, and (d) what types of revenue measures are required to raise the needed funds.

The Council would be instructed to render a report with conclusions and recommendations to the President and the Congress on or before August 31, 1984.

49. As noted in a *Washington Post* editorial of August 6, 1983, States and localities which want to raise taxes in order to provide additional governmental services are placed at a serious short-term disadvantage because existing businesses may relocate to States with lower tax rates and new industries are less likely to settle in the State. A self-perpetuating problem is created. As industry leaves and the tax base is eroded, the State is forced to consider even higher taxes simply to maintain existing services. Therefore, it is essential that the Council on Educational Financing consider innovative approaches to ensure that anti-competitive tax disadvantages among the States are eliminated. For example, a tentative idea which the Council should consider is whether the Federal government could impose a tax which would not be effective if the state government imposed a tax at one-half the Federal rate. In other words, this is a scheme under which the Federal government would induce the States to raise additional money, but it is done in such a way that the Federal government is in no way involved in the collection or allocation of the funds. It would be a state tax. Yet no State would be placed at a competitive tax disadvantage, since any State that failed to enact the tax would subject its citizens to a higher tax payable to the Federal government. This idea is not a recommendation of this Commission. Rather, it is only an illustration which the Commission hopes would induce members of the Council to think of imaginative ways to raise the additional resources required by the recommendations in this Report.

Respectfully Submitted,

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September 12, 1983

EXHIBIT A

LISTING OF PROGRAMS AND ACTIVITIES REVIEWED BY THE COMMISSION

Following is a representative listing of programs and activities that have been reviewed by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology. It was not possible to include all of the many interesting programs that have come to the attention of the Commission. The list is organized according to the sector playing the major initiating or management role, although many programs involve partnerships among multiple groups or sectors.

Federal Government

A Federal presence and interest in precollege education extends as far back as the Ordinance of 1785 setting aside public lands for the support of schools in every township. A broad national interest in an educated public, concern about manpower in health, agriculture, science and engineering, and defense, and—more recently—about equal access to education, have helped shape major Federal commitments to education.

Principal responsibility for elementary and secondary education rests with state and local governments. The Federal share of expenditures in this area has always been less than 10 percent of the total cost and today amounts to 7.7 percent. Where there has been a strong national interest and a need for focused national leadership, goals and resources, the Federal government has historically assumed greater responsibility.

The Commission has discussed precollege education issues and perspectives with representatives of the Executive Office of the President (Office of Management and Budget and Office of Science and Technology Policy) and with congressional staff members. It has received detailed presentations on past and planned programs from the National Science Foundation, the Department of Education, and the Department of Defense, including the programs listed below. Many other Federal agencies with science-related missions, such as the Departments of Commerce, Energy, and Health and Human Services, and the National Aeronautics and Space Administration, have programs involving mathematics and science in the schools. These often include summer internships and employment, visiting lecturers, and field trips, as well as support for programs using technology in education. Also, many of the programs and activities listed under other sectors received support from Federal sources.

Department of Defense: U.S. Army's Junior Science and Humanities Symposium, Research and Engineering Apprenticeship and Uninitiated Introduction to Engineering Programs for socially and economically disadvantaged students, support for science and engineering fairs and the U.S. Mathematical Olympiad. U.S. Navy's JOBS program and Educator Orientation Visit program. U.S. Air Force's Project Tech 2000, Aerospace Education Foundation, and Explorer Posts. U.S. Defense Communication Agency's National Science Center for Communication and Electronics and project LINK for direct broadcasting to schools. Defense Department activities also include a presentation that stresses the skills, including a knowledge of mathematics and science, that new recruits need to have, which will be available to junior high schools, and the Partnership in Educational Development Program with computer companies, which focuses on ROTC high schools.

Department of Education: The Smith-Hughes Act of 1917, later the Vocational Education Act, the National Defense Education Act of 1958 to improve the teaching of science, mathematics, and foreign languages at precollege levels, Title I of the Elementary and Secondary Education Act of 1965, allocating funds to school districts with concentrations of low-income children, to meet the special needs of educationally deprived children (now Chapter I of the Education Consolidation and Improvement Act of 1981), and the Education for All Handicapped Children Act of 1975, to provide greatly increased assistance to the handicapped for educational access.

National Science Foundation: Summer and In-Service Teacher Institutes for Elementary and Secondary School Teachers, Summer Fellowships for Secondary School Teachers, Research Participation for Secondary School Teachers, Elementary and Secondary School Course Content Improvement, Cooperative College-School Science, Elementary and Secondary Materials Development, Instructional Improvement Implementation, Student Science Training, Resource Centers for Science and Engineering, programs for women, minorities and handicapped in science and engineering, and Public Understanding of Science.

State Governments

There are rapidly developing initiatives at the state government level that address elementary and secondary education in mathematics, science and technology. Two concerns are uppermost: (1) Most States believe their ability to attract high technology industries and adapt to technological change in traditional occupations is crucial to their economic future. (2) These States generally believe that the availability of well trained scientists and engineers and a high quality work force, both of which directly concern education, are crucial to achieving these ends.

State programs deal with the entire range of problems in mathematics, science and technology education. The areas where States have especially great leverage are: standards for teacher certification, which they determine; requirements for high school graduation; endorsements of particular curricula and texts; and, increasingly, statewide competency testing of teachers and students. Additional information about state programs appears in the volume of source materials accompanying this Report.

Alabama: This State was one of the first to adopt a scholarship and loan program for mathematics and science teachers. The State has also provided that teachers may take content programs in the subject they teach rather than approved education programs to obtain advanced certification.

Alaska: The Governor's Task Force on Effective Schooling resulted in plans for increased local review of school needs and more assessment of student performance to be carried out with technical assistance from the State. The "Learn Alaska" program uses satellite technology from four transmitter sites for courses on mathematics, biology, and other subjects.

Arizona: The Governor's Six-Point Program for Academic Excellence in precollege mathematics, science and technology includes higher state university admissions requirements, mathematics and science centers at the state universities, summer institutes for teacher training, a computer literacy requirement for precollege teacher certification, and the use of industry mathematicians and scientists in the classroom.

California: The Investment in People program seeks to strengthen mathematics, science, and computer instruction in elementary and secondary schools. It includes demonstration projects, summer institutes, curriculum efforts, computer training and software evaluation. A "Mentor" teacher program was recently enacted providing higher pay and additional responsibilities for assisting other teachers together with higher starting salaries for all teachers. The State Board of Education has passed a resolution urging at least three years of mathematics, two years of science, and one semester of computer science for every high school student.

Connecticut: The Department of Education's Distinguished Citizens Task Force on Quality Teaching issued recommendations in 1983 to improve recruitment and retention of high quality teachers particularly in mathematics and science.

Delaware: The Governor has recently appointed a Task Force to recommend steps for improving the schools, and the Delaware Board of Education has appointed another group to study the problem of teacher shortages in mathematics and science. The Jobs for American Graduates program, involving customized training for specific jobs, was developed through a committee of corporate and educational leaders and is now a model for other States.

Florida: The Governor's Commission on Secondary Schools has recently issued a report with recommendations for teacher training and high school graduation requirements, which includes three years each of mathematics and science. Task Forces led by the House Speaker and Senate President have also made recommendations to the Florida legislature to upgrade student performance, encourage students to enter mathematics and science teaching, and raise teacher certification requirements.

Georgia: The State Board of Regents and Board of Education have recommended differential teacher pay for priority locations such as low income areas, disciplines such as mathematics and science, and improved student performance. The legislature has enacted a mathematics and science scholarship loan program for future teachers.

Indiana: The Governor's proposals to promote excellence in public schools include matching funds to local school districts for computer hardware, software loans to less affluent districts and teacher training.

Iowa: The Education Committee of the Iowa Academy of Science made recommendations for science and mathematics education to the Governor, including upgrading and implementing teacher certification requirements, recognizing outstanding teacher and student performance and using mathematics and science consultants to help upgrade teachers. The State has instituted a pilot program to train biology teachers to teach the physical sciences. To do this, it has developed a new curriculum package and a telelecture interactive telephone system designed especially for rural areas.

Kentucky: This State was one of the first to enact a program of loan forgiveness for future mathematics and science teachers. It has also established a certification plan that requires competency testing, a one-year internship and a three-year commitment to teach. The State recently increased high school mathematics and science graduation requirements, established a "Governor's School" for outstanding high school students, and enacted a new school accreditation plan focused on district-wide performance of students, rather than performance level by individual school. This places more responsibility on the school board to assure that the district meets accreditation standards.

Louisiana: The Louisiana School of Mathematics, Science and the Arts, a public, residential, coeducational high school for exceptional students, was established by the State legislature in 1981.

Maine: The Governor has established a Commission to develop recommendations on how to improve the quality of the labor force from entry level, blue collar workers, to professional engineers.

Maryland: The Education Committee of the Governor's Science Advisory Council is examining mathematics and science programs at the precollege and university levels. The Commission for Quality Education has proposed differential pay and an eleven-month contract for teachers.

Minnesota: Minnesota Wellspring, a coalition of state government, business, labor and education is working to improve technological and economic strength in the State. The Minnesota Alliance for Science Education, composed of scientists, industry, and educators, is engaged in a joint effort to upgrade science education, K–12.

Mississippi: The Governor's Comprehensive Plan to upgrade public education includes ten percent pay increases for teachers, tougher teacher certification standards, a compulsory school attendance law, and performance standards for school accreditation.

New Hampshire: The Corporate Council for Critical Skills, financed by thirty New Hampshire businesses, provides summer jobs and supplemental training for mathematics and science teachers in critical-thinking and problem-solving skills to help them better equip students for jobs in industry. It plans to involve higher education and the state government, as well.

New Jersey: The New Jersey Council on Mathematics and Science Teacher Supply and Demand is considering proposals for training and retaining teachers in these fields. It was established by the Commissioner of Education and the Chancellor of Higher Education.

New York: The Center for Learning Technologies, established by the State Department of Education in the spring of 1982, will provide technical assistance to schools and implement new programs emphasizing computer literacy.

North Carolina: The North Carolina School of Science and Mathematics is a statewide, state-funded residential high school for able and motivated juniors and seniors. Recommendations have been issued by the Governor's Task Force on Science and Technology, the North Carolina Board of Science and Technology, and the State Department of Public Instruction to improve science and mathematics education. The State has enacted programs requiring that teachers be teaching in field by the fall of 1983, extending employment for selected mathematics and science teachers, providing summer institutes for junior high mathematics and science teachers, and establishing a Quality Assurance Program for teacher training.

Ohio: A Commission representing schools and colleges has recommended more rigorous high school courses, including three years each of mathematics and science for college-bound students.

Oklahoma: A statewide Master Teacher plan pays an additional $500 a year to teachers who help train other teachers.

Pennsylvania: The State Department of Education has established summer science programs at Carnegie-Mellon University for students who perform exceptionally well in science at the sophomore and junior high school level.

Rhode Island: A proposal is pending in the state legislature for a feasibility study of a state secondary school for mathematics and science. The Governor has also proposed a program of forgivable loans for future mathematics and science teachers.

South Carolina: The State Board of Education's "Move to Quality" program involves increased high school graduation requirements. The State Superintendent has proposed adding science to the state's "Basic Skills" list and establishing special mathematics and science teacher training programs.

Tennessee: The Governor's proposal for a Master Teacher program to provide merit pay, based on the legislature's Tennessee Comprehensive Education Study, narrowly failed to be enacted this year. The Governor has also proposed increasing high school mathematics and science requirements.

Texas: The Essential Goals for College Success project of the Texas Commissioner of Higher Education involves greater efforts to make students aware of the need for a strong precollege program. House Bill #246 has been enacted to restructure the K-12 curriculum with increased mathematics and science emphasis. A Workshop on the Mathematics and Science Teacher Shortage in Texas was sponsored by the Texas Education Agency, Coordinating Board, and Southwest Texas State University.

Utah: The Governor's Solving the School Crisis Program proposes forgivable loans and tuition grants for prospective mathematics and science teachers, a longer work year, links with business for summer employment of teachers, use of scientists in schools, upgrading state teacher training and certification, allocation of resources to computer equipment, building career ladders and eliminating clerical and custodial duties for teachers.

Virginia: The Governor's Task Force on Science and Technology recently issued forty-four recommendations including proposals for education programs in mathematics, science and computer technology, the raising of high school graduation requirements, salary increases for all public school teachers and a pilot master teacher program.

Washington: The Governor's Committee on High Technology Training and Advancement issued its recommendations in January 1983. Inservice training and retraining of K-12 teachers in science, mathematics and computer literacy was third in priority out of fourteen recommendations.

Wisconsin: A recommendation has been made to the University of Wisconsin Regents by a state-appointed council urging three years each of science and mathematics for all college-bound students.

Education Commission of the States: Its recent report, "The Information Society: Are High School Graduates Ready?" presents results of the National Assessment of Educational Progress and recommendations for changes at the precollege level. A special briefing to the National Governors' Association Annual Meeting, August 1982, "Education for a High Technology Economy," contains recommendations for state-level action. The Advanced Leadership Program Series (ALPS) holds regional meetings and workshops for state legislators involved in education.

Southern Regional Education Board: "The Need for Quality", a report of the SREB Task Force on Higher Education and the Schools, June 1981, contains twenty-two recommendations addressing teacher training and certification, school leadership, the quality of the curriculum and vocational training. The Southern Regional Education Board is a consortium of fourteen States concerned with issues at all levels of education.

Local Governments/School Districts

Local control of education has been a hallmark of the American public school system from its beginning. Local school systems, district superintendents, boards of education, school boards, and local municipalities have important roles to play in establishing local policies and implementing Federal and state directives. In most school districts the school board has tax levying power and develops and has control over its own budget. Where this is the case the local school board is the immediate unit of government at the local level as far as schools are concerned.

Today, each of the more than 16,000 local school districts has a major role in determining policies in that district particularly in the following areas: Standard-setting beyond what is directed at the state level, selection and development of curriculum, enforcement of teacher certification requirements and determination of salary where there is not statewide bargaining, evaluation and assessment of teachers and students, determination of codes of conduct in the classroom, and the responsibilities of an ombudsman who works with the local community and state and Federal government.

Mesa Public Schools, Arizona: The District has been selected as one of the top twelve in the United States in elementary school science programming by the National Science Teachers Association. It has an innovative science coordinator for all elementary science programs, who plans curricula, assembles and distributes materials, and works with teachers in the district.

Tucson Unified School District, Arizona: The University High School provides an academic magnet program from which it sends ninety-six percent of its graduates to college (eleven National Merit Scholars in 1981) and works with the University of Arizona to provide special courses for more advanced students.

Santa Cruz, California: The Green Acres Elementary School's Life Lab Program combines science, nutrition and gardening lessons and their applications by using a three and one-half acre garden site. It was selected as an outstanding program by the National Science Teachers Association's "Search for Excellence in Science Education" project.

Denver, Colorado: George Washington High School is noted for its extensive program in computer mathematics, which allows students to progress from computer literacy to writing programs.

Lakewood, Colorado: The Jefferson County Revised Elementary Science Program, operating in all seventy-six elementary schools, features a "hands-on" inquiry approach based on district adaptation of the Elementary Science Study (ESS), the Science Curriculum Improvement Study (SCIS) and locally developed units. Programs in physical science and in Science/Technology/Society were selected as outstanding by the National Science Teachers Association's "Search for Excellence in Science Education" project.

Washington, DC: The DC school board has adopted a city-wide, high-expectation curriculum. Six new high school career programs have been initiated in cooperation with private industry support, including engineering, information technology, and the health sciences. Jefferson Junior High School uses instructional TV in conjunction with Howard University to share classroom strategies with teachers and requires parents to sign a contract providing that students will do a certain amount of homework each night. Five high schools use computer-assisted remediation.

Wilmington, Delaware: Brandywine High School's model biology program in Human Ecology was chosen as an outstanding program by the National Science Teachers Association's "Search for Excellence in Science Education" project. It seeks to relate individual development to the social and physical environment.

Merritt Island, Florida: Merritt Island High School's model programs in biology and inquiry encourage students to go beyond usual courses to do independent research investigations. They were selected as outstanding by the National Science Teachers Association's "Search for Excellence in Science Education" project.

Atlanta, Georgia: The Resource Center for Science and Engineering at Atlanta University, begun with NSF supp...t, provides training, facilities, research and other opportunities at precollege, university and community levels for the S...theastern Region. It has Saturday and summer programs for elementary and secondary students to heighten career awareness and establish links between the education and business communities.

Chicago, Illinois: The Chicago Adopt-a-School program, involving local industry and an emphasis on science, mathematics and technology programs, and the local MATHCOUNTS program, an accelerated high school mathematics coaching project, have been pioneered by the Board of Education in the last two years. The Pre-Algebra Development Center was the recipient of an Educational Pacesetter Award. Computer-assisted instruction is used in forty-four elementary schools, and there are six specialty senior high schools for computer science programs. These programs have been cited as exemplary by the Human Resources Research Organization.

La Grange, Illinois: The Lyons Township High School Computer Literacy Program introduces teachers and students to a range of instructional uses of personal computers. It attempts to provide training for all staff and students in the use of the computer, its functions in society and its promise as an educational tool. Teachers in all disciplines help to develop computer courseware.

Prince George's County, Maryland: The county has proposed three new programs to retrain non-mathematics teachers in mathematics, to provide in-service training for mathematics teachers, and to establish a team of elementary school teachers in mathematics to train others.

St. Louis, Missouri: The Ladue School District merit pay program provides three salary schedules for teachers according to criteria recommended by a Committee on Teacher Evaluation, on which teachers are heavily represented. Evaluation points are then assigned by the principals.

Sunburst, Montana. [illegible] County High School's program in physical science and inquir[illegible] [illegible]th, 11th and 12th grade students to plan and complete scientific [illegible] of interest to them. It was selected as outstanding by the Natio[illegible] [illegible]achers Association's "Search for Excellence in Science Educat[illegible] [illegible]t.

New York City, New York: The Comprehensive Mathematics and Science Program, started with support from the National Science Foundation, has sought to counter the overall decline in mathematics achievement by working with ninth graders from ten high schools, to bring them into science and pre-engineering courses. The Manhattan Center for Science and Mathematics in East Harlem, a four-year (9-12) magnet school which accepts students from throughout the city and is funded by the Board of Education, also includes the Isaac Newton School for Mathematics and Science, an intensified middle school program. The high school has an eight-period day, a microcomputer laboratory, and emphasizes preparation for college science and engineering courses. Its advisory board includes officials from Hunter College and major corporations. The Aviation High School in Queens simultaneously prepares students for careers in aviation and for the NYS Regents diploma. Morris High School in the South Bronx, which now requires nightly homework and contracts with parents certifying that they understand the course requirements, recently received a Ford Foundation award for substantial progress in improving achievement scores.

Charlotte-Mecklenburg, North Carolina: The school district's Master Plan proposes to offer a differentiated salary ladder for career teachers by assigning them additional administrative duties. It aims to pay career teachers (the highest of five levels) salaries comparable to those of middle management.

Seiling, Oklahoma: Teachers are designated as master teachers on the basis of student scores on standardized tests. All teachers in a school receive a bonus if the students in that school have higher scores than the district average, and individual teachers receive extra bonuses if their students score higher than the school average. Master teachers can earn up to $1,000 more in addition to bonuses, through added responsibilities.

Houston, Texas: The Houston Second Mile Program provides incentive pay for teachers who teach in schools where educationally disadvantaged students are concentrated, in fields of teacher shortages, or in schools that exceed predicted achievement scores, or who have outstanding attendance and participate in professional growth activities. Also "Project Search" seeks to identify and recruit teachers in mathematics and science. There are "Magnet" programs in mathematics and science at the elementary and secondary school levels. The High School for the Engineering Professions sends its graduates to outstanding universities across the United States.

Fairfax County, Virginia: The "hands-on" elementary school science program provides science education for all elementary students (60,000), mandatory inservice training for all elementary teachers, and instructional resources (materials, guides, and science reading materials) for each classroom.

Richmond, Virginia: Newly certified mathematics and science teachers are offered a $2,000 bonus by the Richmond school district in return for a two-year commitment to teach.

Milwaukee, Wisconsin: The High School Unlimited Program provides that each of the city's high schools has it own unique career and skill focus.

Wausau, Wisconsin: Wausau West High School's program in Science, Technology, Society and Inquiry is a unified science approach with the goal of developing scientific literacy in all students. It was selected as an outstanding program by the National Science Teachers Association's "Search for Excellence in Science Education" project.

Institutions of Higher Education

The Nation's colleges and universities are in a position to provide particular leadership in improving elementary and secondary education in mathematics, science and technology. They have the major role in setting admissions requirements for higher education, which in turn directly affect high school curricula and graduation requirements. They train elementary and secondary school teachers, develop curricula, and guide students into career paths, including the path of elementary and secondary school teaching. Thus they are closely involved in influencing the quality of precollege education and the preparation of the students who graduate from the Nation's high schools.

In addition, by working with state and local governments, local communities, and principals, teachers and students from elementary and secondary schools, higher education institutions can help to formulate goals and develop public awareness of the need for excellence in mathematics, science and technology education at the elementary and secondary level.

Arizona State University: A task force on implementation of the Governor's Six-Point Program for Academic Excellence has been established in the university. The College of Education has an innovative and growing Program for Computer Literacy. The College of Engineering's Center for Engineering Excellence, jointly supported by industry, conducts summer programs for women, minority and gifted high school students to encourage them to enter engineering careers.

Carleton College: The college operates summer computer workshops for teachers who attend from throughout the nation. The program includes computer science, training in LOGO and Pascal and in use of the computer with handicapped students.

City College of New York: A new program at the A. Philip Randolph School for 9–12th grade, located on the City College campus, provides rigorous training in mathematics and science as preparation for the health professions. Most of the students are economically disadvantaged and drawn from all five Manhattan boroughs. The program is supported by the Macy Foundation and uses the facilities and professional resources of City College to supplement its own. Ninety-five percent of the program's ninth graders this year passed the NYS Regents biology examination.

Detroit Area Precollege Education Program: This five-university consortium focuses on junior high school programs to enrich training in science, mathematics and pre-engineering and to increase interest in science and engineering careers.

Duke University: The university's Talent Identification Program for sixteen southeastern states identifies mathematically and verbally talented twelve-year-olds for schools, states and parents. The university itself runs several summer programs for talented twelve- to fifteen-year-old students. It also publishes an educational opportunity guide which lists programs, by state, for talented students.

Eastern Illinois University: The university has a graduate program for experienced high school teachers of chemistry and physics - MS Ed in Physical Science - to enable them to increase their subject matter knowledge in both fields during three or four summer sessions.

Harvard University: The new Graduate School of Education program seeks to train mid- to late-career mathematicians and scientists from industry to become certified Massachusetts secondary school teachers. It will also offer an inservice summer program for current high school mathematics and science teachers.

Howard University/University of Maryland: METCOM is a summer program operated jointly by Howard University and the University of Maryland to expose urban high school students to engineering. It is supported by private industry.

Mount Holyoke College: The Summer Mathematics Program prepares high school women for more effective study of mathematics at the college level.

New Jersey Institute of Technology: The Precollege Institute in Mathematics, Science and Engineering is designed for secondary students and teachers.

Princeton University: The Dreyfus Institute on High School Chemistry, held in the summer of 1982, selected fifty high school chemistry teachers nationwide for four weeks of intensive training, including use of microcomputers, in order for them to become master teachers in their home regions.

Simmons College: The Dreyfus Institute on High School Chemistry, like the program at Princeton University, trained master high school teachers, primarily in chemistry, to conduct inservice workshops in their school systems.

Spelman College: The college conducts a postsecondary, precollege summer program of intensive science and mathematics instruction for black women to enhance student preparation for science majors and to encourage entry into science and engineering careers. It emphasizes study skills, homework and rigorous discipline.

The Johns Hopkins University: The Center for the Advancement of Academically Talented Youth conducts a talent identification program for the Middle Atlantic states as well as several summer programs for secondary level students.

University Inservice Teacher Education Network (UITEN): A consortium of seven Philadelphia-area colleges and universities is working with the Philadelphia School District on secondary school mathematics certification.

University of Arizona: The Department of Mathematics' innovative program of work with high school teachers is serving as a model for other departments. An Ad-Hoc Committee on Mathematics and Science Education has been established to coordinate intra-university programs and outreach with both the precollege and business communities.

University of California, Berkeley: Project EQUALS, developed at the Lawrence Hall of Science, provides multi-state training programs and curricula for teachers, counselors and administrators of grades K-12. The project has strong links to the professional education community and emphasizes attracting and retaining women and minority students. The Math/Science Network holds conferences to acquaint parents and students with the importance of mathematics and science. EQUALS IN TECHNOLOGY works with school districts to reduce the technology gap between males and females and advantaged and disadvantaged students.

University of Kan[illegible] curriculum, Career-Oriented Modules to Explore Topics in Science [illegible]S) was designed for use in grades 5-9 to supplement science and sc[illegible]entered language arts courses.

University of Maryland: The university has a Science Teaching Center, which features joint appointments between the academic departments and the Center for faculty engaged in training secondary school science teachers. The Center also serves as an international clearinghouse for science and mathematics curriculum development.

University of New Mexico: The Southwest Resource Center for Science and Engineering provides training, facilities, research and other opportunities for the Southwestern Region with a particular focus on mathematics and science programs for elementary and secondary school youth.

University of Oklahoma: The American Indian Engineering program seeks to increase interest by American Indians in engineering careers and to prepare students better in mathematics and science.

University of Utah: The university has announced it will provide remedial training for only three more years. After that, if students do not have adequate precollege preparation in mathematics, for example, they will not be admitted.

University of Vermont: Starting in the fall of 1983, the university will offer a program to retrain retiring or mid-career industry scientists and mathematicians to be precollege teachers, similar to the new program at Harvard's Graduate School of Education.

University of Wisconsin: Multiplying Options and Subtracting Bias is an intervention program designed to eliminate sexism from mathematics education, developed at the university for use at the precollege level. In addition, efforts are underway to establish a national Institute for Chemical Education that would provide continuing inservice workshops as well as research opportunities for precollege and college teachers.

Wesleyan University: The summer institute held by the university for elementary and junior high school mathematics teachers continues a program originally funded by NSF that includes courses and workshops on mathematics and mathematics anxiety.

Professional Societies/Associations

As a bridge between professional mathematicians, scientists and teachers, the Nation's professional societies have a special role in any effort to improve our educational system in the areas of mathematics, science and technology. The Commission was told of many outstanding programs that are currently being operated by professional societies to help teachers and to motivate students. In every case the programs involve professionals in the individual disciplines who help with the presentation of that discipline in the schools. An illustrative listing of such programs follows:

American Association for the Advancement of Science: The AAAS has established the Coalition for Education in the Sciences to involve AAAS members directly with schools, developing resource materials and increasing science and technology understanding in local communities. It is collaborating with the Association of Science-Technology Centers and five of its member centers in a pilot project to encourage scientists and engineers to do volunteer work with the centers on school and public understanding projects. It has had a long-term commitment to use its unique resources to improve science and mathematics education in the Nation's schools. Financial support from Phillips Petroleum and Standard Oil of Ohio is being used to develop mathematic and science resource materials for junior high schools, to be used by students, teachers, administrators, librarians and parents.

American Chemical Society: ACS has established a high school chemistry office that conducts and coordinates a range of activities to improve chemical education and science education in general. It maintains a film library, distributes career information materials and guidelines for chemistry teacher training and continuing education, a teacher newsletter (Chemistry), and a student publication (Chem Matters). The Society is developing a year-long course, Chemistry in the Community, that stresses applied chemistry for the general student. It also sponsors regional workshops for teachers and conducts a career development program for disadvantaged students. The Society confers the James Bryant Conant Award annually on an outstanding high school chemistry teacher, and many local ACS sections provide teacher awards as well. It also encourages industrial chemists to work with schools.

American Geological Institute: AGI has developed earth sciences career information materials. It publishes *Earth Science*, a non-technical magazine for amateur geologists, teachers and students and continues to revise earth science films and the ninth-grade earth science program, *Investigating the Earth.*

American Physical Society: APS has established a joint APS-American Association of Physics Teachers College-High School Interaction Committee to promote working relationships between departments of physics and high school teachers, including industry support, summer jobs and equipment loans. It distributes career materials, including one that focuses on women's careers, and information packets for junior and senior high school counselors. Recently it opened an office in Washington and is following congressional and executive branch activities in the area of precollege mathematics and science education.

American Society of Civil Engineers: The Society supports a summer intern program for minority high school students at Northeastern and Notre Dame Universities.

Association of Science-Technology Centers: Association members conduct numerous programs both inside and outside of the schools for teachers, students and the general public.

Geological Society of Washington, DC: Its Committee on Precollege Education arranges field trips for local high school science teachers to acquaint them with sites for use in teaching. It also judges science fairs and holds award ceremonies for student winners and is trying to encourage more interaction among earth science teachers in the Washington area and more recognition of the importance of earth science at the precollege level.

Institute of Electrical and Electronics Engineers: IEEE has prepared and distributed materials explaining careers in electrical engineering and computer science. It is developing a curriculum for a one-year high school course on computer science and a corresponding achievement test.

Mathematical Association of America: The Association develops recommended guidelines for mathematics teacher training, including detailed content coverage and level of courses. It sponsors the American High School Mathematics Examination, taken by more than 400,000 students, and the Invitational Mathematics Examination that selects the U.S. team for the International Mathematics Olympiad. Support is also provided for lecturers, often directed at encouraging women and minorities to participate more in mathematics.

National Association of Biology Teachers: NABT sponsors an annual awards program for outstanding high school biology teachers.

National Association of Secondary School Principals: NASSP has recently surveyed changing entrance requirements, particularly among state universities, and issued a report, *College Admissions: New Requirements by the State Universities*, which discusses the implications of these rising admissions requirements for secondary schools.

National Council of Teachers of Mathematics: NCTM developed and published *Priorities in School Mathematics* and *An Agenda for Action: Recommendations for School Mathematics of the 1980s*. It has recommended guidelines for the preparation of teachers of mathematics and holds regional and national meetings to help in the professional growth of its members. It is a sponsor of the American High School Mathematics Examination, the Invitational Mathematics Examination and the International Mathematics Olympiad.

National Science Teachers Association: NSTA's project on "Search for Excellence in Science Education" examined outstanding elementary and secondary science programs throughout the country, evaluating them to identify the elements responsible for their success.

National Society of Professional Engineers: The Society initiated MATHCOUNTS, a national tournament to increase public awareness of the importance of mathematics and to enhance the interest and motivation of 7th and

8th grade mathematics students. The tournament involves the collaboration of the National Council of Teachers of Mathematics and the Mathematical Association of America with financial support from the CNA insurance companies.

Society of Sigma Xi: The Society has a program to encourage local chapters to recognize through a reward ceremony outstanding teachers of science.

Business and Industry

American business and industry are increasingly concerned about the quality of elementary and secondary schools. A majority of the new employees under twenty-five years of age who are hired by business are not college graduates. Business is particularly focusing on the quality of elementary and secondary education as it relates to the learning skills, problem-solving abilities and discipline of new employees entering the labor force. A number of companies are developing programs in cooperation with school systems to provide assistance in a variety of ways. Those that employ a high proportion of scientists, engineers and technicians have shown increasing interest in mathematics and science education especially at the high school level.

A number of companies such as DuPont, Exxon, General Electric, Phillips Petroleum, Westinghouse and Xerox have had a long-standing interest in and commitment to public education as a matter of corporate responsibility. This interest is becoming more widespread. According to a recent survey by The Conference Board, over 1,000 businesses and corporations now place public education as a "primary agenda item in their companies' public affairs programs."

Atlantic Richfield Company: The company provides released time for company employees to teach mathematics and other subjects in inner-city schools in Los Angeles.

Bell Laboratories: The Summer Science Program provides hands-on experiences in a research laboratory for minority students who have completed the 8th grade.

Ciba-Geigy Corporation: The company sponsors national exemplary science teaching awards for elementary, junior and senior high school teachers.

Control Data: Working with a number of educational institutions, the company developed the PLATO computerized learning system for mathematics, reading and English in grades 3-8. PLATO is being used for education in schools, business and government, providing training in a self-paced manner.

Dow Chemical Company: The Dow Michigan Division's Frontiers in Science program provides for the exchange of industry scientists and high school teachers.

E.I. DuPont de Nemours and Co.: The company supports pre-engineering programs targeted at minority secondary school students at fifteen colleges and universities. It also has provided support for the Del-Mod Program, a major effort to improve science and mathematics education in the Delaware public schools.

Exxon Corporation: Numerous grants, largely through the Exxon Education Foundation, have been made for selected objectives. These include promoting minority student interest in engineering, advancing the application of technology to the instructional process, fostering exemplary teacher programs, and providing support for IMPACT-II, a teacher-to-teacher dissemination program in New York City and Houston.

General Electric: The company provides support for "PIMEG" (Program to Increase Minority Engineers), which now has eighty precollege programs conducted by General Electric in forty-eight communities throughout the Nation to increase the number of minority high school graduates preparing for careers in engineering, science and technology. The program involves students, teachers, parents and other employers.

Hewlett-Packard: The company has helped to establish and fund Peninsula Academies to reach high school dropout students, emphasizing computers and microelectronics. The computers are provided by Hewlett-Packard and the teachers by several high technology companies, including Hewlett-Packard. It provides support for the Institute of Computer Technology, involving the collaboration of three high schools and two full-time staff from H/P and IBM. In addition, Hewlett-Packard has contributed computers to many high schools.

Honeywell: The company provides support for Summatech, a magnet school under the Minneapolis public school system, which focuses on a core curriculum in mathematics, science and technology, grades 9-12, with an emphasis on computers. The school is located in a predominantly minority community.

International Business Machines: In conjunction with the Educational Testing Service, IBM is supporting a "Computer Literacy Program" involving twelve colleges and universities and eighty-four secondary schools selected by the Educational Testing Service in California, New York and Florida to train teachers and introduce computers into the secondary school curriculum. IBM is also donating 1,500 microcomputers and related software to the secondary schools.

Kaiser Aluminum and Chemical Company: The company provides financial support and released time for personnel to assist in mathematics and science education in the Oakland, California school system.

Mitre Corporation: The company has a program to encourage interest in science and engineering careers on the part of minority students in secondary school. It provides scholarship support, summer employment, seminar speakers, and minority professionals as role models.

Phillips Petroleum: The "Search for Solutions", a film series and related text to augment science instruction in secondary schools, was developed with an investment of over $7 million by Phillips, including provision for national distribution and assessment of the materials. A $6.5 million four-year grant has recently been made to the American Association for the Advancement of Science to develop mathematics resource materials for middle-school students—"Challenge of the Unknown"—emphasizing critical thinking and problem solving.

RCA: Among other projects, support was provided to the Camden, New Jersey high schools for a student experiment with carpenter ants carried out on the space shuttle. It was undertaken particularly to interest minority students in science.

Tandy Corporation: The company has announced a plan to offer twenty-three hours of computer instruction to one teacher from every public and private school at four hundred sites nationwide.

Standard Oil Company (Ohio): The company has targeted for support the areas of mathematics and science education, uses of technology in education and educational management issues. It has made a grant of $1.7 million to the American Association for the Advancement of Science for a Science Resources for Schools program to upgrade junior high school science teachers' knowledge and curricula. The Cleveland Teacher Internship program provides summer employment in industry with SOHIO a leading source of funds and placement opportunities. The company together with TRW began a Saturday enrichment program in the Cleveland area for students in grades 7-12 directed at motivating minorities and women to take science courses. The company provides scholarships for Cleveland area students to participate in the MS^2, (Mathematics and Science for Minority Students) at Phillips Academy in Andover, a rigorous three-summer program in mathematics, science and communication skills. It has increased funding to the Educational Computer Consortium of Ohio (ECCO) to expand its software literacy and teacher network.

Texas Instruments: Among other projects, the company initiated Project Seed in Dallas in grades 4-6 to help develop positive attitudes toward mathematics through regular provision of employees, who are qualified mathematics professionals, to work with students. Other industries now participate as well.

U.S. Chamber of Commerce—National Chamber Foundation: The "Task Force on Education and America's Workforce: Helping Schools Make Better Workers," is looking at steps local business can take to work with schools in strengthening students' skills.

Walt Disney Educational Media Company: The Epcot Teacher Center offers materials and guides on education and technology. It also produces educational software for computers.

Westinghouse: A long history of interest in and support for precollege science education characterizes this company. It has supported the national Science Talent Search conducted by Science Service for the past forty-two years. It followed the early lead of the General Electric Company in providing support for summer institutes for science teachers beginning in the late 1940s. These eventually became the model for the National Science Foundation's institute program.

WICAT Systems: This company provides support for Waterford School, K-8 (to be expanded to K-12), an experimental school established for developing and evaluating curriculum materials delivered by technology. Commencing in kindergarten, the children use WICAT computers specifically designed for the education market.

Xerox Corporation: The company has initiated a program to bring volunteer employee scientists and engineers into the Rochester, New York and Tampa, Florida elementary schools on a bi-weekly basis for demonstrations and hands-on experience in physical science and mathematics. Xerox has also developed curricula kits for the program that enable regular classroom teachers to follow up on the sessions.

Museums, Science Academies, and Other Informal Education Programs

Museums, state academies of science, private foundations and other groups outside the formal system of education have played a role at the most innovative edge of elementary and secondary education in mathematics, science and technology. The unprecedented number of children and adults flocking to science museums across the country attests to the power of creative ideas and hands-on experience. Attendance at science museums and related institutions is almost as large as at all other museums combined—roughly 150 million per year—more than the total attendance at all baseball, football and basketball games played each year.

The private foundations have always been in the vanguard of new initiatives in education. Many of the most successful developments in formal public education, such as the Houston High School for the Engineering Professions, received initial support from private foundations such as the Carnegie, Ford, Macy and Sloan foundations. These organizations have also played a catalytic role in mobilizing other community groups and institutions to participate in supporting and working with local school systems.

Following are some of the many activities that have come to the Commission's attention:

Capital Children's Museum (Washington, DC): This museum was selected for the AAAS/Association of Science-Technology Centers program to use volunteer scientists and engineers to work with schools, teachers and the public in increasing interest in and understanding of science. It is a hands-on museum, and this philosophy is carried through to its teacher training program.

Camille and Henry Dreyfus Foundation: The foundation provided support for the Dreyfus Institutes in High School Chemistry at Simmons College and Princeton University to train promising chemistry teachers as "Dreyfus Master Teachers," and to develop curricular materials and a network of master teachers throughout the country.

Cranbrook Institute of Science (Bloomfield Hills, MI): The Institute was selected for the AAAS/Association of Science-Technology Centers program to use volunteer scientists and engineers to work with schools, teachers and the public to increase interest in and understanding of science. The Institute has a wide variety of educational activities, particularly in environmental and nature education.

Exploratorium (San Francisco, CA): The museum centers around the theme of perception. It is designed so that children and adults can interact with the exhibits in exploring, for example, vision and light, hearing and sound, waves and resonance, and patterns and motion.

Fernbank Science Center (DeKalb County, GA): The Center was designed to supplement and extend the science curriculum for K-12 students from DeKalb County and other school systems. It offers independent study programs for secondary students who work with professional staff at the Center. A special course in Scientific Tools and Techniques covers all major science fields and gives students access to major scientific equipment such as electron microscopes. There are also programs for teachers and traveling exhibits for schools.

Florida Foundation for Future Scientists: This is a recently formed private foundation to encourage and provide support for talented young people to enter careers in science and engineering.

Ford Foundation: Among many projects, the City High School Recognition Program made awards in 1982 to 110 high schools nationwide that are succeeding in making self-improvements in such areas as academic achievement, student life and parental participation. Fifty schools were selected among these for larger grants to continue building on their successes. The program is being repeated in 1983.

Franklin Institute (Philadelphia, PA): The Institute has a variety of education programs for school groups and the general public including a special program for academically talented children. A traveling science show visits local school assemblies and shopping malls. It uses scientific apparatus and audience participants for a hands-on reenactment of significant experiments. In this way it provides an actual science lesson to schools that do not have the equipment and resources for this, at the same time generating interest in science and in obtaining more materials for classroom use.

Girl Scouts, USA: Special science programs based on the TV series "3-2-1 Contact" have been developed, which include science badges requiring research and practical experience, such as Computer Fun, Math Whiz, Science Around Town, Science in Action and Science Sleuth. Over 10,000 science badges were awarded in Washington, DC alone during the first year.

Girls' Clubs of America: This organization has established a program to link its national level youth employment initiatives with interests in new technology.

League of Women Voters Education Fund: The League has distributed a publication to all chapters and members, *Math, Science and Technology: Adding It Up for Women*, which focuses on the labor market and essential scientific and technical skills.

Macy Foundation: Since the early 1950s the foundation has supported numerous projects to improve medical education and in 1968 began an initiative to increase minority participation in the medical professions. In 1982, grants totaling nearly $4 million were made to inner city and rural high schools for demonstration projects offering special opportunities for minority youngsters wishing to pursue medical careers.

Maryland Science Center (Baltimore, MD): The center's exhibits include geology, evolution, and the Chesapeake Bay. It has live demonstrations of actual science experiments and over 100 instructors including many university professors who provide science instruction.

Museum of Science and Industry (Chicago, IL): The museum has organized "Summer Science," a science training program for inservice teachers, administrators and school board members. It conducts a Children's Science Book Fair and has weekend science workshops for families and young children. In cooperation with a local public TV station, it offers teacher workshops related to the "3-2-1 Contact" program. It has been selected for the AAAS/Association of Science-Technology Centers program using volunteer scientists and engineers to work with schools, teachers and the public in increasing interest in and understanding of science.

New York Academy of Sciences: The Academy has a Scientists in Schools program, computer workshops, and helps to arrange summer employment for students and teachers in industry or in other scientific laboratories.

New York Hall of Science (Flushing, NY): This museum was selected for the AAAS/Association of Science-Technology Centers program to use volunteer scientists and engineers to work with schools, teachers and the public in increasing interest in and understanding of science. The museum operates a number of educational and summer science programs for children and adults in astronomy, electronics, and the natural sciences.

North Carolina Museum of Life and Science (Durham, NC): This museum was selected for the AAAS/Association of Science-Technology Centers program to use volunteer scientists and engineers to work with schools, teachers and the public in increasing interest in and understanding of science. Originally a children's museum, it now serves all the citizens of North Carolina. There are many hands-on exhibits, a physics playground and a pre-history trail with full-scale models.

Oregon Museum of Science and Industry (Portland, OR): The museum's exhibits cover industry and the physical and natural sciences. It operates an extensive educational program for children and adults including in-service training for science teachers and three outdoor science camps for children that provide an opportunity for learning skills and concepts from a number of natural sciences such as geology, botany, zoology, paleontology, archaeology, astronomy and ecology. The camp program receives community support from local and regional science-related groups including industry.

Public Education Fund: With a $6 million grant from the Ford Foundation and additional funds still to be raised, the Fund will seek to forge partnerships between schools and the community through "grass roots" education groups in forty to fifty cities over the next five years. It will make matching grants to local education foundations and districts, some of which will be used to support innovative teacher projects.

Sloan Foundation: During the 1970s the Sloan Foundation made a major investment focused on increasing the number of minorities entering the engineering professions. Several projects were directed toward improving pre-engineering programs in high schools and motivating increased minority participation. The High School for the Engineering Professions in Houston was started with a $56,000 planning grant from Sloan.

Squam Lakes Science Center (Holderness, NH): With support from corporate and individual contributions, this Center provides life and earth science education services to New Hampshire schools, K-12. The 200 acres of fields, forest, and ponds are used for scientific studies of native flora and fauna.

University of the Air: This nonprofit corporation is concerned with the development of materials and a national telecommunications network for satellite communications to serve civilian and military education needs, particularly in mathematics and science instruction and teacher training. Support has been provided by the Commerce Department to develop a network for teacher training via satellite with public school systems in six regions of the country.

Multiple Collaboration Among Sectors

Allegheny Conference on Community Development (Pittsburgh, PA): The Conference, which was formed by private businesses in Pittsburgh, has provided financial and policy assistance in developing education programs including magnet schools, desegregation plans, and summer and after-school programs. It has supported innovative teacher projects and partnerships-in-education linking corporations with the schools. It is the model for the newly-created Public Education Fund (PEF) which will seek to encourage similar groups in cities throughout the Nation (see above).

Atlanta Partnership in Business and Education: Private businesses, working together, have established adopt-a-school and adopt-a-student programs to assist students in career planning and to encourage them in the study of mathematics and science.

Chicago Area Pre-College Engineering Program (CAPCEP): This partnership of employers of engineers and technical personnel, precollege schools and engineering colleges was formed to encourage the entrance of minorities into engineering and technical careers through support to the schools. It involves teacher training, curriculum development, materials and adjunct personnel, and a program of recognition for those schools that do an exceptional job.

Chicago United: This is a consortium of business executives and professionals that works with the Chicago Board of Education to help improve the quality of education and career preparation.

Children's Television Workshop: "3-2-1 Contact" is a television series aimed at interesting students in science and technology, which was developed with support from the Corporation for Public Broadcasting, United Technologies, Department of Education and National Science Foundation.

Committee on Economic Development: It has initiated a project to assess the economic impact of education and the cost to business, industry and the economy in general of poor quality education. Particular attention will be given to how to improve quality in the public schools and what private business can do to help.

Detroit Area Precollege Education Program: This program is designed to identify students with aptitude for mathematics, science and engineering and to work with them in special education programs and counseling to encourage their interest in these areas.

Institute for Educational Leadership (Washington, DC): The Institute brings together heads of education, business, government and union organizations for policy sessions on education, including how to strengthen elementary and secondary education.

Junior Engineering Technical Society (JETS): A national youth activity operating through student chapters, JETS strives to increase interests and skills in mathematics, science and technology. It is cosponsored by several professional societies and supported by industrial sources and the volunteer services of individual engineers.

Mathematics, Engineering, Science Achievement (MESA): This intensive enrichment program was begun in 1970 with support from the business and education communities to increase the preparation of minority students in mathematics and science and to interest them in entering careers in these fields. It is now operating in over 125 high schools in California and also in Colorado, New Mexico, and Washington. The program involves tutoring, counseling and field trips together with summer employment and scholarship support.

Minnesota Educational Computing Consortium (MECC): This quasi-governmental organization coordinates inservice training and the use of Federal, state and local funds for hardware and software purchases for computer programs. It is linked to all the state's school districts, and a number of other states have joined the network as well.

National Action Council for Minorities in Engineering: The Council provides support for eighty-five colleges of engineering that operate summer institutes for minority high school students focused on mathematics and science skills.

New Jersey Business/Industry Science-Education Consortium: The consortium includes sixteen corporations, state and local education officials, professional societies and educators. The corporations donate funds that are supplemented by local school systems receiving grants from the consortium. Projects have particularly focused on training programs for science and mathematics teachers and career counseling to encourage students to seek careers in these fields.

Northeast Educational Center, North Carolina: The agricultural extension agent format is used to help rural schools provide equal access to education.

Philadelphia Regional Introduction for Minorities to Engineering (PRIME): The program identifies minority students in grades 7-12 with high aptitude in science and mathematics and provides academic year and summer activities for them with specially trained teachers and staff.

Program for Rochester to Interest Students in Science and Math (PRISSM): Originated by Rochester, N.Y. industry, the program seeks to improve economic stability and to increase the number of minority students qualified to enter engineering schools. It funds teacher training and teams of teachers to develop curricula, arranges field trips and provides scientific and technical staff for classroom and summer internships for students. It also works with parents and the community to create awareness of the need for preparing for a technological society.

Project to Increase Mastery of Mathematics in Connecticut (PIMM): This state-wide organization of business, labor, state government and education has the aim of raising the level of mathematics competence and thereby helping people achieve vocational and professional goals. It provides job requirement analyses and works with teachers and school counselors. Funding is provided by industry.

Staten Island Cooperative Continuum of Education: Many schools and colleges, businesses, community agencies, private foundations, and government are brought together for the purpose of joining educational needs and interests with resources. The Cooperative acts as a clearinghouse and ombudsman for education throughout the community and at all age levels.

Southeastern Consortium for Minorities in Engineering (SECME): Representatives of twenty-two universities in eight States are involved in developing local projects with the participation of secondary schools, universities and corporations to increase the number of minorities in the engineering profession. Most support for the program comes from engineering employers with the remainder from foundations and professional societies.

EXHIBIT B

SUGGESTIONS FOR COURSE TOPICS AND CRITERIA FOR SELECTION

In preparing an outline of topics and criteria, the Commission has been fortunate to have the advice of experts who have spent much time developing materials and contributing to conferences on elementary and secondary mathematics, science and technology education. The Commission is confident that the thrusts of the recommendations from these conferences go in appropriate directions. Some suggested course topics from Commission-sponsored meetings and other groups and professionals are cited in this section.

At the same time, it is one thing to give a list of the ideas and objectives desired, and another to create the courses appropriate to pupils in a specific school system in such a way that an integrated educational program results. Such programs require substantial work by groups of professionals at all levels. No one course of study is appropriate for all students and all teachers in all schools in all parts of the country. Nor is there just one good curriculum. Various parts of the Nation must develop their total curriculum and revise it repeatedly to keep it suitable for students and teachers. We hope this paper and the cited references will help with the process.

In the fields of mathematics and science, we have many more years of experience in curriculum development than we do in the area of technology, where clearly special efforts are required. Technology is a part of everyone's daily life. Even so, most people do not appreciate the complexity of our technological society. Yet, a key to understanding problems among nations, communities, and individuals can be found through our actions in producing goods and services. The needs of today demand useful inventions, productive research, efficient production, quality workmanship, and personalized service. To achieve these goals, we must begin to develop our human resources in the elementary and secondary schools through a comprehensive, contemporary, technology education for all.

Computers and related software systems are developing at a great rate. These developments must go well beyond speeding arithmetic work or electronic page turning. Computers can effectively be integrated into virtually all teaching and learning areas such as the teaching of reading, development of graphing techniques, development of skills in composition and development of physical insights through modeling and interaction with the real world.

Creating better computer programs and uses to assist with learning should proceed in parallel with curriculum development. For this technology to have an appropriate impact on our schools and national economic program, it will require close and continuing attention and development.

To conduct curriculum development as though the disciplines exist independently of each other does an injustice to the natural and necessary integration of mathematics, science and technology. However, for obvious and practical reasons we have addressed course topics under the headings involving the mathematical sciences, the natural sciences (further divided into physics, chemistry and biology) and technology. Such a presentation does not necessarily recommend classroom delivery through these same categories. Rather, we hope that teachers of mathematics, the natural and social sciences, technology, of reading and writing, history, English and the arts, will seize the numerous opportunities to demonstrate the interdependence of human knowledge and encourage students to apply the skills and concepts from one discipline in seeking solutions in the others.

Caution

We know some students in secondary school do not display special talent in mathematics or may have difficulties stemming from poor preparation; many others are not headed for careers in the sciences or technology. For these reasons, suggested topics should be considered in view of student needs and skills and modified accordingly to allow all students to benefit from their knowledge of science and technology and for all to reach their highest potential. Courses encompassing important mathematics principles must be developed to meet the needs of these students. We urge the consideration of computers as both mathematical tools and facilitators of learning. They can offer a fresh window into learning for the average student.

Mathematics

K-8 Mathematics

The Commission recommends changes that are fairly substantial, but at this level they are primarily in emphasis rather than in overall content. When implemented, the desired changes at the K-3 level lead to even more significant improvements at the 4-6 and 7-8 grade levels. The changes de-emphasize excess drill in formal paper and pencil computations and provide various procedures to develop better number sense on the part of the student. We must design instruction to build upon the young child's innate numbers sense. Mathematics education must try to develop confidence and minimize "math anxiety." We feel that the desired changes will bring a new sense of vitality to mathematics education.

Instruction at the K-8 level should be designed to achieve the following outcomes:

—Understanding of arithmetic operations and knowledge of when and where specific operations should be used.

—Development of a thorough understanding of and facility with one digit number facts.

—Ability to use selectively calculators and computers to help develop concepts and to do many of the tedious computations that previously had to be done by using paper and pencil.

—Development of skill in the use of informal mental arithmetic, first in providing exact answers to simple problems and later, approximate answers to more complicated problems.

—Development of skills in estimation and approximation.

—Development of problem-solving abilities. Trial and error methods, guessing and guestimating in solving word problems should be actively encouraged at all levels.

—Understanding of elementary data analysis, elementary statistics, and probability.

—Knowledge of place value, decimals, percent, and scientific notation.

—Understanding of the relationship of numbers to geometry.

—Understanding of fractions as numbers, comparison of fractions, and conversion to decimals.

—Development of an intuitive geometric understanding and ability to use the mensuration formulas for two- and three-dimensional figures.

—Ability to use the concepts of sets and some of the language of sets where appropriate. However, sets and set language are useful tools, not end goals, and it is inappropriate to start every year's program with a chapter on sets.

—Understanding of elementary function concepts including dynamic models of increasing or decreasing phenomena.

—Ability to use some algebraic symbolism and techniques, particularly in grades 7-8.

Secondary School Mathematics

The current secondary school mathematics curricula are organized into separate year-long courses covering algebra, geometry and precalculus topics, but there are some who question these traditional divisions. There is a growing sense that the traditional components can be streamlined, leaving room for important new topics. The current sequence, isolating geometry in a year-long course rather than integrating subjects of geometry over several years with other mathematics, must be seriously challenged.

Although the following analysis uses conventional course headings for discussion of proposed changes, this does not constitute an endorsement of the *status quo*. We must give serious consideration to the development of an integrated secondary school mathematical sciences curriculum.

Instruction should be designed to achieve the following outcomes:

Algebra

For all students:

—Ability to recognize basic algebraic forms and know how to transform them into other forms.

—Understanding of the logic behind algebraic manipulations.

—Skill in solving linear equations and inequalities.

—Skill in solving quadratic equations.

—Ability to graph linear and simple quadratic functions and use these in interpreting and solving problems.

—Familiarity with permutations, combinations, and simple counting problems.

—Knowledge of relations and functions.

—Development of problem-solving abilities.

In addition to the above, students exhibiting interest in and talent for mathematics should receive instruction designed to achieve the following outcomes:

—Skill in solving higher degree equations and inequalities.

—Knowledge of various types of functions including polynomial, exponential, logarithmic and circular functions.

—Ability to graph higher degree functions.

—Familiarity with the binomial theorem.

—Skill in solving trigonometric, exponential and logarithmic equations.

—Familiarity with arithmetic and geometric sequences and series.

—Knowledge of simple matrix operations and their relation to systems of linear equations.

—Skill in operations with complex numbers.

New computer technology allows the introduction of pertinent new material into the curriculum and new ways to teach traditional mathematics. Particularly noteworthy in this context at the secondary level are:

—Symbolic manipulation systems which even now, but certainly far more in the near future, will allow students to do symbolic algebra at a far more sophisticated level than they can be expected to do with pencil and paper.

—Computer graphics and the coming videodisc systems which will enable the presentation and manipulation of geometric and numerical objects in ways which should be usable to enhance the presentation of much secondary school mathematical material.

Geometry

We believe that the geometric ideas listed below should be acquired by all students. We again suggest that serious attention be given to introducing geometry together with algebra in the 8th and 9th grades rather than having a separate year-long course interrupting instruction in algebra. Instruction should be designed to achieve the following outcomes:

—Ability to think logically.

—Ability to work through short sequences of rigorously developed materials while de-emphasizing column proof.

—Knowledge of two- and three-dimensional figures and their properties.

—Ability to think in two and three dimensions in terms of congruence and similarity.

—Ability to use the Pythagorean theorem and special right triangle relationships.

—Understanding of algebraic methods in geometry and analytic geometry; and vector algebra, especially in three dimensions.

—Familiarity with computer graphics packages to get a visual sense of geometric concepts and transformation.

Other Mathematics

Instruction should be designed to achieve the following outcomes:

—Knowledge of discrete mathematics (basic combinatorics, graph theory, discrete probability).

—Understanding of elementary statistics (data analysis, interpretation of tables, graphs, surveys, sampling).

—Knowledge of computer science (programming, introduction to algorithms and iteration).

—Familiarity with the philosophical basis of calculus and understanding of the elementary concepts of the subject (e.g., rates of change, intuitive ideas of limits).

Science

The desired outcomes of science instruction involve understanding and appreciation of the external and internal biological and physical environments. Such learning must clearly be a lifelong process. Thus, there are many choices as to what topics are to be included from science and technology in elementary and secondary school education, whereas, in mathematics, there is a generally accepted sequence to provide essential building blocks.

The desired outcomes of science and technology involve various levels of rigor in topics and the stimulation of student interest to continue science and technology study throughout a lifetime. In the early years, students should have many opportunities to experience science in a real world (laboratory) context in a manner that does not separate the sciences into biological and physical science. The natural environment of the community and school can also be used as a laboratory setting. In the later years of high school, specialized courses will naturally be provided for those students especially motivated to pursue one or more of the science areas in greater depth.

Instruction in the sciences and technology in *grades K-5* should be designed to achieve the following outcomes:

—Knowledge of phenomena in the natural environment and opportunities to use applicable arithmetic in the learning of science. In addition, the integration of science with the teaching of reading and writing should be actively pursued.

—Growth in the natural curiosity of children about their physical and biological surroundings.

—Ability to recognize problems, develop procedures for addressing the problem, recognizing, evaluating and applying solutions to the problem.

—Personal experiences with appropriate level hands-on science activities with both biological and physical phenomena.

—Ability to use appropriate level mathematics in describing some science and in solving science problems.

—Ability to communicate, orally and in writing, observations of and experiences with scientific phenomena.

—Some knowledge of scientific and technical careers and of the necessary background for continued study in these areas.

Instruction for students in *grades 7 and 8* should place emphasis on the biological, chemical and physical aspects related to the personal needs of adolescents; and to the development of qualitative analytical skills. Instruction at this level should continue to build on students' earlier experiences and be designed to achieve the following outcomes through experimentation, text and community resources:

—An understanding of how their own bodies function.

—Recognition of societal issues related to science and technology.

—Development of greater skill in observing, classifying, communicating, measuring, hypothesizing, inferring, designing investigations and experiments, collecting and analyzing data, drawing conclusions and making generalizations.

—Growth in problem-solving and decisionmaking abilities.

—Ability to ask questions, manipulate variables, make generalizations and refine concepts.

—A beginning understanding of the integration of the natural sciences, social sciences and mathematics.

—Familiarity with the usefulness of integrating technologies (calculator, computer, cable television) with experiences in the sciences.

—Appreciation of local resources such as museums, scientists and specialists to extend learning experiences beyond the school walls and hours.

—Continued development of a sense of a potential science role in career or life choices.

Secondary School Science

The number of topics covered in high school science courses should be drastically reduced. Attention should then be directed toward the integration of remaining facts, concepts and principles within each discipline and with other sciences and areas such as mathematics, technology and the social sciences. Ideas should be selected which can be developed honestly at a level comprehensible to high school students; developed out of experimental evidence that high school students can gather or, at least, understand; and tie into other parts of the course so that their use can be reinforced by practice. In addition, all courses should provide opportunities to develop the ability to read science materials.

Biology

The primary need for the revitalization of biology education is the need for a conceptual framework that is more in harmony with understanding oneself and which is supportive of the national and global welfare.* The educational context of the biological sciences should be more sharply focused at different schooling levels. The curriculum in *grades K-6* should emphasize a study of nature and biological phenomena. In the life sciences of *grades 7-9*, the emphasis should be upon understanding oneself as a human being. General biology in the high school (*grade 10*) should emphasize biology in a social/ecological context.

Instruction should be designed to achieve the following outcomes:

—Understanding of biologically based personal or social problems and issues such as health, nutrition, environmental management, and human adaptation.

—Ability to resolve problems and issues in a biosocial context involving value or ethical considerations.

—Continued development of students' skills in making careful observations, collecting and analyzing data, thinking logically and critically, and in making quantitative and qualitative interpretations.

—Ability to identify sources of reliable information in biology that they may tap long after formal education has ended.

—Understanding of basic biological concepts and principles such as genetics, nutrition, evolution, reproduction of various life forms, structure/function, disease, diversity, integration of life systems, life cycles, and energetics.

*Recommendations of the Conference on Goals for Science And Technology Education Grades K-12, Report of The Working Group on Biology Education, March 11-13, 1983.

Chemistry

At all levels, the social and human relevance of chemistry should be emphasized. The curriculum should incorporate a proper selection and integration of topics from both descriptive chemistry and theoretical chemistry.

Instruction should involve extensive hands-on experience and should be designed to achieve the following objectives:

—Illustration of how answers to chemical questions are obtained.

—Familiarity with the molecular description of matter and implications of such a particulate view.

—Understanding of elementary atomic structure and the regularities contained in the Periodic Table.

—Understanding of molecules and chemical bonds.

—Understanding of reactions (stoichiometry, equilibrium, energetics, rates).

—Familiarity with the chemistry of common substances (descriptive chemistry).

—Understanding of the states of matter, and the nature of solutions.

—Familiarity with applied chemistry (radioactive materials, common poisonous and combustible chemicals, water purification, prevention of food spoilage).

—Familiarity with the variety of chemistry-related careers.

Physics

An understanding of the basic principles of physics is a necessary foundation for most of the other sciences. The students' earlier exposure at the elementary level will have begun this understanding which is especially important for an understanding of many technological applications of science. Even for those students who do not go on to major in science or engineering, physics provides important examples of how the physical world works and the kind of answers scientists can (and cannot) give to the important questions of life. For this reason, courses must be designed for a wide variety of students.

Instruction should be designed to achieve the following objectives:

—Laboratory experiences including opportunities to acquire information inductively.

—Opportunities for continued development of more advanced mathematical techniques as applied to science matters.

—Comprehension of fundamental units, derived units and systems of measurement.

—Understanding of the concepts of motion from the smallest particle to celestial bodies.

—Understanding of the conservation of mass and momentum, of energy, the kinetic theory of gases and wave phenomena.

—Understanding of light and electromagnetism.

—Appreciation of atomic and nuclear physics, and of relativity.

—Familiarity with the variety of physics-related careers.

Computer Competencies

One major goal of education is to help students prepare to cope with situations they will encounter later in life. Every student will encounter change, much of which will be based upon developments in science and technology. Consequently, the educational system has a responsibility to impart certain skills to all students. This list of student outcomes for computing skills is differentiated for those students who may be particularly interested in computing or will pursue careers in scientific and technical areas and for those students with other interests and abilities.

Instruction should be designed to achieve the following outcomes:

—Basic knowledge of how computers work and of common computer terminology, including a general understanding of the various applications of computers.

—Experience in using the computer as a tool, which should include experiences in the use of standard applications software such as word processing systems, and filing systems.

—Familiarity with one high-level computer language and ability to use that language as a means of interacting with the device.

—Ability to use a computer language to do problem-solving tasks in the context of normal academic experiences and at a level which reflects the individual student's level of ability.

—General understanding of the problems and issues confronting both individuals and society as a whole in the use of computers, including the social and economic effects of computers, the history and development of computing, and the ethics involved in computer automation.

In addition to the competencies outlined for all students, those students showing a special interest in and ability for computing, and those who may pursue further study in scientific and technical fields should:

—Have a thorough knowledge of how computers work, including an in-depth understanding of varied computer applications and automated information sources.

—Have experience in using the computer as a tool, with particular emphasis on applications such as text editing, computer-assisted composition, computer-based statistical analysis, simulation, data logging and manipulation when the computer is connected to the experience, and use of common computer utilities.

—Be able to use at least two computer languages in the context of other academic experiences, with an emphasis on appropriate problem-solving skills and development of readable, structured programs.

Technology

Although technological concepts are inseparable from their natural content in the sciences and mathematics, the Commission considers the topic to be of critical importance and meriting separate treatment. Appropriate instruction in technology should be integrated into the curriculum for grades K-12. Doing so will serve to strengthen the teaching of science, mathematics and computer literacy. This will require a major emphasis on the development of new teaching materials and on the training of teachers to enable them to handle technological concepts.

In 1970, the writers of the Preface to *The Man Made World* stated that "The problems we face as a nation are monumental. We not only need to understand technology, we must also anticipate its side effects. Change today is so rapid and the visible effects are often so delayed that the wrong decision can lead to major problems before the effects can be reversed." That statement has grown in significance. It is imperative that the precollege education of today and the future equip students:

—To use technology to improve the quality of many personal and professional technology-based decisions.

—To participate intelligently as informed citizens in the transition from an industrialized society to a post-industrialized service and information age.

—To be more active in shaping public policy, which often involves the use of sophisticated technology.

Two approaches are often suggested: a specially developed one-year course treating technological concepts; or thorough integration of technology throughout other instructional topics, K-12. Since there are few precollege courses about technology or the integration of technological concepts into other disciplines, development efforts are greatly needed in this area. It is important to begin to identify some of the content, and desired student outcomes of such courses.

Students should have opportunities to examine technology-related concepts in some of the following systems:

—Communications, transportation

—Energy production and conservation, resource management

—Shelter, residential use of space

—Food production, health care delivery, safety

—Biotechnology, nuclear issues

—Computers and their applications

Through learning about technology, students should gain some skills in:

—Formulating and solving problems and identifying alternative solutions to problems.

—Making connections between theory and practice, building and testing models.

—Examining trade-offs and risk analysis, synthesizing and designing.

—Using the concepts of feedback and stability.

Conclusion

Hopefully, the ideas contained herein will enrich ongoing discussions and encourage further study and development of curriculum in mathematics, science and technology at the elementary, middle and secondary school levels. There has been little treatment here of methodology, nor have examples been provided for the delivery of content. The reader is strongly encouraged to consult the references provided at the end of the paper for much more detailed information about the desired state for education at the precollege level in mathematics, science and technology.

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To obtain information about the references listed above, contact the following:

(a) NSB Commission on Precollege Education in Mathematics, Science and Technology
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(b) American Association for the Advancement of Science
1776 Massachusetts Avenue, NW
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(c) American Association of Physics Teachers
Graduate Physics Building
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Stony Brook, NY 11790

(d) American Chemical Society
1155 16th Street, NW
Washington, DC 20036

(e) American Industrial Arts Association
1914 Association Drive
Reston, VA 22091

(f) W. H. Freeman & Co.
660 Market Street
San Francisco, CA 94104

(g) Office of Academic Affairs
The College Board
888 Seventh Avenue
New York, NY 10106

(h) National Academy Press
2101 Constitution Avenue, NW
Washington, DC 20418

(i) McGraw-Hill Book Co.
1221 Avenue of the Americas
New York, NY 10020

(j) The National Association of Biology Teachers
11250 Roger Bacon Drive
Reston, VA 22090

(k) National Council of Teachers of Mathematics
1906 Association Drive
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(l) Kenneth R. Mechling
Clarion University of Pennsylvania
Clarion, PA 16214

(m) National Science Teachers Association
1742 Connecticut Avenue, NW
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(n) Holt, Rinehart and Winston, Inc.
383 Madison Avenue
New York, NY 10017

EXHIBIT C

COSTS OF RECOMMENDED FEDERAL INITIATIVES

SUMMARY

The following is a list of the Commission's major recommendations for Federal action and an indication of the annual costs, above current estimates of spending, needed to implement each. Detailed notes on each recommendation follow this summary listing.

1. The President should immediately appoint a National Education Council made up of representatives from a cross-section of national interests. This Council should report regularly to the President. It should provide leadership in developing, coordinating and implementing plans to improve and maintain the quality of the Nation's elementary and secondary education in mathematics, science and technology. The President's National Education Council should, on a continuing basis, (1) identify educational goals and recommend the changes needed in the form and content of education to reach those goals; (2) ensure that the assessment mechanism described below is developed and maintained for measuring and comparing student achievement, participation and progress toward these goals in every State, school district and school; and (3) monitor and report annually to the American people on the status of American education and progress toward achieving these educational goals. It should also facilitate the sharing of information about successful mathematics, science and technology educational programs. Finally, the President's National Education Council should recommend incentives to encourage state, local and private investment in education.

   Cost: **$2.75 million**

2. The Federal government should finance and maintain a national mechanism to measure student achievement and participation in a manner that allows national, state and local evaluation and comparison of educational progress. This assessment mechanism should be overseen by the President's National Education Council. The actual assessment, however, should be performed by the groups responsible for the National Assessment of Educational Progress or other such entities experienced in testing procedures and techniques.

   Cost: **$5 million**

3. The unique national role of the Federal government (including important Department of Education and National Science Foundation programs) in ensuring access in its broadest sense to educational opportunity must continue.

   Cost: **$157 million**

4. The Federal government should encourage and finance, in part, the establishment of exemplary schools or programs in mathematics, science and technology in each community throughout the Nation to serve as examples and catalysts for upgrading all schools. The Federal government should evaluate current resource allocation policies, entertain redistribution and, where necessary, appropriate funds to support the development of such programs. . . . The Federal government should appropriate funds to aid the establishment of at least 1,000 such exemplary schools at the secondary level and at least 1,000 such schools at the elementary level throughout the country.

Cost: **$829 million**

5. The Department of Education and the National Science Foundation should support and facilitate the dissemination of information to help build this national network of exemplary programs.

Cost: **$0 added**

6. The Federal government has a responsibility to ensure that such [teacher] training is available and should provide funding for in-state teacher training programs in mathematics, science and technology. Summer and in-service institutes, supported by the National Science Foundation, provide a proven model for upgrading of teacher skills.

Cost: **$349 million**

7. The National Science Foundation should provide seed money to develop and establish state-wide or regional on-site teacher training programs using the new information technologies.

Cost: **$30 million**

8. The National Science Foundation, which has recognized expertise in leading curriculum development, should again take the leadership role in curriculum evaluation and development for mathematics, science and technology. The National Science Foundation should set up a process to evaluate existing curricula, identify good curricula, disseminate information, act as a clearinghouse and promote the development of guidelines for new curricula as necessary. [Also] The National Science Foundation should support the development of courses to meet this need [courses dealing with technology at grades 8 and 9]. . . To achieve this objective, the Commission suggests, as one mechanism for the National Science Foundation to consider, that a Mathematics, Science and Technology Curriculum Council be established in the National Science Foundation . . . . It should appoint and coordinate the activities of [4] specific committees . . . . The responsibility for each committee should include: determination of the best course content for its subject area; critical review of the available texts and other teaching materials; publication through the National Science Foundation of the results of the critical evaluation; identification of the areas where improved materials and totally new course materials are needed; identification of the areas where future research is

needed in curriculum development and the processes of teaching and learning . . . . The Council and committees should work with widely dispersed demonstration centers to test new curriculum.

Cost: **$52 million**

9. Research into the processes of teaching and learning should be supported with Federal funds at both the basic level and the level of classroom application. This research should further the recent progress in the cognitive sciences, and particular research projects should investigate the integration of educational technologies into the processes of teaching and learning.

Cost: **$10.5 million**

10. The National Science Foundation . . . should again take the leadership role in evaluating the status of developments in this area [educational applications of new technologies]. This should include such actions as determining needed initiatives, supporting prototype demonstrations, disseminating information on model materials and practices, and supporting research on integration of educational technologies with the curriculum. To achieve this, the Commission suggests, as one mechanism for the National Science Foundation to consider, that a Council for Technology Application in Education be established . . . . This group would advise the National Science Foundation on initiatives in this area including: supporting research into the fundamental aspects of the integration of modern technology into the processes of teaching and learning; developing mathematics, science and technology curricula that can integrate computer systems and supporting materials effectively; promoting private industry, colleges and universities to collaborate in training in-service teachers in the utilization of high technology systems [e.g., out-of-school and in-service training programs, computer conferences, training programs for schools of education]; encouraging and assisting school systems to acquire computers, software, instructional materials and science equipment [e.g., via tax incentives]; assisting in making the highest quality software available on the broadest possible scale.

Cost: **$36 million**

11. Science broadcasts are an important and cost-effective vehicle of informal learning, which warrant continued and substantial Federal investment and support.

Cost: **$13 million**

12. Federal regulation of commercial [broadcasting] stations should include a required period of educational programming for children.

Cost: **$0 added**

13. The Federal government should provide supplementary support for museum education activities in mathematics, science and technology at a level that will encourage a rich spectrum of activities and options.

Cost: **$25 million**

14. Private industry and government agencies should create programs and opportunities which let children see science and technology in actual operation in their plants and installations.

Cost: **$0 added**

TOTAL COST: **$1.51 billion**

DETAILED NOTES

1. *The President should immediately appoint a National Education Council made up of representatives from a cross-section of national interests. This Council should report regularly to the President. It should provide leadership in developing, coordinating and implementing plans to improve and maintain the quality of the Nation's elementary and secondary education mathematics, science and technology. The President's National Education Council should, on a continuing basis, (1) identify educational goals recommend the needed changes in the form and content of education h those goals; (2) ensure that the assessment mechanism described below is developed and maintained for measuring and comparing student achievement, participation and progress toward these goals in every State, school district and school; and (3) monitor and report annually to the American people on the status of American education and progress toward achieving these educational goals. It should also facilitate the sharing of information about successful mathematics, science and technology educational programs. Finally, the President's National Education Council should recommend incentives to encourage state, local and private investment in education.*

   This Council has the following functions assigned to it:

   a. Developing and coordinating plans to improve and maintain the quality of education in mathematics, science and technology;
   b. Identifying educational goals;
   c. Overseeing the national assessment mechanism (see recommendation #2 below);
   d. Monitoring and reporting on the status of education;
   e. Facilitating the exchange of information about successful programs.

The Department of Education now spends approximately $200,000 to support the National Council on Educational Research, which formulates educational policy. It does not, however, have a study or policy analysis budget, required for the activities of the proposed National Education Council. If the National Education Council is to have national impact and a staff to conduct and facilitate implementation of policy recommendations, it will require a professional staff and budget for analyses. It is estimated that this will cost $1 million.

The costs of the national assessment mechanism are discussed under #2 below.

The National Center for Education Statistics, which is budgeted at approximately $8.7 million, monitors educational progress. Their annual report costs approximately $750,000, but rests heavily on the data gathered through the $8.7 million program. The costs of the proposed National Education Council's annual report should be about the same.

There currently are two mechanisms to facilitate the exchange of information about successful model programs. The ERIC centers in the Department of Education receive approximately $6 million to collect reports on education and to act as a clearinghouse. The National Diffusion Network receives $10 million per year to disseminate information and materials which have been validated. They are currently emphasizing information on mathematics, science and technology. In order to formalize the exchange of information, this program would have to be increased, by a level approximating $1 million.

The total estimated cost above current expenditures is **$2.75 million per year**.

2. *The Federal government should finance and maintain a national mechanism to measure student achievement and participation in a manner that allows national, state and local evaluation and comparison of educational progress. This assessment mechanism should be overseen by the President's National Education Council. The actual assessment, however, should be performed by the groups responsible for the National Assessment of Educational Progress or other such entities experienced in testing procedures and techniques.*

The Educational Testing Service currently receives approximately $4 million for the National Assessment of Educational Progress (NAEP). Previous budgets for this activity were much higher. While the assessment is required by Congress to provide information on mathematics, it does not require such information for science or technology. The National Science Foundation, on a one-time basis in 1982, supplemented the assessment to obtain figures for science (approximately $600,000). The current assessment covers mathematics, science and social science and includes very little on technology. If additional testing and analyses were established, such that it could effectively assist local communities, as is now done for States, a much larger budget would be needed.

The estimate of additional funds required is **$5 million per year.**

3. *The unique national role of the Federal government (including important Department of Education and National Science Foundation programs) in ensuring access in its broadest sense to educational opportunity must continue.*

The Department of Education and the National Science Foundation have initiated a variety of programs over the years that have specifically addressed issues of access in education. The Department of Defense has also operated significant programs in this area.

The major DoEd programs are Title I of the Elementary and Secondary Education Act of 1965, now Chapter I of the Education Consolidation and

Improvement Act of 1981, and the Aid to All Handicapped Children Act of 1975. The Chapter I program has not kept pace with inflation. In order to maintain FY 1983 expenditures at constant, real levels, an additional $150 million will be needed for that program.

The NSF does not at present have any funded programs that are specifically aimed at motivating women and minority students at the elementary and secondary level in mathematics, science and technology. At one time this funding was estimated to total around $7 million.

Thus, maintaining DoEd programs at constant, real levels of funding and reinstituting NSF programs at recent levels will require additional funding of at least **$157 million per year**.

4. *The Federal government should encourage and finance, in part, the establishment of exemplary schools or programs in mathematics, science and technology in each community throughout the Nation to serve as examples and catalysts for upgrading all schools. The Federal government should evaluate current resource allocation policies, entertain redistribution and, where necessary, appropriate funds to support the development of such programs. . . . The Federal government should appropriate funds to aid the establishment by local communities of at least 1,000 such exemplary schools at the secondary level and at least 1,000 such schools at the elementary level.*

This recommendation calls for the initial establishment of an additional 1,000 exemplary secondary schools and 1,000 exemplary elementary schools. The recommendation also speaks of "establishment" and "development" of these schools and programs; thus only start-up costs are discussed here.

Start-up costs for a new program, based on studies now in progress and on experiences of existing programs, are estimated at $750,000 each for secondary schools and $525,000 each for elementary schools. These estimates include the assumption that economies of scale in building multiple exemplary programs would result in cost savings of about 10% per school.

It is assumed that, on the average, the Federal government would provide 65% of the start-up costs for these exemplary schools. This is estimated to be a minimum contribution needed to ensure that these programs are established.

The Federal share would actually be distributed over a period of three years, but immediate authorization and appropriation are required to establish the scale of the program and provide the necessary credibility and assurance to state and local governments.

Thus, the total cost of the progam would be $1.275 billion, with the Federal government contributing **$829 million**. The Federal share, however, will be disbursed at the rate of $276 million per year over a three year period.

One Commission member feels that the plan to create 1,000 exemplary secondary schools and 1,000 exemplary elementary schools is too ambitious. That member feels that the number should not exceed 1,000 of such schools and that the Federal share of the costs per school should be $100,000.

5. *The Department of Education and the National Science Foundation should support and facilitate the dissemination of information to help build this national network of exemplary programs.*

This activity could be coordinated through the National Education Council. Thus, costs for this activity are assumed to be included in recommendation #1 (e), above. Therefore this recommendation results in **no added cost.**

6. *The Federal government has a responsibility to ensure that such [teacher] training is available and should provide funding for in-state teacher training programs in mathematics, science and technology. Summer and in-service institutes, supported by the National Science Foundation, provide a proven model for upg ding of teacher skills.*

It is assumed that most teachers would receive some training. The number of mathematics and science teachers at the junior and senior high level is approximately 200,000; at the K-6 level, it is approximately 1.17 million. It is assumed that about 15% of current teachers will not need such training for various reasons, including some who are new or just out of school and others who will be retiring in a year or two. Thus, these calculations assume that slightly more than 1.16 million teachers from both levels would receive some training.

There are many ways teachers might receive such training, and not all teachers would require the same amount. Moreover, different types of training might be needed by different groups of teachers. Some might require relatively minimal training that could be accomplished in a large group or through the effective use of technology for relatively low cost. On the other hand, many will require extensive training, perhaps equivalent to substantial portions of a college major in mathematics or a science discipline. The average cost of training per teacher is estimated to be $3,000 (based on past National Science Foundation programs and the experiences and estimates of other groups). Thus, the total cost of training the Nation's current pool of teachers would be $3.49 billion.

It would not be possible to provide this training for all teachers at one time. It is estimated that this training program would have to be spread over a five-year time period. Therefore, the yearly cost of this program would be $698 million.

It is estimated that the Federal government would provide half of the funds for this program, with the states expected to match on an equal basis. Thus, the costs to the Federal government would be **$349 million per year.**

One Commission member believes that the proposed retraining of American elementary and secondary mathematics and science teachers is not a workable means of upgrading teacher quality because, in that Commission member's opinion, there are insufficient facilities to complete the training of all teachers in the five-year time frame. As a result, that Commission member believes the cost of this recommendation would be lower annually because fewer teachers would be receiving training.

7. *The National Science Foundation should provide seed money to develop and establish statewide or regional on-site teacher training programs using the new information technologies.*

(1) Estimating a minimum of 10 grants needed for prototype development and demonstration of a range of alternative approaches (cable or closed circuit TV; interactive telecommunications; computer controlled videodisc) at an average cost of $500,000 per grant, would require a minimum expenditure of $5 million.

(2) Additionally, estimating 100 state or regional on-site teacher training programs, ranging in cost from $100,000 to $1 million (average $500,000), would require approximately $50 million. If these, however, were matched on a 50-50 basis by the States this would require $25 million in Federal funds.

Thus, the total required costs would be **$30 million per year.**

8. *The National Science Foundation, which has recognized expertise in leading curriculum development, should again take the leadership role in curriculum evaluation and development for mathematics, science and technology. The National Science Foundation should set up a process to evaluate existing curricula, identify good curricula, disseminate information, act as a clearinghouse and promote the development of guidelines for new curricula as necessary. [Also] the National Science Foundation should support the development of courses to meet this need [courses dealing with technology at grades 8 and 9]. . . . To achieve this objective, the Commission suggests, as one mechanism for the National Science Foundation to consider, that a Mathematics, Science and Technology Curriculum Council be established in the National Science Foundation. . . . It should appoint and coordinate the activities of [4] specific committees. . . . The responsibility for each committee should include: determination of the best course content for its subject area; critical review of the available texts and other teaching materials; publication through the National Science Foundation of the results of the critical evaluation; identification of the areas where improved materials and totally new course materials are needed; identification of the areas where future research is needed in curriculum development and the processes of teaching and learning. . . . The Council and committees should work with widely dispersed demonstration centers to test new curriculum.*

The recommendation includes the suggestion of a new advisory committee for NSF, with four operating subcommittees. The NSF activity would include:

a. Evaluation of existing curricula and instructional materials;

b. Dissemination of information about curricula and instructional materials; these committees would coordinate closely with the suggested NSF Council for Educational Technology;

c. Support of curriculum development activities.

The maintenance of five advisory committees for the National Science Foundation, estimating 4 meetings each per year, $25,000 per meeting, would cost $500,000 per year.

The development of instructional materials for precollege mathematics, science and technology would involve 35 new starts per year, at an average cost of $500,000. Estimated cost: $17.5 million.

Demonstration and dissemination efforts should include:

- 20 demonstration projects (new starts) per year at an average cost of $200,000. Estimated cost: $4 million.
- One national science and mathematics instructional resource facility. Estimated cost: $5 million.
- 25 regional resource and teacher assistance facilities (with joint local/state/Federal funding). Estimated Federal cost: $25 million.

The total estimated cost would be **$52 million per year.**

9. *Research into the processes of teaching and learning should be supported with Federal funds at both the basic level and the level of classroom application. This research should further the recent progress in the cognitive sciences and particular research projects should investigate the integration of educational technologies into the processes of teaching and learning.*

Research into the processes of teaching and learning (cognitive sciences) should be supported at a rate of 35 new starts per year and an average cost of $150,000. Estimated cost: $5.25 million.

Research into the fundamental aspects of the integration of modern educational technology into the processes of teaching and learning should be supported at an estimated rate of 35 new starts per year and an average cost of $150,000 (see also Recommendation #10).
Estimated cost: $5.25 million.

The total estimated cost would be **$10.5 million per year.**

10. *The National Science Foundation . . . should again take the leadership role in evaluating the status of developments in this area [educational applications of new technologies]. This should include such actions as determining needed initiatives, supporting prototype demonstrations, disseminating information on model materials and practices, and supporting research on integration of educational technologies with the curriculum. To achieve this, the Commission suggests, as one mechanism for the National Science Foundation to consider, that a Council for Technology Application in Education be established. . . . This group would advise the National Science Foundation in this area including: supporting research into the fundamental aspects of the integration of modern technology into the processes of teaching and learning; developing mathematics, science and technology curricula that can integrate computer systems and supporting materials effectively; promoting private industry, colleges and universities to collaborate in training in-service teachers in the utilization of high technology systems [e.g., out-of-school and in-service training programs, computer conferences, training programs for schools of education]; encouraging and assisting school systems to acquire computers,*

software, instructional materials and science equipment [e.g., via tax incentives]; assisting in making the highest quality software available on the broadest possible scale.

This recommendation suggests an advisory council for the National Science Foundation and sets a series of activities for NSF to support:

a. Disseminating information on model materials and practices;

b. Supporting research into the fundamental aspects of the integration of modern educational technology into the processes of learning and teaching;

c. Developing science and technology curricula that can integrate computer systems and supporting materials effectively;

d. Promoting collaboration in training teachers;

e. Encouraging and assisting school systems to acquire materials and equipment;

f. Assisting in making software available on the broadest possible scale;

g. Testing and evaluation of courseware and integrated curricula in order to quantify the benefits of the technology and to facilitate its introduction into the classroom.

Establishing an advisory committee, assuming it would meet about 4 times per year, with appropriate staff support, would cost an estimated $100,000.

Significant research is needed, which will not result in the near term from private efforts, to provide a solid base of knowledge to permit effective, maximum utilization of modern educational technology which is integrated into the curriculum of mathematics and science courses. Assuming an average 3-year grant for prototype development of $1.5 million (in total), and an estimated 50 grants to cover prototypes for mathematics and science courses K-12, the estimated yearly cost would be $25 million.

It is assumed that teacher training and curriculum development as outlined here would be covered in recommendations 6 and 8, respectively, as discussed above. No added cost here.

Encouraging and assisting school systems in acquiring materials and equipment would involve: (a) models for adoption: 5 projects per year at $600,000 per project (cost estimate $3 million per year); (b) 15 papers and studies per year at $200,000 per project, (cost estimate $3 million per year). Total cost estimate is $6 million per year.

Assistance in making software broadly available would require planning and prototype development for dissemination, estimated at a level of $5 million per year.

The total estimated cost would be **$36 million per year.**

11. *Science broadcasts are an important and cost-effective vehicle of informal learning, which warrant continued and substantial Federal investment and support.*

Ongoing support for two daily science-mathematics TV series (e.g., 3-2-1 Contact) for distribution via PBS and other appropriate channels at $6 million per year each; the cost is $12 million per year.

Instructional materials for use in classrooms and to enhance the skills and background of teachers—one series per year at a cost of $1 million.

The total estimated cost would be **$13 million per year.**

12. *Federal regulation of commercial [broadcasting] stations should include a required period of educational programming for children.*

    This recommendation has **no costs** to the Federal government associated with it.

13. *The Federal government should provide supplementary support for museum education activities in mathematics, science and technology at a level that will encourage a rich spectrum of activities and options.*

There are approximately 1,000 science and technology museums and centers. Assuming that one-half of the museums would participate, with equal cost-sharing, and a grant of $100,000 per institution, the estimated cost would be **$25 million per year.**

14. *Private industry and government agencies should create programs and opportunities which let children see science and technology in actual operation in their plants and installations.*

It is assumed that both private industry and the government agencies would provide this service on a volunteer, **no-cost** basis.

EXHIBIT D

IMAGINATIVE WAYS TO ENHANCE TEACHER COMPENSATION

Increased attention is being given throughout the country to the problem of attracting competent people into the teaching profession. There are numerous proposals under consideration, including master teacher plans that involve differential salary schedules, scholarships for outstanding students who plan to enter teaching, summer employment for exceptional teachers, and recognition that includes monetary prizes. Although no single proposal would be applicable to all 17,000 school districts in the country, the Commission encourages communities to examine innovative ways to provide incentives that will attract and hold well-qualified teachers.

- Merit Pay—The merit pay plan has received considerable attention recently as an alternative to the single salary schedule. In an effort to keep and attract more talented and qualified teachers, such plans seek to reward the best performing teachers with higher salaries. These salaries may or may not be accompanied by greater responsibilities, a longer teaching year, or other factors.
- Differential Pay—This term refers to the proposal to pay the salaries required to attract qualified teachers, in this case mathematics and science teachers, who are currently in short supply. Underlying it is the premise that no courses should be offered unless they are taught by qualified teachers. The response at the local level to shortages in particular fields has usually been temporary certification of persons trained in other fields, rather than differential pay sufficient to compete in the marketplace. Increasingly, however, efforts are being made to augment mathematics and science teachers' salaries, frequently combined with giving them added responsibilities, an extended work day/year, etc. See, for example, the description of the Houston Second Mile Plan in the following item.
- Houston Independent School District: The Second Mile Plan—Implemented in the 1979-80 school year, the Second Mile Plan offers "incentive" pay to teachers who meet several criteria, including teaching in schools with a high concentration of educationally disadvantaged students, instructing in fields where there are critical teacher shortages, and maintaining outstanding attendance. A yearly stipend of $2,000 is awarded to science and mathematics teachers, with an additional $400 available to teachers who take courses in their specialization. The plan allows teachers to supplement their income by amounts in excess of $5,000 per year. A prominent aspect of the plan is its reliance on objective measures in determining eligibility for salary increases.

- The Ladue, Missouri Plan—This working plan and salary program created three salary schedules—schedule III is the equivalent of a master teacher in which teachers are evaluated and assigned points ranging from 0 to 15. Each point is worth $300 with a $4,500 salary supplement possible. The average evaluation is about 10, or a $3,000 salary benefit. Promotions from schedule I, II and III are based on the fulfillment of several criteria, including standardized test scores and ability to teach lessons clearly. These are criteria recommended by the Committee on Teacher Evaluation on which teachers are heavily represented. Evaluation points are then assigned by principals.

- The Master Teacher Plan: The Tennessee Proposal—This proposal, designed to improve the performance of all teachers, classifies teachers as apprentice, professional, senior or master. A master teacher is a good classroom manager, has a good relationship with students and fellow teachers, teaches challenging lessons with clarity and enthusiasm, and enjoys the subject. Because of demonstrated skill in the classroom, master teachers would serve as model teachers, conduct demonstration lessons for beginning teachers, and be given administrative responsibilities such as curriculum development. This plan would provide a salary 60% higher than a regular teacher's salary.

- The Charlotte-Mecklenburg Master Teacher Plan—Similar to the Tennessee proposal, this plan proposes to offer teachers more promising and lucrative career ladders by providing teachers with additional administrative responsibilities. It differs from the Tennessee plan in that the career path which is offered is less structured and more informal.

- Head Teacher—In Augusta, Georgia, one teacher in each of Richmond County public school system's 40 elementary schools has been designated head teacher, with the responsibility of observing other teachers, giving advice and providing continuing education for the teachers.

- Increasing School Hours and Teacher Workload—Some educators have suggested a longer school day. Under such a plan, students can receive more science and mathematics instruction and teachers will have a heavier workload which will, in turn, qualify them for a salary increase.

- Summer Employment in Schools—Summer vacation is a troublesome time for teachers since many cannot find summer employment to supplement their teaching income. Schools can ease the plight of some teachers by increasing their summer teaching and administrative workforces.

- Part-time Employment in Industry—Suggestions have been made to provide tax credits to businesses which employ science and mathematics teachers during the summer months. Many teachers now work at summer jobs that have little if any relation to their work as a teacher in order to supplement their teaching income.

- Loans and Scholarships—Earlier this year Governor Babbitt of Arizona proposed a student loan program to encourage more mathematics and science teachers. The program would allow college students being trained as mathematics and science teachers to finance their education with a loan which carries the understanding that, upon graduation, one year of the loan would be forgiven for each year of teaching in Arizona public schools. Seventeen states have passed or are considering bills that would offer tuition loans to college students to encorage them to become mathematics and science teachers. Legislation currently pending in Congress (HR 1310 and S 1285) would also authorize Federal support for such loans or scholarships to outstanding students and require a commitment to teach a certain number of years.

EXHIBIT E

USING COMPUTERS IN THE SCHOOLS: TECHNOLOGY WORKS

The use of computers and other information technologies promises to improve the quality of instruction not only in mathematics and science, but in all subjects in the Nation's elementary and secondary schools. In the course of its investigation, the Commission learned of many "exemplary programs" integrating the use of technology in education. These range from statewide systems to individual classroom instructional programs.

Computers Increase Student Performance

- Separate studies conducted by the Educational Testing Service (grades 1-6) and the University of Michigan (grades 6-12) show Computer-Assisted Instruction improves initial results and retention. CAI secondary students learned faster than non-CAI peers—with up to 88% time savings.
- Asbury Park, NJ high school students achieved higher levels in algebra, geometry, trigonometry, calculus and applied mathematics when CAI was combined with traditional instruction. The school district also offers a computerized remedial middle school mathematics program and a gifted program at a "magnet" elementary school that includes programming.
- Computerized instruction in the Houston Independent School District's normal curriculum has improved the basic performance of a typically low-achieving student body.
- Students one or two grade levels below their age-mates made significant skills gains with only 10 minutes a day on a CAI reading program created by Massachusetts' Merrimack Education Center. (The Center's 6th-9th grade CAI program also includes mathematics and language arts and supplements teachers' daily classroom work in individual and small group tutorial sessions.)
- Formerly "turned off" junior high students are so motivated by the computer programs at Cupertino, CA that it's a problem to get them to go home from school as their lab work passes beyond introductory courses to computer logic and advanced programming. This "Silicon Valley" district's K-8 computer literacy curriculum instills "computer awareness" by the end of 6th grade and "computer use" by the end of 8th grade.

Computers Are Used in Many Ways

- The 4,000 Lyons Township, IL high school students use over 200 microcomputers in 8 labs to analyze and solve biology problems, develop budgets for consumer education and learn social science facts.

They are also used for extended special education drill-and-practice. The math and business curricula include computer specialty courses.

- Houston Independent School District's High School for the Engineering Professions is staffed by regular faculty and engineers "on loan" from a local hi-tech company and gives its graduates the equivalent of two years of training in computer programming.
- Pawtucket, RI 5th and 6th graders get two 30-minute sessions weekly of "Individualized Prescriptive Arithmetic Skills Systems" instruction. IPASS has proven to be an effective, cost-efficient program to supplement most mathematics curricula without modification.
- Gifted and high-achieving 6th and 7th graders in Leon County, FL may take COMPUTRONICS, a 40-hour course in programming, problem solving and computer literacy. The "Computers in Society" unit covers the history of computers and present and future uses; "Problem Solving with Computers" teaches pupils to program word problem solutions using BASIC language.
- Parents and students learn to use computers together in "Computers Can," an after-hours project at two predominately black/Hispanic Houston elementary schools. The program reinforces basic skills, motivates learning, promotes educational use of spare time, stimulates cognitive development, improves writing, and encourages quality parent-child interaction.
- IBM's computer/audio program "Write to Read," now being field-tested in six states, is expected to teach kindergartners and 1st graders thousands of words (rather than the "normal" 200) in their earliest school years. The company is promoting computer literacy through the donation of 1,500 personal computers and software to 12 teacher-training institutes and 84 secondary schools in California, Florida and New York.
- The Center for Children and Technology at New York City's Bank Street College of Education is experimenting with computers to teach the deaf. Computers enable physically handicapped students to engage in a wide range of learning and creative activities—optical readers translate visual information into tactile signals for the blind; robotics allow the muscular disabled to operate learning equipment; speech simulation helps the learning disabled.
- Alaska's state instructional network employs the latest computer and telecommunications technology. Electronic Mail and Audio Conferencing now link distant campuses for student seminars, and the addition of instructional TV will allow "interactive courses." Students in remote high schools receive high-quality secondary education via "Individualized Study by Technology" computer-based courses.

Several Organizations Offer Services to Educators

- Minnesota's 435 school districts access the Minnesota Educational Computer Consortium's statewide time-sharing network for instructional computing. MECC gives the State's 26,340 teachers in-service training and provides a 1200 program courseware library. A national leader, Minnesota has a computer for every 50 students.

- Computer-Using Educators, founded in 1978 by 12 teachers, now has 3,500 members worldwide. This teacher support group persuaded hardware manufacturers to equip a Microcomputer Center in San Mateo. CUE runs SOFTSWAP, a software exchange of 300 educational programs, and is a prime source of information on computers in education.
- Educational Products Information Exchange (EPIE), Southhampton, NY evaluates hardware as well as software programs for K-12, focusing on specific topics such as mathematics and science. Recommendations are made available to public and private schools, parents and interested business or governmental groups.
- The Houston Independent School District has established a Department of Technology to train teachers and evaluate software. No school can purchase a computer until the teacher using it and the principal of the school have been instructed in computer use.
- "Computers in Education" focuses on computer literacy and mathematics, spelling, social studies, science and language arts at all Lexington, MA public school grade levels. Parents help train teachers, write software, and oversee hardware purchases. Beginning high schoolers already have impressive programming skills—several have created software for elementary classroom instruction and local small businesses.
- Oxford, MA joined with six other nearby rural school districts to fund the Cooperative Federation for Educational Experiences. COFFEE equips vocational students in electronic assembly and data processing for entry-level jobs. Faculty is taught computing through the French River Teachers Center which also runs a "computer bus" from school-to-school to give pupils hands-on computer experience.

Computer-Managed Instruction

- Within 24-48 hours, Hopkins, MD teachers and students get test results, class performance data and test form evaluation from CAM, a teacher-defined CMI system for objective- or competency-based instruction and mastery learning approaches. CAM's microcomputer programs are used in 1,000 classrooms for most subjects in grades 1-12.
- Overall attendance improved at Falmouth High School on Cape Cod when a "mini" was used to process student attendance records. Computerized attendance accounting resulted in early recognition of attendance problems and prompt student/parent remedial counseling, reduced classroom paperwork for teachers, and kept records more accurately.

Preschoolers Use Computers

- Using Texas Instruments' "Magic Wand Speaking Reader," preschoolers can teach themselves to read through technology combining voice reproduction and vocal instruction. A plastic "magic wand" passed over bar-code strips printed under words uses infrared light to decipher codes for an oral simulation of "being read to."
- LOGO, a language written by MIT's Seymour Papert, is so easy to use that preschoolers can learn to program computers to design mathematical figures before they can read. Children learn how to analyze problems step-by-step and through a variety of effects—drawings, color, shape and speed changes, pulsating designs—to execute ideas logically in their own heads.

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Governor of Arizona

Ludwig Braun
Professor of Instructional Development
New York Institute of Technology

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Terry T. Saario
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