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ABSTRACT

This is a report on the hearing for solutions to the problems in science, mathematics, and engineering education at the postsecondary level. Topics of prepared statements and the testifiers are: (1) educating scientists and engineers (Daryl E. Chubin); (2) science and engineering education needs viewed from the perspectives of the national laboratories (E. Michael Campbell); (3) current status and plan for United States-based companies (M. J. Montague); (4) quality education for minorities (R. O. Hope); (5) programs of excellence in mathematics education (Shirley A. Hill); (6) problems and solutions in elementary school science (Cynthia K. Yocum); (7) students, teachers, and resources in secondary school science (Kent Kavanaugh); (8) education satellite networks (Hal Gardner); (9) challenge and future of science education (Dennis M. Wint); (10) preserving Americas' scientific preeminence (David Eli Drew); (11) graduate education in science and mathematics perspectives both as administrator and as scientist (Judson D. Sheridan); and (12) efficiency of graduate fellowships in areas of national need (Ed Wilson). (YP)

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MATH, SCIENCE AND ENGINEERING EDUCATION: A NATIONAL NEED

HEARING

BEFORE THE

SUBCOMMITTEE ON POSTSECONDARY EDUCATION

OF THE

COMMITTEE ON EDUCATION AND LABOR
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

HEARING HELD IN KANSAS CITY, MO, MAY 1, 1989

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CONTENTS

MATH, SCIENCE AND ENGINEERING EDUCATION: A NATIONAL NEED

MONDAY, MAY 1, 1989

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON POSTSECONDARY EDUCATION,
COMMITTEE ON EDUCATION AND LABOR,
Kansas City, MO.

The subcommittee met, pursuant to notice, at 8:57 a.m., in room 110, Federal Building, 601 East Twelfth Street, Kansas City, Missouri, Hon. Pat Williams, [Chairman] presiding.

Members present. Representative E. Thomas Coleman of Missouri.

Staff present. Rick Jerue and Michael Lance.

Mr. WILLIAMS. Good morning. I'm Pat Williams, chair of the House Subcommittee on Postsecondary Education. For the information of those who don't know me and whom I don't know, I represent western Montana in the Congress.

I am pleased to be here with my friend and colleague and the ranking member of our subcommittee, Tom Coleman.

Tom, I feel to some degree that I'm back home. Tom and I went to school at the same place, although not together. We both went to William Jewell up here at Liberty. My folks on my father's side are from Olathe. I haven't been in Kansas City for a while, but I'm glad to be back, and I see everything is still up to date here.

I want to thank all of you for being here to discuss an issue that is of great concern to this country, and that is the need for future engineers, mathematicians and scientists.

The economies of all major nations have international significance. America's economy, if it is to not only compete but to lead, must successfully compete with other nations by continuing to generate new ideas through research, through innovation and productivity, and through an educated work force that can keep pace with changes in this technologically based society.

At the time when we Americans have experienced the shift towards a technology-based economy, we are also, ironically, witnessing an apparent erosion in our education of future mathematicians, scientists and engineers. Although our education system remains the envy of the world, our colleges and universities are becoming more and more dependent upon foreign faculty, and we are graduating more and more foreign science and math students.

Today, 75 percent of graduate students receiving financial support from university engineering departments are foreign nationals. By the year 2000, we estimate that 85 percent of new entrants to the nation's work force will be members of minority groups or women. Yet these groups are significantly underserved by our schools.

For example, while Blacks represent 12 percent of the total population, they earn four percent of the baccalaureate degrees, and they earn one percent of the doctorates in science and engineering.

Women make up 51 percent of the American population, and they represent 11 percent of the scientific and engineering work force. Only seven percent of engineering Ph.D's were awarded to women.

It appears that we do not have enough scientists and engineers on the way. By the time students reach their freshman year of college, there seems to be little interest in majoring in the sciences. What interest there is, is declining. Of every 10,000 high school seniors, nationwide, only 1,800 indicate an interest in science and engineering as a possible choice of study or career path. Of these students, only 850 will earn B.A. degrees in these disciplines; only 110 will earn Master's degrees; and of those 10,000 high school students, 20 will earn a doctorate.

During the past two decades, freshman enrollment in science majors has declined by one-third. Since 1982, interest in engineering is down by a fourth. At the same time, interest in computer sciences has fallen by more than two-thirds. Imagine that. In a nation as apparently interested in computers and as increasingly dependent upon them as we are, the interest, as defined here, in computer sciences among students has collapsed.

We will hear this morning from a wide variety of witnesses, including researchers, faculty members and experts in the math and science education. This is an issue that deserves our careful attention, and we are eager to hear your short and long-term solutions to this critical problem.

I want to particularly thank my colleague, Tom Coleman, for suggesting that we hold this hearing. As I think many of you know, I know his constituents understand that he has been one of the real leaders in the Congress of the United States in calling congressional attention to the problems of American education. During the past reauthorization of the Higher Education Act, Tom sponsored a proposal that created a graduate fellow program to focus on critical national needs in graduate education. I'm pleased to be in his state to hold this hearing with him this morning.

Mr. COLEMAN. Mr. Chairman, thank you very much. Welcome again to a town that you need no official welcome to, since you have the heritage and the family members who came from our community. We are glad to have you back with us for a meeting of our subcommittee. This is a very important meeting dealing with a very important subject, that is, mathematic, science and engineering education, a national need. I thank you especially for having this hearing in my district and my area to receive testimony from a variety of witnesses, some from the Midwest, and some from both Coasts. We have an outstanding and impressive roster of witnesses that we look forward to hearing from this morning.

We will hear from those who have studied the problem from the perspective of public policy and from the point of view of making reforms in the manner and method of teaching. We will also get a perspective from representatives of our national research and development laboratories and our research-based institutions. We will hear from classroom teachers, who are extremely important, and whose work in stimulating the minds and shaping the attitudes and habits of their students is so essential. Without them, little of what we discuss today will ever have much of an impact.

We will hear about informal science programs and about ways of expanding science and math education through technological means. Finally, we shall hear of the current educational level and the needed educational level for our future scientists, engineers and mathematicians at the postsecondary level, as well as how we encourage students to enter teaching and research career..

We've gathered here today as a subcommittee because our nation is facing a crisis in the way that we educate American students in these critical academic disciplines. At the elementary and secondary school level, we are simply not stimulating and challenging our students to become proficient in mathematical and scientific reasoning and problem-solving skills. When compared with children of other nations, American students lag behind. In a recent study which compared the results of mathematic and science problem solving by 13-year-olds in several countries, American 13-year-olds performed substantially below and behind their counterparts in European and Asian countries.

In math, for example, almost 80 percent of the South Koreans who took the test performed at high levels of math. Less than 20 percent of the American 13-year-olds could do so. In science, almost twice the percentage of Koreans than American youngsters could use scientific procedure and analyze scientific data to draw conclusions.

The problem continues. Beginning in the junior high, we see the percentage of students taking math courses declines by one-half each year. So, it is little surprise to know that at the undergraduate level, by the time these students reach college, of the 340,000 freshmen entering in 1980 into our undergraduate schools who intended to major in math and science disciplines, approximately 200,000 graduated four years later with a degree and only 61,000 then began graduate study. Of those 61,000, it is estimated that only 9,700 will attain a Ph.D. degree in science and engineering by 1992, 16 percent of those who started out.

We have two charts here which, I think, vividly shows the problem. We have a declining number of people in mathematics, for example, going after the Ph.D. At a high in 1975 of almost 800, we're down to close to 400 by 1987. This shows, in dramatic form, where this nation is headed. And it is headed downward, in the wrong direction.

At the same time, as Chairman Williams has indicated, foreign students have increasingly filled this vacuum or void created by the decline of American students pursuing the advanced degree to the extent that some of our advanced degree programs are, frankly, dependent upon foreign enrollment and foreign students.

Another chart which we have shows, in four-year periods, in the last 20 years, the number of Ph.D's that have been awarded by U.S. institutions to foreign nationals in physical sciences, mathematics and engineering, and those are on the increase. Just as our own Ph.D's are on the decline, we are increasingly educating people from other countries who then return to their own country to compete with us in areas of international economies and so forth.

In fact, looking at the statistics, we have almost 41 percent of the doctorates going from U.S. institutions to foreign nationals, people with temporary student visas. These are the people who are least likely to stay behind, if you will, to become part of our system.

I might also add as a side note, to show how important this subject is, almost half of the patents that the U.S. Patent Office is granting, are being granted to foreign nationals as well. So, it is a technology-oriented presence that we have. We are falling behind. We are here to find out how we can improve the system.

As was mentioned, my concern has focused on areas of critical national need of math and science, and foreign languages as well. This is where we see the number of U.S. students pursuing advanced degrees declining. This is a concern because of international competitiveness. It is also a concern because of national security.

We need to help American students in these classrooms, and as a result, the program that I helped pass, and which has been funded now for two years, has allowed a number of U.S. students to pursue those Ph.D degrees in these areas of critical national need. We are working on the third year of funding this year, and we hope to be able to secure it. Part of the record that we will make here today in this hearing will be to go toward convincing my colleagues and the Administration to support the third year of funding for this very important program.

It is not unlike in 1957, or so, when the Soviets sent Sputnik into space. I can recall it vividly as a youngster here in Kansas City. We were stunned as a nation. We were stunned locally. We did a lot of things differently after that. We increased and changed our curriculum. The Federal Government spent a lot more money on research and development and educational support at all levels. We instituted new programs for people going to college. I was helped by some of those programs.

In the meantime, we have fallen behind after that. We were very successful in catching up. We walked on the moon just a few years later. America seized that challenge and that opportunity and met it head on.

I think we have the same type of challenge today, and we as policy makers have a lot to learn from you, the experts, and people in the field. That is why we are here today, and I look forward to receiving your testimony, and again thank Pat Williams for coming here and Rick Jerue and Michael Lance, our two staff people who are with us today from Washington, and look forward to this very important testimony that you will provide.

Thank you Pat.

Mr. WILLIAMS. Thank you. Let's have our first panel come to the table: Daryl Chubin, Michael Campbell, Michael Montague, Richard Hope. If you will put the name cards up as you arrive at your place, being as you know who you are and we don't, turn the name toward us.

I want to advise all of our witnesses that we have the following difficulty: Some of the witnesses who are on the latter part of

Panel Two and Panel Three have, as do Tom and I, another engagement which will require us to continue to move along. I'm sure that each of you, just as Tom and I, could speak for a half hour about this topic and then still have more to say. I wish the time today, as it occasionally does in our jobs, would permit a lengthy hearing. However, unfortunately that isn't so. We either had to do it this way, frankly, or not be in Kansas City at all today.

So, I am going to have to ask each of the witnesses to submit your full testimony for the record, and if it takes longer than five, six, seven minutes to read it, then I'm going to ask you to summarize it. At about six minutes, I'll tap the gavel, and, really, when we would reach about seven or eight minutes, time will expire and we'll have to move on to the next witness. I'm not sure that is going to do justice to everything you have to say to us today, but in fairness to those who are going to come at the end of the panel, as well as to the next groups of people that Tom and I must meet with, I'm hopeful that you can all assist us.

Let's begin today with Dr. Chubin, who is the Senior Analyst in the Office of Technology Assessment from Washington, D.C. Dr. Chubin, it is nice to see you here today. We appreciate your coming out and look forward to your testimony.

STATEMENT OF DR. DARYL CHUBIN, SENIOR ANALYST, OFFICE OF TECHNOLOGY ASSESSMENT, WASHINGTON, DC.

Dr. CHUBIN. Thank you, Mr. Chairman, good morning. Good morning, Mr. Coleman.

The importance of scientists, engineers, and mathematics and science teachers to the future of the nation led the House Committee on Science, Space, and Technology to ask the Office of Technology Assessment to study the recruitment and preparation of students for technical careers. The study resulted in a policy report, Educating Scientists and Engineers: Grade School to Grad School, issued last June; and two supporting documents published since December, 1988.

In these pieces, OTA developed the big picture of science education in the United States. I would like to highlight that picture and in doing so, touch on some of the themes of this hearing. Among the themes I will not address in my oral statement are the vital contributions of families, teachers, intervention programs, informal education, and the Department of Education to science literacy and career choice. Science, math, and engineering education is best seen as part of all one system, diverse educational environments, in school and out, across all grades, culminating in the award of undergraduate and graduate degrees.

The passage of students through the so-called science and engineering pipeline, today as ever, requires individual aspiration and institutional commitment. Easing the transition of students from high school to college, from two to four-year institutions and from the baccalaureate to the master's and Ph.D. degrees, is in the mainstream of the traditional Federal role: providing financial support to ensure individuals educational opportunity and assisting colleges and universities to fulfill their mission of preparin. new entrants to the U.S. work force.

Two major trends are challenging our perceptions of the traditional path to a science or engineering career. These are the growing proportion of minorities in the population, coupled with possibly smaller college enrollments, and the resultant increased competition among fields for student talent. These two trends will require universities, employers, and the Federal Government to adjust their models and mechanisms of recruitment. The pool of potential talent needs to be large and versatile, whether or not there is reason to fear a future shortage of scientists and engineers.

The Federal Government has two strategies at its disposal to influence the composition and size of the science and engineering talent pool. The retention strategy would target current undergraduate and graduate students and could increase the number of scientists and engineers within a few years.

A recruitment strategy would, over the long term, enlarge the base of potential scientists and engineers by attracting more and different students into these fields.

O.T.A. finds that the pipeline is permeable and career choices remain fluid for women and men, whites and minorities, well into the college years.

A litany of reports has recently documented that the best U.S. math and science students do not score as well as their peers in other countries on standardized tests. We must remember, however, that scores alone are just one set of indicators. In fact, since the first international comparisons were done in 1964, the United States has consistently ranked below other nations. Yet, during this same period, the basic science achievements of America, as measured by prizes, publications, and citations have been second to none.

The career intentions of college-bound students, as measured by UCLA's annual American Freshman survey, provide a better foreshadowing of degree trends. In 1987, few first-time, full-time freshman at four-year institutions, regardless of race or ethnicity, planned science and engineering majors. But this, too, is not a new trend. In actual degree taking, natural science and engineering baccalaureates have maintained a remarkably constant 20 percent share of total baccalaureates. This proportional pattern has been conspicuous for 30 years.

The attractiveness of graduate study is strongly influenced by the health of the research enterprise. Graduate enrollments and Ph.D. awards respond to the availability of fellowship and assistantship funding and to the outlook for research funding and employment.

Today, a large segment of the graduate student talent pool, especially in engineering, consists of foreign citizens. We must weigh the benefits of retaining the skills, creativity, and energy embodied by these noncitizens, and the risk of depending on foreign stock to replenish part of the academic and industrial work force. Immigration policy could be an important lever in future U.S. science and technology policy.

The lead agency for Federal involvement in school math and science education has been the National Science Foundation, and as such, has principally been interested in outstanding students who are most likely to become Ph.D. scientists and engineers, and the institutions that produce them.

The mission agencies, however, are a potent and under-valued source of Federal influence on science education at all levels of the system. These agencies have a direct interest in developing a pool of skilled talent, especially the programs of NIH, NASA, DOE, DoD, and USDA.

Finally, scientists and engineers, although only four percent of American workers, have specialized skills that are vital to the welfare of the nation.

The OTA reports do not suggest that anyone can become a scientist or engineer. But many students with the ability to do so are culled out by lack of preparation, insufficient social support, or the wherewithal to persist. We know what works. The challenge is to serve students through formal and informal education, in schools and out. The Federal Government can help bridge educational aspirations to achieve this.

[The prepared statement of Dr. Daryl E. Chubin follows:]

EDUCATING SCIENTISTS AND ENGINEERS: GRADE SCHOOL TO GRAD SCHOOL

Statement of Dr. Daryl E. Chubin
Project Director
Office of Technology Assessment
U.S. Congress

Testimony Before
Subcommittee on Postsecondary Education
Committee on Education and Labor
U.S. House of Representatives

Field Hearing on
"Math, Science, Engineering Education: A National Need"
Kansas City, Missouri

May 1, 1989

Statement of Dr. Daryl E. Chubin
Project Director
Office of Technology Assessment
U.S. Congress

The importance of scientists, engineers, and mathematics and science teachers to the future of the Nation led the House Committee on Science, Space, and Technology to ask the Office of Technology Assessment to examine the factors affecting the recruitment and preparation of students for technical careers. The study resulted in a policy report, Educating Scientists and Engineers: Grade School to Grad School, issued last June. Two supporting documents, Elementary and Secondary Education for Science and Engineering and Higher Education for Science and Engineering, were published in December 1988 and March 1989. respectively. In these pieces, OTA developed the "big picture" of science education in the United States. I would like to highlight that picture -- and in doing so, touch on many of the themes of this hearing.

The "All One System" Approach

Science, mathematics, and engineering education is best seen as part of "all one system" -- diverse educational environments, in school and out, across all grades, culminating in the award of undergraduate and graduate degrees. Various factors draw students to science; other factors influence whether or not they succeed (see Attachment 1, table 2-1).

The passage of students through the so-called science and engineering pipeline, today as ever, requires individual aspiration and institutional commitment. Facilitating the transition of students from high school to college, from 2- to 4-year institutions, or from the baccalaureate to the master's and Ph.D. degrees, is in the mainstream of the traditional Federal role: providing financial support to ensure individuals educational opportunity, and assisting colleges and universities to fulfill their mission of preparing new entrants to the U.S. work force.

Although higher education inherit problems from the K-12 system, it must do more than remediate students and lament the burden. It must forge partnerships with schools districts, as well as local business and industry, to reach students early in their educational experience, and illuminate alternative pathways from education to employment.

Trends and Opportunities: The Demographics of Participation

Two major trends are challenging our perceptions of the traditional path to a science or engineering career. These are the growing proportion of minorities in the population, coupled with possibly smaller college enrollments and the resultant increased competition among fields for student talent (Attachment 2). These two trends will require universities, employers, and the Federal Government to adjust their models and mechanisms of science and engineering recruitment. The pool of potential talent needs to be large and versatile, whether or not there is reason to fear a future shortage of scientists and engineers.

Fortunately, the changing demographics of the college-age population do not necessarily predict declining numbers or quality of entrants to the science and engineering talent pool. A broader base of learners has always been possible. There are proven ways to increase the participation of <u>all</u> kinds of students at <u>each</u> level of the educational system.

The Federal Government has two strategies at its disposal to influence the composition and preparation of the science and engineering talent pool (Attachment 3). The <u>retention</u> strategy would target current undergraduate and graduate students. By reducing attrition, retention programs could increase the number of scientists and engineers within a few years. (Attrition signifies failure by the institution to invest in students selected by their admissions process. Role models, mentoring, and hands-on experience in the laboratory provide intellectual and emotional supports; they, too, are institutional investments.) The second approach, a <u>recruitment</u> strategy, would enlarge the base of potential scientists and engineers by attracting more and different students into these fields. Such a long-term strategy entails working with schools and colleges, and with families, teachers, and staff, to renovate elementary and secondary mathematics and science education. Thus, recruitment and retention are both national investment strategies

Elementary and Secondary Education: The Federal Role

OTA finds that, contrary to conventional wisdom, the science and engineering pipeline is not filled solely with committed students who display early aptitude and achievement. One quarter of those who eventually go on to major in science and engineering come from outside the high school academic curriculum track (Attachment 4, figure 2-2). While losses of aspiring science and engineering students occur at every juncture of the pipeline, encouragement, preparation, and perceived opportunities can attract students into these fields even after they enter college. The pipeline is permeable, and career choices remain fluid -- for women and men, whites and minorities -- well into the college years (Attachment 5, figures 1-4 and 1-5).

Beginning in elementary school, practices such as ability grouping or tracking, as well as poor teaching and limited course offerings in mathematics and science discourage students. Families -- especially parents' commitment to education -- are critically important. So are teachers. The challenge is to attract good people to teaching, then provide the climate to make them effective teachers who want to remain in the profession. While starting salaries for teachers trail those of other technical professionals, issues of empowerment and career development may be bigger impediments to recruiting high-quality mathematics and science teachers, particularly minority teachers (Attachment 6, figure 3-2 and table 3-1).

Special intervention programs spark interest and proficiency in mathematics and science and open an alternative gateway to science and engineering. Based both in the community and in the schools, they can motivate children, especially female and minority youth, to explore mathematics and science. So does the informal education that takes place in museums and science centers, summer camps, and through educational television (Attachment 7, box 2-C and table 5-1).

A litany of reports has documented that the best U.S. mathematics and science students do not score as well as their peers in other countries on standardized tests. We must remember, however, that scores alone are just one set of indicators. In fact, since the first international comparisons were done in 1964, the United States has consistently ranked below other nations. During this same period, the basic science achievements of America -- as measured by prizes, publications, and citations -- have been second to none. The link between test scores and scientific preeminence has yet to be demonstrated (Attachment 8).

The career intentions of college-bound students, as measured by UCLA's annual American Freshman survey, provide a foreshadowing of degree trends. In 1987, few first-time, full-time freshmen at 4-year institutions, regardless of race/ethnicity, planned science and engineering majors. But this is not a new trend (Attachment 9, figure 2-4 and table 2-6). The 1988 freshmen data show that business and education majors continue to grow, though over twice as many students prefer the former to the latter. More alarming is that only 12 percent plan to seek the Ph.D. and that the category of "educator" -- K-12 through college -- as probable career occupation totals slightly over 9 percent. Competition for this talent among various sectors of the economy is only going to intensify.

Higher Education and the Federal Role

Any Federal program that alters the size of total undergraduate enrollments is likely to be reflected in enrollments in science and engineering majors. Natural science and engineering baccalaureates have maintained a remarkably constant 20 percent share of total baccalaureates. This proportional pattern has been conspicuous for 30 years. Enrollments rose with increases in student aid available first under the G.I. Bill. Title VI of the Civil Rights Act of 1964, the Higher Education Act of 1965, and Title IX of the 1972 Education Amendments all boosted college attendance by minority and women students, thus expanding the supply of scientists and engineers.

Financial support for undergraduate science students differs little from support for all undergraduates. Any financial aid helps students attend and complete college. Loans are growing in importance as a proportion of undergraduate student support. While the amount of debt incurred during undergraduate education does not affect most students' decisions to pursue graduate study, it is more likely to deter minority students.

The attractiveness of graduate study is strongly influenced by the health of the research enterprise. Graduate enrollments and Ph.D. awards respond to the availability of fellowship and assistantship funding, and to the outlook for research funding and employment (Attachment 10, figures 3-10 and 3-5). The National Defense Education Act, the Apollo Program of the 1960s, and the War on Cancer launched in 1971, testify to the mobilization of talent to fulfill Federal research missions.

Today, a large segment of the graduate student talent pool -- especially in engineering -- consists of foreign citizens. We must weigh the benefits of retaining the skills, creativity, and energy embodied by these noncitizens, and the risk of depending on foreign stock to replenish part of the academic and industrial work force. For example, engineering degrees earned by American minorities, especially at the doctoral level, contrast starkly with the upward trend in Ph.D. awards to foreign citizens (Attachment 11, figure 3-11 and table 4-2) Immigration policy could be an important lever in future U.S. science and technology policy.

The Federal Government has in the past made several successful attempts to improve mathematics and science education in the schools. The lead agency for Federal involvement in school mathematics and science education is the National Science Foundation (NSF). NSF has principally been interested in outstanding students who are most likely to become Ph.D. scientists and engineers, and the institutions that produce them. But large research universities, small liberal arts colleges, historically Black institutions, traditionally women's colleges, 4-year comprehensive institutions, and 2-year and community colleges all award degrees and replenish the work force. Ideally, each institutional category also supports and interacts with the others.

Because there is growing recognition that all categories of higher education institutions contribute degree recipients who enter the science and engineering work force, there are now renewed calls to "broaden the base" of students learning science and mathematics. Upgrading the "science literacy" of all students must complement the traditional NSF goals of preprofessional training and research support

At the Department of Education, mathematics and science education has had relatively low priority. In addition, since most of the funds are administered on a formula basis, their impact tends to be diluted The program specifical'y addressed to K-12 mathematics and science educatiot. Title II of the Education for Economic Security Act, is a case in point (Attachment 12, figure 6-1).

The other mission agencies, however, are potent, and under-valued, source of Federal influence on science education, at all levels of the system. These agencies have a direct interest in developing a pool of skilled talent; the programs of especially NIH, NASA, DOE, DoD, and USDA reflect this interest (Attachment 13, tables 1-3 and 6-4).

Invigorating the National Work Force

Scientists and engineers, although only 4 percent of American workers, have specialized skills that are vital to the welfare of the Nation. The national goal of invigorating a productive and engineering work force demands that capable young people must welcomed throughout the educational process, their individual talents nurtured, and their expectations raised about employment opportunities that provide fulfilling work.

The OTA reports do not suggest that anyone can become a scientist or engineer. But many students with the ability to do so are culled out by lack of preparation, insufficient social support, or the financial inability to persist. We know "what works." The challenge is to serve students through formal and informal education, in schools and out. Through its commitment to equal opportunity and financial support (both merit- and need-based) for all segments of the population, the Federal Government can help bridge educational aspirations to achievements.

ATTACHMENT 1

Table 2-1.-F ...rs Affecting Undergraduates' Choice of a Science or Engineering Major

Most students have decided on a major by the time they enter college. Innate interest, school experiences, and teacher influences play a large role. Demographic factors, particularly socioeconomic advantages, parents' backgrounds, and education and career values associated with certain ethnic groups, confer preferences that are difficult to affect through policy. However, there is substantial readjustment during the college years, as students tackle college-level courses, encounter new subjects, and face the prospect of earning a living. Many students leave science or engineering altogether; some shift among the sciences; and a few enter from nontechnical majors. Various factors during the college years encourage students to enter or stay in science or engineering.

Factors that attract students:

- Job market for scientists and engineers
- Academic preparation and achievement in high school (particularly including coursework in mathematics; science and computer coursework are also important)

Factors that reduce attrition (and improve the chances of college graduation in any field, not just in science or engineering):

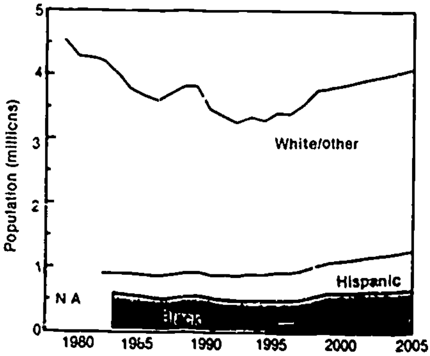
- University attention to student completion ("institutional nurturing")
- Intervention programs and peer support
- Research participation
- Good teaching
- Financial support
- Part-time work or cooperative study

SOURCE: Office of Technology Assess. ..nt, 1988.

FROM: Higher Education for Science and Engineering

ATTACHMENT 2

Size of 18-Year-Old Population, by Race/Ethnicity, 1979-2005



There will be a significant decline in the size of the college-age population in the early 1990s. Action will be required to sustain the supply of scientists and engineers

SOURCE U S Census Bureau, various reports

FROM: Educating Scientists and Engineers. Grade School to Grad School

ATTACHMENT 3

Policy Options to Improve Science and Engineering Education

Recruitment—Enlarge the Pool

- *Elementary and secondary teaching* encourage and reward teachers, expand support for preservice and inservice training
- *School opportunities* reproduce science-intensive schools, adjust course-taking and curricula, review tracking, and revise testing
- *Intervention programs* increase interest in and readiness for science and engineering majors, transfer the lessons from successful programs encourage sponsorship from all sources
- *Informal education* increase support of science centers, TV fairs and camps
- *Opportunities for women* enforce Title IX of the Education Amendments of 1972 and provide special support and intervention
- *Opportunities for minorities* enforce civil rights legislation and provide special support and intervention.

Retention—Keep Students in the Pool

- *Graduate training support.* "buy" Ph D s with fellowships and traineeships, these people are most likely to join the research work force
- *Academic R&D spending* bolster demand and support research assistants, especially through the mission agencies
- *Foreign students* adjust immigration policy to ease entry and retention
- *Undergraduate environments* support institutions that reward teaching and provide role models, such as research colleges and universities and historically Black institutions
- *Hands-on experience* encourage undergraduate research apprenticeships and cooperative education that impart career skills
- *Targeted support for undergraduates.* link need- or merit-based ... to college major

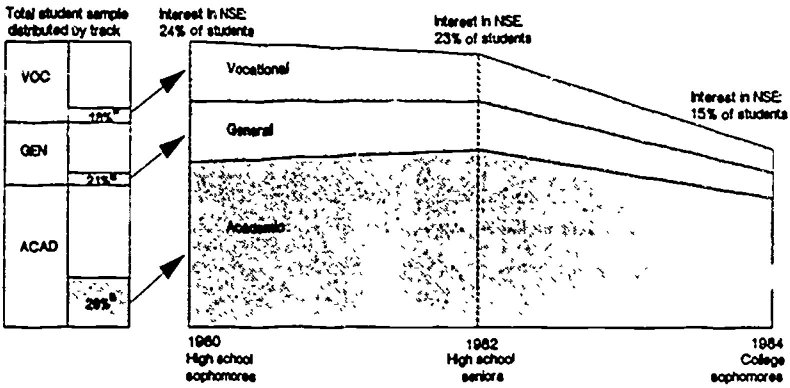
Strengthen Federal Science and Engineering Education Efforts

- *National Science Foundation as lead science education agency* underscore responsibility through the Science and Engineering Education Directorate for elementary through undergraduate science programs
- *Federal interagency coordination and data collection.* raise the visibility of science education and the transfer of information between agencies and to educational communities

FROM: Educating Scientists and Engineers, Grade School to Grad School

ATTACHMENT 4

Figure 2-2. - Interest of College-Bound Students in Natural Science/Engineering by Curriculum Track: 1982 High School Seniors



[a] Percent of students in that track (who have not ruled out attending college) who are interested in natural science/engineering majors. Natural science/engineering does not include the social sciences.

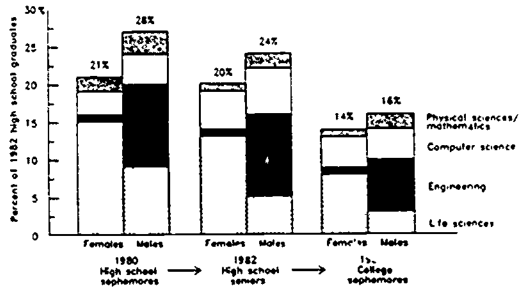
NOTE: Overall interest in natural science/engineering majors declines with time (24% of students in 1980 but only 15% in 1984 are interested in NSE). Students in the academic track are most likely to be interested in natural science/engineering majors and more likely to persist with their interest. At high school sophomore year, 80 percent of students interested in natural science/engineering majors were in the academic track; by sophomore year of college 74 percent were from the academic track. Student cohort of college-bound high school students is drawn from the High School and Beyond Survey of 1980 Sophomores.

SOURCE: Valerie E. Lee, OTA contractor report, 1987.

FROM: Educating Scientists and Engineers: Grade School to Grad School

ATTACHMENT 5

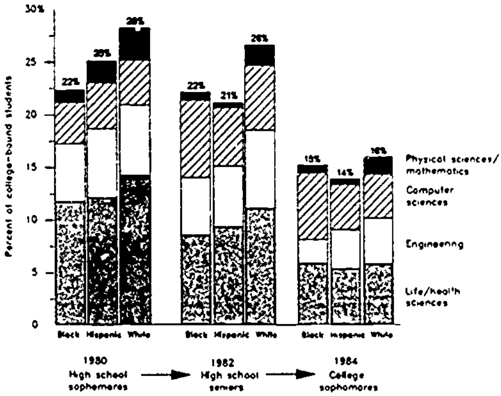
Figure 1-4.—Interest of 1982 High School Graduates in Natural Science and Engineering, by Sex, 1980-84



NOTE: [illegible]

SOURCE: [illegible]

Figure 1-5.—Interest in Natural Science and Engineering by College-Bound 1982 High School Graduates, by Race/Ethnicity, 1980-84



NOTE: [illegible]

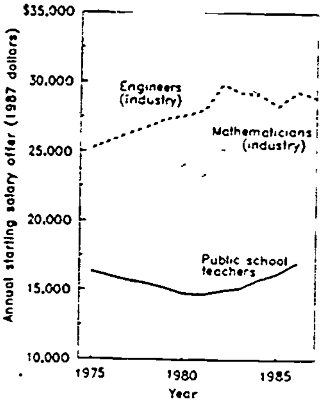
SOURCE: [illegible]

FROM: <u>Elementary and Secondary Education for Science and Engineering</u>

14

ATTACHMENT 6

Figure 3-2.—Starting Salaries for Teachers, Compared to Other Baccalaureates in Industry, 1975-87 (constant 1987 dollars)



NOTE: Uses gross national product deflator. Industry estimates of salary offers are based on a survey of selected companies; this may tend to inflate salaries slightly. The teacher data are "minimum mean" salary from the National Education Association, and probably are underestimates. Various other salary surveys report slightly different data. However, the basic message remains the same: teachers are paid much less than most other baccalaureates.

SOURCE: U.S. Department of Commerce, *Statistical Abstract of the United States* (Washington, DC: U.S. Government Printing Office, 1988), p. 130; based on data from The Northwestern Endicott-Lindquist Report, Northwestern University.

Table 3-1.—Mathematics and Science Teachers, by Race and Ethnicity, 1985-86 (in percent)

Subject and grade	Black	Hispanic	White	Other[a]	Unknown
Mathematics					
K-3	10	1	84	0	4
4-6	12	2	84	0	2
7-9	6	1	90	1	3
10-12	3	1	94	1	1
Science					
K-3	9	4	82	1	4
4-6	8	4	86	1	1
7-9	5	1	88	1	4
10-12	5	1	92	2	1

[a]Includes Native American, Alaskan Native, Asian, and Pacific Islander.
NOTE: Some rows do not sum to 100 percent due to rounding.

SOURCE: Iris R. Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987), table 35.

FROM: Elementary and Secondary Education for Science and Engineering

ATTACHMENT 7

Box 2-C.—Characteristics of Intervention Programs That Work

Over the past 10 to 20 years, special programs have been used to encourage children's interest and proficiency in academics and especially in science and engineering. Programs have worked in school and out of school, with students of all ages, cultures, and races; with youngsters of exceptional mathematics and academic achievement and with high school dropouts; in fields from agriculture to engineering. Some programs use professional experts and the latest in testing and computer technologies; others work on shoestring budgets with egg cartons and volunteers. From these experiences, both successes and failures, have emerged lessons about what makes an intervention program work. The characteristics of successful intervention programs are listed below:

- learly defined educational goals.
- high expectations among teachers and leaders,
- committed leadership,
- role models to motivate students,
- peer support with critical mass of students,
- student commitment and investment (increased study time),
- hands-on laboratory experience,
- assessment and feedback to students,
- specific goals for minorities or women,
- recruitment,
- financial aid (fellowships and traineeships augmented by research assistantships),
- multi-year involvement with students, and
- program evaluation based on student achievement.

SOURCES: Office of Technology Assessment, 1988; Government-University-Industry Research Roundtable, *Nurturing Science and Engineering Talent* (Washington, DC: National Academy of Sciences, July 1987), pp. 36-38.

Table 5-1.—Estimated Proportions of Target Populations That Participate in Informal Science and Engineering Education Programs

Occasional viewers of *3-2-1 Contact* —50 percent of 4- to 12-year-olds
Regular viewers of *3-2-1 Contact* —30-35 percent of 4- to 12-year-olds
Did a science-related activity after viewing *3-2-1 Contact* —25 percent of 4- to 12-year-olds
Visit a science center or museum —25 percent of school-age students each year
Visit a science center or museum —50 percent of 4- to 12-year-olds
Visit an aquarium or zoo —90 percent of 4- to 12-year-olds
Take an inservice course at a science center or museum —Less than 1 percent of teachers
Participate in an intervention program —Less than 1 percent of Black and Hispanic students
Participate in an intervention program —Less than 0.1 percent of female students
Enroll in a weekend or summer science enrichment program —0.1 percent of high school graduates

SOURCE: Office of Technology Assessment, 1988.

FROM: (Top) Educating Scientists and Engineers: Grade School to Grad School, and (Bottom) Elementary and Secondary Education for Science and Engineering

ATTACHMENT 8

Mathematics and Science Education in Japan, Great Britain, and the Soviet Union

During recent years, a steady stream of international comparisons of elementary and secondary education has painted an increasingly bleak picture of the deficiencies of American mathematics and science education. Depressing comparisons with teaching practices in Japan, Taiwan, Hong Kong, and South Korea have been seized on by many of those pressing for the United States to address its crumbling competitiveness. The source of competitive advantage is often referred to as "human resources" or "human capital"—skilled, talented, and flexible workers. For example, a recent commentary noted that international comparisons of mathematics education ". . . typically depict Korean 10-year-olds working out the Four-Color-Map Problem in their heads while Americans of the same age struggle to do double-digit multiplication without removing their socks."[1]

Problems in Making International Comparisons

While international comparisons do point to significant differences in mathematics and science course offerings, curricula, and teaching, it is important to bear in mind two major problems in any sort of policy-oriented comparisons among cultures and countries:

- developing a sufficiently accurate explanation of the causes of observed differences which are very often rooted in what are, to the outsider, opaque cultural and social differences in the roles of families, business, the State, law, and education; and hence
- determining what aspects of other systems could readily be *appropriated and transferred* across cultures and societies, and which would be foolish or even counterproductive to consider transferring

For example, the United States could adopt a national curriculum, but such a move would be resisted strongly by many policymakers Such a move would threaten the fragile compacts between national and local autonomy stipulated in the Federal as well as State constitutions. Further, a "national curriculum" would likely consist of little more than a lowest common denominator of topics defined by special interest groups and argued out line by line in highly partisan congressional debates Rather than providing models to be emulated, the ultimate value of doing international comparisons may be to provide a kind of "mirror" in which to examine and better understand the reasons for well-entrenched, culturally rooted American educational practices and policies.

On an analytical level, it is difficult to make sound international comparisons in education unless studies are designed to compare "like with like" and to collect enough data to build a picture of overall educational capacity—teachers, students, and schools—in each country. In considering the high school students' exposure to mathematics and science, for example, it is important to note that the American school system is designed to retain all students to age 18 (and actually succeeds in enrolling about three-quarters of this group), whereas schools in other countries typically enroll a much more select group of students in the 14- to 18-year-old range.

These caveats aside, it is generally agreed that the American education system devotes relatively less time to mathematics and science education compared with other countries; estimates are that American students spend only one-third to one-half as much time on learning science as their peers in Japan, China, the U S S R., the Federal Republic of Germany, and the German Democratic Republic.[2] Significant differences in the mathematical progress of children in selected cities in the United States, Taiwan, and the People's Republic of China have been found from the elementary grades. Japanese kindergarten children already surpass American children in their understanding of mathematical concepts.[3] It is evident that differences are across the entire educational system of each nation

[1] Edward B Fiske, "Behind Americans Problems With Math, A Question of Social Attitudes" *New York Times* June 15 1988 p B4

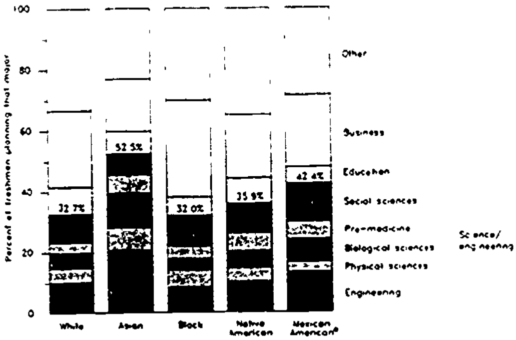
[2] F James Rutherford et al *Science Education in Global Perspective: Lessons From Five Countries* (Washington DC American Association for the Advancement of Science 1985)

[3] Harold W Stevenson et al "Mathematics Achievement of Chinese Japanese, and American Children," *Science* vol. 231 Feb 14 1986 pp 693-699

FROM: Elementary and Secondary Education for Science and Engineering

ATTACHMENT 9

Figure 2-4 - Planned Freshmen Majors by Field and Race/Ethnicity Fall 1987



[a]Includes freshmen who categorized themselves as Mexican/American or Chicano does not includes Puerto Rican-Americans
NOTE First-time full-time freshmen in 4-year institutions only
Physical sciences include mathematics and computer science

SOURCE Cooperative Institutional Research Program The American Freshman (Los Angeles CA University of California Los Angeles annually)

Table 2-6. — Planned Majors and Careers of Freshmen at 4-Year Institutions, by Sex, 1978 and 1986
(in percent)

	1978			1986		
	Total	Men	Women	Total	Men	Women
Major						
S/E pool	36 7	45 8	29 8	33 6	41 3	27 1
Engineering	10 2	18 0	2 9	10 1	17 8	3 2
Social sciences	9 2	6 8	11 8	9 4	7 0	11 9
Biological sciences	7 1	8 1	6 1	5 5	5 8	4 9
Pre-medicine	4 5	5 4	5 2	3 8	3 9	3 8
Physical sciences	4 2	5 8	2 6	2 9	4 2	2 1
Computer science	1 5	1 7	1 2	1 9	2 6	1 2
Career						
Engineer	8 9	15 7	2 5	9 0	15 6	3 0
Scientific researcher	2 8	3 4	2 2	1 8	2.2	1 4
Computer programmer	2 8	3 3	2 4	3 0	4 3	1 8

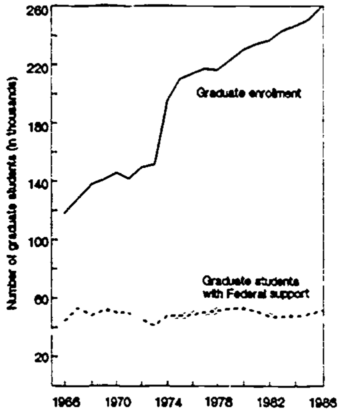
NOTE. Biological sciences includes agricult and forestry; physical sciences includes mathematical sciences Total is freshmen at 4-year institutions only Total number of students in the unweighted sample was 209,627, percentages reflect weighted national norms

SOURCE Kenneth C. Green, University of California, Los Angeles, personal communication, 1987

FROM: Higher Education for Science and Engineering

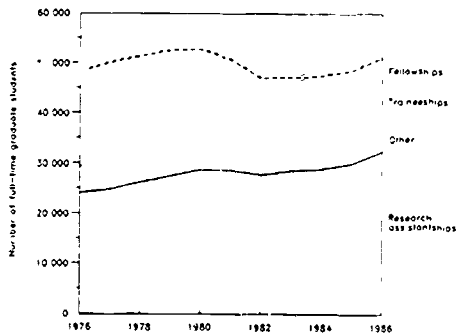
ATTACHMENT 10

Figure 3-10.—Full-Time Science/Engineering Graduate Students With Federal Support in Ph.D.-Granting Institutions, 1966-86



SOURCE: National Science Foundation, Science Resources Studies, Academic Science/Engineering: Graduate Enrollment and Support.

Figure 3-5.—Federal Support of Full-Time Graduate Students in Ph.D.-Granting Institutions, by Type: 1976-86



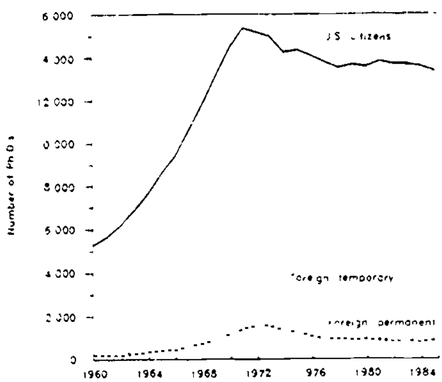
NOTE: Data for 1978 are interpolated.

SOURCE: National Science Foundation, [illegible] Graduate Enrollment and Support, Fall 1986, [illegible] (Washington DC 1988), p. 152, and National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, NSF 85-300 (Washington DC 1985), p. 12?

FROM: (Top) Educating Scientists and Engineers: Grade School to Grad School, and (Bottom) Higher Education for Science and Engineering

ATTACHMENT 11

gure 3-1 —Science/Engineering Ph.D Awards by Visa Status 960-85



NOTE U.S. citizens include unknown citizenship

SOURCE National Science Foundation, Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook, NSF 86-305 revised (Washington, DC 1986) p. 91

Table 4-2.-Engineering Degrees, by Level and Race/Ethnicity, 1987

	B.S.	M.S.	All Ph.D.s	U.S. Ph.D.s, 1986
Blacks	2.9 %	1.5 %	0.4 %	1.4 %
Hispanics[a]	3.1	1.6	0.6	2.0
American Indians	0.2	0.1	0.1	0.3
Asian-Americans	6.7	7.3	5.6	15.2
ALL MINORITIES[b]	12.9	10.5	6.7	19.0

[a] Includes degrees awarded by the University of Puerto Rico (UPR). If these data are not included, Hispanics are 2.4% of B.S. degrees. UPR data would not change M.S. or Ph.D results.

[b] U.S. minorities as a percent of engineering Ph.D.s awarded to U.S. citizens. "U.S." includes foreign citizens on permanent visas.

SOURCE: Richard A. Ellis, "Engineering and Engineering Technology Degrees, 1987." Engineering Education, vol. 78, No. 8, May 1988, p. 785.

FROM: Higher Education for Science and Engineering

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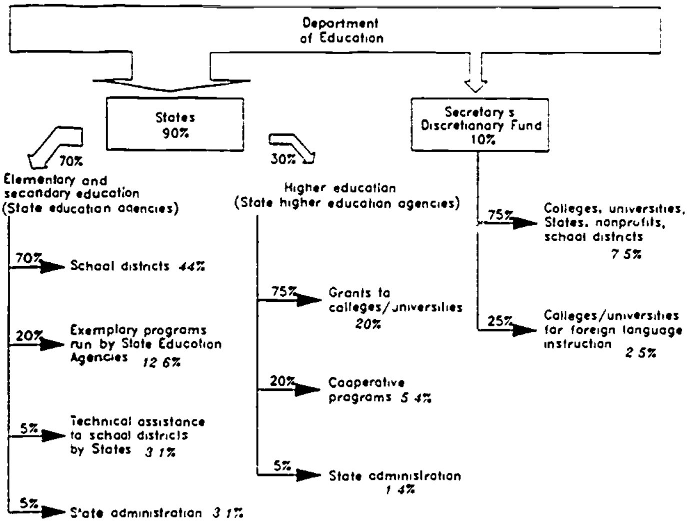
ATTACHMENT 12

Figure 6-1 —Distribution of Federal Funds Appropriated Under Title II of the Education for Economic Security Act of 1984



NOTE. Numbers in italics are final percentages of the original Department of Education 100% allocation; the numbers [not] italicized are distribution formulas.
SOURCE: Office of Technology Assessment, 1988, based on data from the U.S. Department of Education.

FROM. Elementary and Secondary Education for Science and Engineering

ATTACHMENT 13

Table 1-3.—Major Federal Programs Affecting the Education of Future Scientists and Engineers

National Science Foundation ($100-$300 million)[a]
- K-12: teacher training, curriculum and materials development, informal education, research, recognition program for exemplary teachers, research participation for high school students
- Undergraduate: research participation, instrumentation, undergraduate creativity awards
- Graduate: graduate fellowships, graduate fellowships for minorities, research assistantships via research contracts, engineering fellowships

U.S. Department of Education ($300-$500 million)
- K-12: Title II, Education for Economic Security Act, used primarily for science and mathematics teacher training, magnet school grants (not specifically targeted to science and engineering); discretionary programs
- Undergraduate: Pell Grants (not specifically targeted to science and engineering), Minority Science Improvement Program, cooperative education (about 15-30 percent of cooperative students are in science and engineering)
- Graduate: Minority Institutions Science Improvement Program; Graduate and Professional Opportunities Program, Javits Predoctoral Fellowships

National Institutes of Health ($400-$600 million)
- K-12: research apprenticeships for minorities
- Undergraduate: Minority Access to Research Careers Program, Minority Biomedical Research Support
- Graduate: National Research Service Awards Predoctoral Training Grants, research assistantships funded via research contracts, National Institutes of Mental Health Minority Fellowships

Other agencies with substantial science education efforts

K 12
- U.S. Department of Agriculture: 4H, research apprenticeships
- U.S. Department of Defense: research apprenticeships at laboratories
- U.S. Department of Energy: Prefreshman Engineering Program, for women and minorities, student research apprenticeships and teacher training institutes at national laboratories
- National Aeronautics and Space Administration: research apprenticeships, teacher workshops, and resource centers

Undergraduate
- U.S. Department of Agriculture: Land Grant allocations (not specifically targeted to science and engineering)
- U.S. Department of Commerce: National Oceanic and Atmospheric Administration Sea Grant Program
- U.S. Department of Defense: Reserve Officer Training Corps (ROTC) (about 75 percent of funds are spent on science and engineering majors)
- U.S. Department of Energy: University-Laboratory Cooperative Program for summer research
- Department of Health and Human Services: Health Careers Opportunities Program

Graduate
- U.S. Department of Agriculture: Land Grant allocations (not specifically targeted to science and engineering)
- U.S. Department of Defense: research assistantships via research contracts, graduate fellowships
- U.S. Department of Energy: fellowships in particular research fields, summer research participation grants, research assistantships funded via research contracts
- U.S. Environmental Protection Agency: research assistantships via research contracts
- National Aeronautics and Space Administration: graduate fellowships, minority graduate fellowships, research assistantships via research contracts

NOTE: Estimates of annual spending are from 1988. With the exception of those in the National Science Foundation, each of the programs listed here is funded at the level of at least $1 million per year; institutional development programs are omitted.

SOURCE: Office of Technology Assessment, 1988.

Table 6-4.—Summary of Mission Agency K 12 Mathematics and Science Education Programs

Agency programs	FY 1988 budget	Number of students	Females/minorities?
Summer research and enrichment:[a]			
DOE High School Honors Research Program	$550 000	320	N
DOE Minority Student Research Apprenticeships	$12[illegible]	200	Y
NIH Minority High School Student Research Apprenticeships	$1.5 M	410	Y
DoD Research in Engineering Apprenticeship			Y
DoD High School Apprenticeship (Office of Naval Research, Army Research Office, Air Force Office of Scientific Research)			Y
USDA Research Apprenticeship (Agricultural Research Service)	$250 000	200	
NASA Summer High School Research Apprenticeship Program		125	Y
General enrichment:[b]			
DOE Prefreshman Engineering Program	$300 000	2,000	Y
DoD/Army Computer-Related Science and Engineering Studies (4 weeks)	$ 50,000	60	
DoD UNITE		500-2 000	Y
NOAA D.C. Career Orientation	$ 30 000	24	Y
EPA summer internships			
USDA 4-H	$70-100 M	5 M	N
Teacher training and support:			
NASA education workshops	$1 M +	unknown	
NASA resource centers		unknown	
DOE research experience and institutes	$250 000	50	
USGS summer jobs for teachers	unknown	20-90	
Informal outreach:[b]			
All agencies (especially NASA and DoD) (also NIST, DOE, USDA, NOAA, USGS, EPA, NIH)		hundreds of thousands	

[a]Research, instruction, career orientation, [illegible] short-term residential.
[b]Classroom visits and demonstrations, science fairs, talent searches, [illegible] fairs, laboratory open houses, weekend instruction and hands-on programs, partnerships ("adopt a school"), materials development and lending.
NOTE: Most programs include cost-sharing with host institutions, [illegible] with local industry and other sponsors.
KEY: DOE = Department of Energy; NIH = National Institutes of Health; USDA = U.S. Department of Agriculture; NASA = National Aeronautics and Space Administration; DoD = Department of Defense; NOAA = National Oceanic and Atmospheric Administration; EPA = Environmental Protection Agency; USGS = U.S. Geological Survey; NIST = National Institute of Standards and Technology

SOURCE: Office of Technology Assessment, 1988.

FROM: (Top) Educating Scientists and Engineers: Grade School to Grad School, and (Bottom) Elementary and Secondary Education for Science and Engineering

Mr. WILLIAMS. Thank you very much.

Michael Campbell is a Program Director of the Nova Project, Lawrence Livermore National Laboratory in California. Dr. Campbell, it is nice to have you with us today. Please proceed.

STATEMENT OF DR. MICHAEL CAMPBELL, PROGRAM DIRECTOR, NOVA PROJECT, LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CALIFORNIA

Dr. CAMPBELL. Good morning to the Committee. I want to thank you for asking me to testify.

What I'm going to do in my testimony is to more or less give you an idea of the sorts of needs that occur in the national laboratories, a breakdown of the workforce and why we see the problem in education, as the Committee is addressing, and then the sort of activities that Livermore is doing.

Lawrence Livermore Laboratory is one of the main Department of Energy laboratories engaged in national security concerns. It has active programs in nuclear weapons: design, development, and testing. It is one of the only two institutions in the country that does that.

It is very much involved in the Strategic Defense Initiative, X-ray lasers, Free Electron Lasers; the 'brilliant pebbles' concept is from Livermore. It is one of the foremost international research centers in fusion research, not counting cold fusion, but Livermore is one of the outstanding institutions in traditional hot fusion.

It has many more important research programs dealing with national security directly, as in, for example, the weapons research, but, as everyone knows, national security is economic competitiveness, also, and high technology down at Livermore is very important to that.

Let me show you an example of a type of research, one that I'm very familiar with—the Nova program—just to show you what it looks like and so you can get an idea of the type of people that we need.

This is a picture of a window. That is a big window the size of a football field It is a 100 trillion watt device. It requires skilled scientists and engineers to both design and build it, construct and to use this facility. Its main purpose is to do Inertial Confinement Fusion for both military and civilian applications. There are typically 200 or so people involved this, about half of whom are scientists and engineers.

The work force of Livermore is composed of around 8,000 people. Of those 8,000, about 3,100 are scientists and engineers. Of those 3,100, approximately 90 to 93 percent are Caucasian men and the rest are women and minorities.

We have an annual budget of $900 million to $1 billion dollars a year. The Government and country spend enormous amounts of resources in national laboratories.

One of the interests we have in education obviously is not only maintaining the work force, but in getting the work force. Typically, Livermore loses about five percent of our work force per year due to retirements and attrition. Science is competitive, and the Bay area is very competitive in terms of top quality people. That translates into about 200 or so scientists and engineers that we deal with or have to try to . ecruit.

Because of the security concerns of research, not only may we not have any foreign scientists, but it is very difficult to get people who want to do classified research. Many scientists become scientists because of the ability to communicate with their peers, to deal in international forums, and this is not possible in much of the classified work. Classification policy really does reduce the amount of people we get interested.

So, typically, about half of the people that we make offers to, accept. That means, typically each year we're looking for about 400 scientists and engineers, which is basically, four percent of the graduating class. So one out of 25 people the U.S. graduates, Livermore is after. That gives you an idea of our concern.

Since they must be American citizens and because security clearances are required, it causes additional difficulty.

The education problems are real for us, and they will impact what we do today and probably what we will do in the future.

Livermore has had, since the late 60's, an educational outreach program directed towards those who are not yet in the work force, starting in kindergarten through postgraduate education, with a lot of emphasis in eighth through twelfth grades. There are about 10 active programs that we have. I won't remember them unless I look at them.

We participate in conferences and skill training. We have people assigned to science teachers in the local high schools come to Livermore to get computer skills, to see what an active research program is.

I am very much involved in touring and speaking to both universities in the typical scientific programs, but also in grammar and high school in the local area.

We targeted the Oberlin school district, which is overwhelmingly minority populated, as a place where we try and basically show them science is fun.

We advise and consult.

We provide materials, because one of the things which is lacking in the early schools is equipment. National laboratories are overwhelmed in equipment and, in fact, a way of transferring out is something that we do.

There are workshops where teachers and the students are brought in.

We have programs during the school year—people can come to work up to fifteen hours a week at Livermore—to try to show them what it is like to work in a research environment.

Summer students: We have an active program in undergraduate and graduate summer students. It is much easier to get undergraduates because they are not involved in thesis work. They come out.

We have teacher training and, when possible, have collaborative research with institutions which have rather large minority enrollments.

So Livermore has an active program because of the future needs of the Laboratory and the changing demographics of the work force.

Science and Engineering Education Needs Viewed from the Perspective of the National Laboratories

Statement prepared for
Subcommittee on
Postsecondary Education

Dr. E. Michael Campbell
Program Leader, Nova Experiments
Inertial Confinement Fusion Program

34

May 1, 1989

University of California
Lawrence Livermore
National Laboratory

From my standpoint, it is clear that what is lacking in our young is the idea that science is not done by nerds, it is fun. Science is fun. I enjoy my work. It is very interesting. I don't watch the clock, which is something, I think, which is an important feature of any job. That doesn't get across very well. It is clear that one of the ways in which science can become a integral part of the society, at least from education's standpoint, is that research institutions require as their job to educate, to be involved in education.

Because research science, again, is fun. It is challenging, and it is not just done by people with slide rules and calculators in their belts.

I think, as the previous speaker said, that agencies such as DOE, which is a heavy funder of Livermore, must recognize it is their job, it is part of their mission to train the next scientific work force. It is not just a part of education because research is such an aspect of that. The future needs of the country will only be met if universities, national laboratories, and industry work together in getting the perception that science is fun to the young students today.

Thank you.

[The prepared statement of Dr. Michael Campbell follows:]

Lawrence Livermore National Laboratory (LLNL), located in Livermore, California, is one of the leading Department of Energy (DOE) institutions dedicated to scientific and engineering research and development in numerous areas of national security concern. LLNL, founded in 1953, is administered by the University of California for the Department of Energy. A similar arrangement exists for both Los Alamos and Lawrence Berkeley National Laboratories.

Numerous topics for national need and security are addressed at LLNL. The most notable present programs are shown in Fig. 1. Most importantly, LLNL and LANL are the only two scientific centers in which nuclear weapons research, design, and development are undertaken. Many of the warheads in the tactical and strategic U.S. arsenal were developed at LLNL. Recent examples include warheads for the MX, Trident, and land based cruise missiles. Many of the concepts for third generation nuclear devices also originated at LLNL. Of particular note is the research directed towards nuclear pumped x-ray lasers of interest to the Strategic Defense Initiative (SDI) Program.

LLNL is also one of the principal contributors to the SDI effort. In addition to the x-ray laser research mentioned above, the Laboratory has leading programs in Free Electron Lasers (FEL) and Kinetic intercept weapons such as the "brilliant pebbles" concept.

The Laboratory has used its expertise in high temperature plasmas and nuclear physics to become one of the premier institutions in the world for fusion energy research. The decline in our domestic capabilities in environmentally acceptable fossil fuels as well as the inevitable global environmental catastrophe resulting from airborne pollutants arising from the use of this fuel, will make advanced energy research such a nuclear fusion an urgent national concern. The Laboratory has two large efforts in this area: Magnetic Confinement Fusion (MFE) and laser driven Inertial Confinement Fusion (ICF). The Magnetic Fusion Program has pioneered the use of magnetic mirrors for plasma confinement, techniques such as neutral beams and free electron lasers for heating plasmas to thermonuclear temperatures, and in reactor designs. This effort has recently been reduced due to pressures on the national magnetic fusion program budget and the resulting concentration on Tokamak devices.

The Laser Fusion Program at LLNL is presently the world leading center for ICF research The 100 trillion watt Nova laser at LLNL shown in Figs. 2 and 3 is the largest and most powerful laser facility in the world The national ICF Program has made significant progress during the past several years. To both illustrate the progress and to better delineate the promise and benefits of ICF, a recent presentation given to the Subcommittee on Energy Research and Development is included with this written testimony. The ICF Program has significant applications for both military and civilian needs. The science and technology associated with ICF is relevant to many issues in nuclear weapons design. In addition, high gain ICF would be valuable for studying and evaluating the effects of nuclear explosives on systems and components (vulnerability and lethality) and for civilian energy applications. The science and technology of ICF are also important in numerous other civilian and military areas Examples include laser physics, x-ray lasers, non-linear optics, high energy density plasma physics, and advanced instrumentation and technologies such as x-ray optics and high speed electronics.

The technology efforts within the ICF Program have lead to other research activities at LLNL. Indeed, these efforts have made the Laboratory an international leader in laser research Two programs are worth noting laser isotope separation and high average power laser research. The former program is developing for commercial and military exploitation, isotope separation techniques for fissionable materials such as uranium and plutonium utilizing powerful tunable lasers This advanced materials processing technique is far more efficient and cost effective then the present gas centrifuge plants that have been used for the past 40 years. The High Average Power Laser Program, sponsored by the Department of Defense, is developing high repetition, powerful lasers for remote sensing, energy sensor destruction, and for oscillators for free electron laser amplifiers.

In addition to the areas presented above, the Laboratory has other research programs of importance to national security Illustrative examples include biophysics, atomic and nuclear physics, super computers, global environment and the effects of nuclear war, super-conductivity, astrophysical research, and nuclear testing verification.

As shown in Fig. 4, the present work force of the Laboratory involved in all these programs is approximately 8,000 career employees. Scientists and engineers comprise about 39% (3,100) of the total work force with the majority of the remaining employees providing technical, administrative, and clerical support. In addition to the career staff, there are approximately 3,000 contract employers (primarily engineers and technicians) on site at LLNL to support the programs. The yearly operation and construction budget for all of the ongoing research programs at LLNL is approximately nine-hundred million to one billion dollars (FY89)

The demography of the LLNL work force is similar to other scientific research institutions. Of the 3,100 scientists and engineers at the Laboratory, approximately 12% and 10% of the work force are women and minorities, respectfully. The vast majority are caucasian males. This lack of representation is especially acute in physics and engineering where women and minorities comprise only 5% of the staff The situation in the technician ranks is similar to the levels reported above except that women are represented at an even lower value (≤3%) This situation is found presently at LLNL despite an aggressive recruiting program for women and minorities.

The cutting edge research needs of the Laboratory demand a highly skilled and motivated labor force. Physicists with expertise in lasers, biophysics, plasma radiation, atomic, nuclear accelerator, and solid-state physics are required. Mechanical and electrical engineers with skills in high speed electronics, optoelectronics, materials fabrication, microfabrication, precision machining, metrology, and vacuum systems are needed. In addition to the professional staff, a pool of skilled mechanical and electrical technicians with expertise in the above areas is also necessary to successively conduct the state of-the-art research found at LLNL. Because of the demanding nature of the research and the need for a security clearance, it typically takes two years of more after arriving at LLNL, for a new employee to become a fully contributing member of the work force.

The yearly workforce turnover rate due to retirements and terminations is approximately 4.5% to 5% of the staff. Thus, to simply maintain the present staffing level, approximately 350 to 400 positions, of which 200 are scientists/engineers, must be filled each year. If the Laboratory grows at all, these numbers will certainly increase. Because of industrial and university competitiveness, the high cost of living in the San Francisco, area and the classified nature of much of the research, the acceptance rate for LLNL employment offers is typically 50%. Thus LLNL alone recruits some 400 scientists/engineers per year. This number represents approximately 4% of the national PhD graduating class in science and engineering.

From the above discussions, it should be apparent why LLNL as well as other research centers in the U.S , are increasingly concerned about both the number of students and the quality of the education in science and engineering. As mentioned above, the Laboratory typically recruits about 4% of the PhD graduating class in science and engineering. This number does not take into account the fact that greater than 40% and 20% of graduate students in engineering and the natural sciences are foreigners and that most programs at LLNL require U.S. citizenship. In addition, the changing demographics of the work force is further cause for concern. As mentioned previously, caucasian men, which presently comprise nearly half of the existing overall labor force, have traditionally provided the pool for the vast majority of the technical staff. The work force at LLNL is clearly representative of this fact. During the next 15 years, however, the changing demographics will markedly affect the composition of the future work force. Of the new workers entering the labor force by the year 2000, only 15% will be caucasian men.

In addition to the numbers of students, the quality of the technical education particularly in grades K through 12, is cause for alarm. The consistently poor performance of U.S. students in international science and mathematic competition attests to the low quality of education that presently exists in our country A highly trained work force is required to perform state-of-the-art research and to enable the U.S. to effectively compete in the military and economic arenas

While such statistics and generalities are now commonly heard, it is worthwhile to relay some of my own experiences. In my present position, I am responsible for the experimental physics program conducted on the Nova laser A staff of approximately 200 scientists, engineers, and technicians are associated with this effort. One of my principal duties is recruiting first rate scientists to conduct the ongoing research effort and to develop new programs. Of the 75 to 100 applicants that I've interviewed during the past 10 years, there have been only two women, four blacks, and one hispanic-American One of the black scientists, although educated in the U.S. and a naturalized citizen, was even born in Cameroon, Africa. Three of the five scientists, that I have most recently hired are not American citizens. They were hired into temporary positions with no classified work assignments Their positions become permanent when they become U.S. citizens. We endure such difficulty and inconvenience because they are simply the best qualified applicants.

It is clear that if the present situation continues, the United States position in a highly technical and competitive world will continue to decline. The present undesirable state of scientific education in the U.S. has taken several decades to develop and it will most likely take a similar length of time to be corrected. A coherent long term national effort to increase the general public's awareness of the importance of science and technology and to improve our science education must be developed. The country must use its national resources to combat both our poor science education and the low scientific literacy of the general population. National laboratories such as LLNL, industry and universities must work together with educators in formulating, developing, and executing such a program. Efforts must be focused on grades K through 12 in which children, parent, and teachers are targeted.

Some efforts along these lines are already underway. Since the late 1960's, LLNL has been involved in educational outreach programs from K through the post doctoral level. As shown in Fig. 5, the Laboratory sponsors 10 types of such programs. The programs target both teachers and students and they include extensive involvement by LLNL scientific and technical staff. Examples of some of the programs are displayed in Figs. 6 through 10 and a partial listing of participating schools are shown in Fig. 11

The Laboratory has also been actively involved in minority programs. Examples of ongoing programs are shown in Figs. 12 through 15. Participating schools ar the college level are shown in Fig. 16 Funding for these educational outreach programs are provided by the Laboratory and various fidual agencies (NSF, DOE, NASA).

In addition to the ongoing programs, more extensive efforts are required to combat the present educational short falls. A true national commitment rather then simple political rhetoric must be made. While a realistic and effective program and strategy must be developed by experts, there are several approaches that are clearly worth mentioning. They include:

- Federal funding directed towards educational programs involving universities, national laboratories and local schools (K through 12) should be established.
- Scientific equipment that is no longer needed by well equipped institutions, such as the national laboratories should be transferred to either universities, or local K through 12 schools.
- Grants for retired scientists/engineers to teach in local schools should be established. The grants should not affect other retirement benefits.

— Science and technology summer camps run by science teachers at the K through 12 level and university teachers or retired scientists should be established.
— Sabattical leave for scientists at universities and national laboratories should be established to teach (or assist teachers) at grades 8 through 12

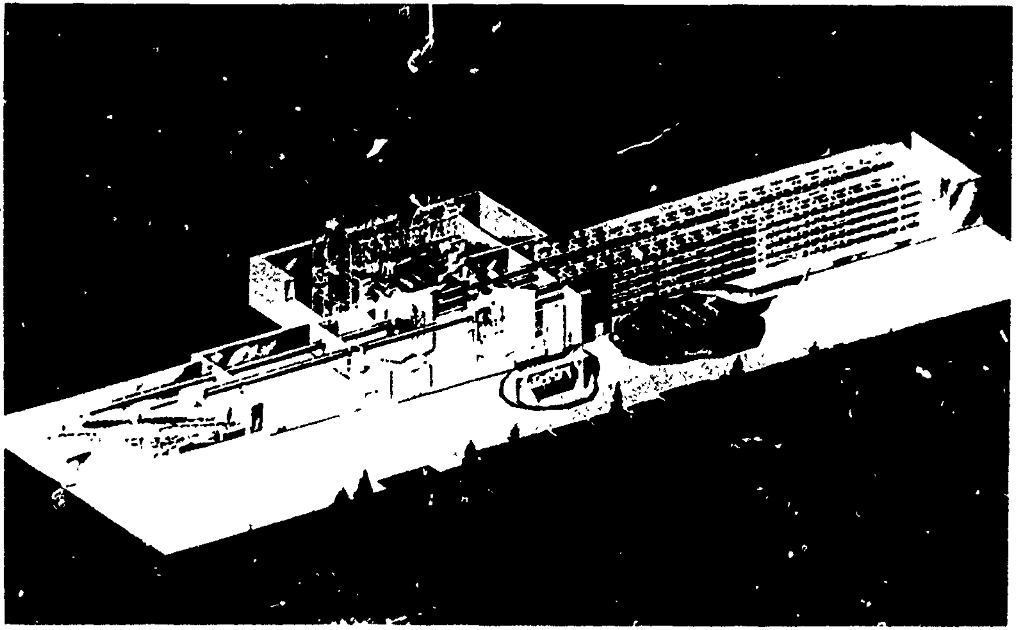
Thank you for the invitation to testify at this subcommittee hearing. Your concern for the future of the country is well founded and I hope that you are successful in your endeavor

Numerous topics for national need and security are addressed at LLNL

- Nuclear weapons design and development
  - tactical and strategic defense
  - third generation weapons (i.e., x-ray laser research)
- Strategic defense initiative
  - x-ray lasers
  - free-electron lasers
  - "brilliant pebbles"
- Fusion energy for defense and civilian applications
  - inertial fusion
  - magnetic fusion
- Laser Isotope Separation for strategic materials
- Numerous others

The Nova laser facility routinely produces 24 kJ of 0.35 μm light in 1 nsec

50-70 kJ on target, pulse shaped by 1990



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LLNL facts

Workforce

- 8,000 career employees
  - — 3,100 scientists/engineers
- 3,000 contract employees on site

Operating/construction budget

- 900 M$ — 1,000 M$/year

45

THERE ARE 10 TYPES OF EDUCATIONAL OUTREACH PROGRAMS/ACTIVITIES

- Conferences
- Skill Training
- Tour/Speakers
- Advisory/Consultant
- Workshops
- School Year Work Experience
- Summer Work Experience
- Teacher Training
- Collaborative Research
- Other

SOME EXAMPLES OF THE LAB'S ACTIVE PROGRAMS -- BY PROGRAM TYPE, TITLE AND GOAL

GRADE LEVEL = K-8TH

- SKILL TRAINING

Logo Classes - Student/Faculty Programs

- Beginning, intermediate & advanced level logo computer classes are offered to 3rd thru 8th grade students. Classes are 2 hours and are held before, during and after school. Summer classes are offered to students as well as faculty.

- TEACHER TRAINING

Hands-On Experimental Laboratory Program (HELP) - Faculty Program

- HELP workshops provide hands-on experiments and projects that elementary and middle school teachers can adapt for their own classrooms. Workshops are conducted at the Science Education Center

GRADE LEVEL = K-12TH

- TEACHER ENRICHMENT

SEC Saturday Lecture Series - Faculty Program

- Lecture series is designed primarily for elementary through high school teachers, to let them meet with leaders of the computer and science fields. This gives teachers an opportunity to experience some of the powerful ideas that they so often have read about, but have never had the chance to experience first hand. The base audience is teachers, but students who attend also find these lectures interesting and informative.

- WORKSHOP

Art in Science - Student Program

- Project goal is to have students understand the role of art in science, science history and learn about black scientists and inventors. The workshop is designed to enhance students' art skills, teach graphic design and discuss careers of art in science.

GRADE LEVEL = HIGH SCHOOL

- SCHOOL YEAR WORK EXPERIENCE

Plant Engineering Experience Program (PEEP) - Student Program

- A high school work experience program for students 16 years of age until graduation. Students work 15 hours weekly during the school year and full-time during the summer and holidays. Major emphasis is learning responsibility and commitment to what having a job means.

- SUMMER WORK EXPERIENCE

DOE High School Student Supercomputing Honors Program - Student Program

- The program offers the brightest high school students in the field of computational science hands-on experience with the world's fastest and most sophisticated computers. In addition, it introduces the students to Laboratory scientists — experts in a variety of disciplines.

GRADE LEVEL = COLLEGE/UNIVERSITY

- ADVISORY/CONSULTANT

Hispanic Engineering Education Support Program - Student Program

- Program provides NAU Hispanic engineering students support in three areas: academic, such as counseling, tutoring and mentoring; cultural, pairing each student with a Hispanic community support group in their hometown; and economic, under which NAU will contact industries in the student's hometown to arrange for part-time, summer or cooperative employment.

50

- COURSE WORK

Undergraduate Summer Institute on Contempory Topics-Applied Physics - Student Program

- DAS, LLNL and the Hertz Foundation offer appointments to outstanding undergraduate physics and engineering students. The curriculum consists of lectures and projects. The Summer Institute students gain hands-on experimental, theoretical or computational physics experience by completing a small project.

GRADE LEVEL = ELEMENTARY/HIGH SCHOOL/COLLEGE

- TOUR/SPEAKER

Speakers Bureau - Student/Faculty Program

- Speakers are available to present virtually every phase of Laboratory operations and work. A few topics: Overview of the Lab, Nuclear Weapons Research & Testing, Arms Control, Computers, Science & Math careers, etc. The Speakers Bureau's goal is to provide current and relevant information about the Laboratory

- CONFERENCE

Preparing for Tomorrow's Technological Needs - Faculty Program

- The goal of the conference was to increase the interest of elementary, high school and college students in careers in science and technology so there will be no shortfall of manpower in these fields in the future. There were 300 Bay Area educators and representatives from private industry and the Laboratory in attendance. As a result of the conference, LLNL staff have been asked to attend curriculum and school district advisory boards.

EXAMPLES OF SCHOOL PARTICIPATION IN LLNL'S EDUCATIONAL OUTREACH PROGRAMS/ACTIVITIES

- Student Programs
  - California High School
  - Claremont Middle School
  - Livermore High School
  - Del Valle Continuation School
  - Northern Arizona University

- Faculty Programs
  - Atlanta University
  - California State University
  - Stanford University
  - Livermore Unified School District
  - University of Virgin Islands

- Student and Faculty Programs
  - Bay Area Elementary Schools (45 miles)
  - Navajo Community College
  - UCSF Medical School
  - Associated Western Universities
  - Howard University

EXAMPLES OF PROGRAMS THAT HAVE CONTRIBUTED GREATLY TO THE LAB'S AFFIRMATIVE ACTION GOALS

- TEACHER TRAINING - (K-8th)

Lawrence Livermore Elementary School Study of Nature (LESSON) - Faculty Program

- The goal of LESSON is to develop and maintain in students the potential for science study and to motivate them to embrace the study of science through high school and college. The Lab provides 2.5 week workshops for elementary/middle school teachers. The workshops demonstrate the "hands-on" approach to teaching science. Materials for in-class and take-home experiments are provided.

- SKILL TRAINING - (Apprenticeship)

Apprenticeship & Pre-Apprenticeship Program (AP) - Student Program

- The program supplies OJT and classroom training lea[illegible] to state certification as a journey-level craftsperson Participants work full-time in ad[illegible] technologies during their 3-4 year apprenticeship Applicants must be 18 and have a high school diploma or (GED) and take a standard math/mechanical test.

EXAMPLES OF AA/EEO PROGRAMS — CONTIN' ' D

- SCHOOL YEAR WORK EXPERIENCE - (High S   ool/College)

Student Technology Experience Program (STEP) - Student Program

- Program offers local high school and college students meaningful work experience and encourages them to continue their education in science, engineering or business. Participants must be full-time students and maintain satisfactory academic standing. 54

- TOUR/SPEAKER - (Community College)

Navajo Community College Program (NCC) - Student/Faculty Program

- LLNL technologists make week-long visits to the Navajo Community College campus and assist the college faculty in teaching classes, evaluating curricula and equipment. Presentations are made to local high schools and junior high schools.

EXAMPLES OF AA/EEO PROGRAMS — CONTINUED

- COLLABORATIVE RESEARCH - (College/University)

Summer Institute for Faculty Program (SIF) - Faculty Program

- The purpose of the program is to enrich the research and education programs at colleges and universities with high enrollments of minorities, women and handicapped students. Candidates should be faculty members from these colleges and universities.

- EDUCATIONAL DEVELOPMENT/SUPPORT - (College/University)

Historically Black Colleges & Universities Program (HBCU) - Student/Faculty Program

- Primary goal of HBUC programs is to increase scientific and technical expertise at individual colleges and universities and to train black students who wish to become scientists or engineers. Currently, the program works with 13 different HBCU's on various projects.

EXAMPLES OF AA/EEO PROGRAMS — CONTINUED

- OTHER-GRADUATE FELLOWSHIP - (Graduate Students)

National Physical Science Consortium for Graduate Degrees-Min/Women -Student Program

- The main purpose and goal of this program is to expand the pool of qualified women and minority PhD's in the physical sciences.

A NUMBER OF SCHOOLS PARTICIPATING IN AA/EEO EDUCATIONAL OUTREACH PROGRAMS ARE AT THE COLLEGE LEVEL

- Alabama A&M University
- Atlanta University
- Fort Valley State College
- Hampton University
- Howard University
- Jackson State University
- Mississippi Valley State University
- Northern Arizona University
- University of Minnesota
- Montana State University
- Stanford University
- University of New Mexico
- Cornell University
- Navajo Community College
- Southern University, Baton Rouge

57

Mr. WILLIAMS. Thank you very much.

Michael Montague is with Monsanto, and is manager of Research Operations and External Funding Biological Sciences. Mr. Montague, it is good to see you here today, please proceed.

STATEMENT OF MR. MICHAEL MONTAGUE, MANAGER, RESEARCH OPERATIONS & EXTERNAL FUNDING BIOLOGICAL SCIENCES, MONSANTO, ST. LOUIS, MISSOURI

Mr. MONTAGUE. Good morning, Mr. Chairman, Mr. Coleman. It is a privilege to address the subcommittee this morning.

I would like to begin by describing the company which I represent. Monsanto is a U.S. based multinational company engaged in researching, manufacturing and marketing a widely diversified line of products, including chemical and agricultural products, pharmaceuticals, low-calorie sweeteners, industrial process controls, manmade fibers and plastics. These products are made possible because of intensive research in both the discovery and development arenas. Thus, Monsanto is a science-driven company. Science allows us to derive the technology, the know-how, which adds value to the raw materials we use to produce our products.

Because science and technology are so essential to our existence, it is absolutely vital that we attract and hire the best scientific and engineering talent available. Indeed, we must attract a large number of scientists and engineers from many different disciplines. Monsanto currently employs approximately 4,000 technical people. Roughly, one employee in twelve is a scientist or engineer. Their expertise covers a wide range of disciplines, including many different areas of chemistry, biochemistry, molecular biology, plant science, animal science, et cetera. The difference between our success and failure in the vast international marketplace rests with the quality of scientific talent that we have in our company. Therefore, the quality of training and the number of scientists and engineers produced in the United States is of serious concern to us.

Over the past ten years, Monsanto has undergone significant restructuring. We have moved away from low value-added commodity chemical businesses and into high value-added specialty chemicals and into products derived using life science based technologies. This new emphasis on the life sciences has necessitated considerable recruitment of scientists in these disciplines. We have been quite successful at recruiting excellent talent, as demonstrated by the considerable progress we have made toward the commercialization of a multiplicity of new products.

Current trends strongly indicate that it will be far more difficult to recruit top-notch scientific talent in the future. These trends suggest that Monsanto and other U.S. based companies will have to develop new strategies to find and attract the scientists and engineers who are so vital to our businesses.

U.S. based companies will have to become more aggressive in recruiting the best talent, especially in the business, scientific and technical areas. They will be forced to develop even more directed, more effective recruitment programs by working closely with university departments to identify top-notch talent early on and follow those individuals through their undergraduate and graduate careers. In some cases, financial support will be essential. Financial support alone is rarely enough, however. University students must be made aware of the opportunities and challenges that science-driven companies have to offer.

These steps will be particularly urgent with regard to the recruitment of women and minorities. Industry must find better ways to encourage the entry of women and minorities into scientific and technical careers.

One program that Monsanto is involved with is called Inroads. This program effectively places minority undergraduate students who possess intellectual ability, scientific aptitude and an interest in pursuing science as a career in our laboratories during the summer. They gain exposure to actual scientific research and begin to experience the intellectual and aesthetic thrill of discovery. Moreover, they learn about the discovery and development of products, first hand. This not only provides these students with information about the scientific world, but it also increases their self-esteem and self-confidence.

Another area for the activity of U.S. based companies is in the support of education. For example, scientists from Monsanto Company have worked with high school biology teachers to develop a curriculum unit on biotechnology. Thus, the latest findings in this exciting new technology have been made available to high school science teachers and through them, to their students, some of whom will become future scientists and engineers.

These kinds of programs are important if we are to counter the trend toward ever greater scientific and technological illiteracy in the U.S.

On yet another front, Monsanto has formed a partnership with the University of Missouri, St. Louis, and the St. Louis area public schools. This partnership is called the Bridge Program. Its goals are designed to raise levels of skill and interest among disadvantaged students in the public schools, to increase the numbers of these students who go on to college, and to motivate them to pursue careers in mathematics, science and technological fields. Monsanto contributed $500,000 to this program.

In other areas, Monsanto offers financial support to a range of projects. We support the Science Fair, various workshops for science teachers, the development of novel exhibits for the St. Louis Science Center, the purchase of desk-top personal computers for the St. Louis public schools, as well as special public lectures on science for the non-scientist.

It may be especially important to reach students at the elementary level. Monsanto supports the development of new curricula at this level. We also help to expose elementary students to our facilities by inviting them for presentations. In addition, our scientists often go out to make presentations to science classes throughout the St. Louis area. They also act as mentors to help students develop suitable science fair projects. It is probably at the elementary level that we would have the most impact in inviting females and minorities to consider science as an interesting and potential career direction.

Corporations will have to develop programs which address the special needs of women employees who often have dual or triple roles at work and at home. Daycare and eldercare provisions are a minimum. In addition, special programs for the continuing education of older employees will be essential because it is likely that their services will become more and more important with the decline in the number of younger entrants into the work force.

But companies cannot resolve these issues by themselves. Everyone has a vested interest in finding solutions to the pressing problem of developing scientific and engineering talent and, indeed, to the problem of obtaining a more highly educated general population. The threat posed by this issue to our standard of living and the defense of our way of life should not be underestimated. As never before, the U.S. must compete in a truly international marketplace of products and ideas. We simply cannot afford to become a second rate nation.

Some of the changes which have to occur to address this issue include the following: One, the public must be helped to understand that science and technology are the driving forces of our civilization.

Two, the choice of science or engineering as a career must be seen as at least as prestigious as medicine, law, or finance.

Three, the government must foster science and science education at a higher financial level than in the recent past. In addition, governmental agencies must regulate the products of technology with laws based upon good science, verifiable data and accurate interpretations, and not on emotional, irrational or anti-technological arguments. Government must take an active role in advocating technology and technological development, helping the public to derive accurate risk/benefit assessments.

Four, we must find new ways to encourage the entry of women and minorities into technical careers. Science careers must be considered to be a viable option for anyone with the ability and interest, regardless of race or gender.

Companies like Monsanto are committed to success in the international marketplace. The achievement of such long-term success is an enormous challenge, given the intense competition from abroad. For science-driven companies, the quality of the technical labor pool is critical. We are committed to the development of novel strategies for recruiting the best of those who are trained in our universities, regardless of race or gender. Moreover, we are committed to doing our part to help to fill the pipeline with those who might never before have considered a career in science.

Thank you.

[The prepared statement of Mr. Montague follows:]

TESTIMONY BEFORE CONGRESSIONAL SUBCOMMITTEE

ON POSTSECONDARY EDUCATION

COMMITTEE ON EDUCATION AND LABOR

U S HOUSE OF REPRESENTATIVES

Mr Chairman:

I am Michael J. Montague, Manager of Biological Sciences Research Operations and External Funding for Monsanto Company, which is headquartered in St. Louis, Missouri. It is a privilege to address the subcommittee this morning

Introduction to Monsanto Company

I would like to begin by describing the Company which I represent Monsanto is a U. S -based multinational company engaged in researching, manufacturing and marketing a widely diversified line of products, including chemical and agricultural products, pharmaceuticals, low-calorie sweeteners, industrial process controls, man-made fibers and plastics. These products are made possible because of intensive research in both the discovery and development arenas. Thus, Monsanto is a science-driven Company. Science allows us to derive the technology--the know-how-- which adds value to the raw materials we use to produce our products.

Because science and technology are so essential to our existence, it is absolutely vital that we attract and hire the best scientific and engineering talent available Indeed, we must attract a large number of scientists and engineers from many different disciplines. Monsanto currently employs approximately 4,000 technical people. Roughly one employee in twelve is a scientist or engineer. Their expertise covers a wide range of disciplines, including many different areas of chemistry, biochemistry, molecular biology, plant science, animal scienc , etc. The difference between our success and failure in the vast international marketplace rests with the quality of scientific talent that we have in our Company. Therefore, the quality of training and the number of scientists and engineers produced in the United States is of serious concern to us.

Current Status of Recruiting

Over the past ten years, Monsanto has undergone significant restructuring. We have moved away from low value-added commodity chemical businesses and into high value-added specialty chemicals and into products derived using life science-based technologies. Biotechnology has become a major thrust within the Company to produce products for human health care (including pharmaceuticals), for the improvement of animal growth and nutrition (including animal growth factors), and for the improvement of crop productivity (including genetically engineered crop plants with resistance to viral diseases and insects). This new emphasis on the life sciences has necessitated considerable recruitment of scientists in these disciplines. We have been quite successful at recruiting excellent talent, as demonstrated by the considerable progress we have made toward the commercialization of a multiplicity of new products.

Future Availability of Scientific Talent

Current trends strongly indicate that it will be far more difficult to recruit top-notch scientific talent in the future These trends suggest that Monsanto and other U.S.-based companies will have to develop new strategies to find and attract the scientists and engineers who are so vital to our businesses.

Some of the trends that portend greater difficulty with recruiting include the following:

(1) There is a decline in the percentage of U. S. born white males entering science and engineering as a career. This may be due to a decline in the regard with which science and engineering are held by the American public. This trend may also be due to the fact that science is considered difficult, not well-compensated, and

therefore unattractive as a career, especially as compared with law or finance.

(2) There is a continuing decline in the percentage of white males entering the total workforce. Only 15 percent of new workers entering the labor force over the next 13 years will be white males, compared to 47 percent today. Because the majority of scientists and engineers have come from the ranks of white males, this is a particularly disturbing trend.

(3) Minorities, women, and foreign nationals will make up more than five-sixths of the net additions to the workforce by the year 2000. At present, these three groups make up only about half the workforce. Traditionally, women and blacks have been under-represented in the technical areas. According to the Council on Research and Technology, women make up 51 percent of the American population, but only 11 percent of the scientific and engineering work force. Only one percent of the doctorates in science and engineering are earned by black Americans.

(4) Foreign students who received their secondary education elsewhere are accounting for a large share of science, mathematics and engineering doctorates awarded each year by American universities.

(5) There appears to be a decline in the technological literacy and general academic preparedness of the U.S.-based workforce. According to a 1987 National Science Teachers Association survey, of the nation's 16,000 high schools, more than 7,000 offer no physics courses, 4,200 no chemistry and 1,900 no biology. The number of undergraduate science majors has fallen by half since 1960, and in another ten years, the number will have dwindled even further. A 1987 National Research Institute study showed that more than 90 percent of U. S. adults are technologically illiterate. In short, they have no background whatsoever in physics, chemistry, biology, or even middle-level mathematics.

The impact of these demographic trends is likely to include the following

(1) The future work environment will require highly skilled labor but the future workforce, if present trends continue, will actually be less skilled than today's labor pool.

(2) Clearly, the numbers of white males will no longer be sufficient to meet the U S. demand for scientifically and technically trained employees.

(3) Significant labor force shortages will exist in the future--especially in science, technology, and engineering-related fields

(4) The shrinking numbers of young people, the rapid pace of industrial change, and the ever-rising skill requirements of the emerging economy make the task of fully utilizing women and minority workers particularly urgent between now and the year 2000.

(5) In addition to the full utilization of women and minorities, industry will be forced to look for high-level scientific and technical talent in foreign nationals and possibly even actively recruit abroad for key talent. The disadvantage of such a strategy is apparent, however, in that trained foreign nationals cannot be spared by their home countries.

(6) There is a substantial risk that the U.S. will decline as a world power because of a loss of scientific and technological leadership. Given the fact that our standard of living, even our very survival, is dependent upon advanced technology, this is one of the most critical issues facing our country today.

Action Plan for U.S.-Based Companies

U S -based companies will have to become more aggressive in recruiting the best talent, especially in the business, scientific and technical areas. They will be forced to develop even more directed, more effective recruitment programs by working closely with university departments to identify top-nutch talent early on and follow those individuals through their undergraduate and graduate careers. In some cases, financial support will be essential. Financial support alone is rarely enough, however. University students must be made aware of the opportunities and challenges that science-driven companies have to offer.

These steps will be particularly urgent with regard to the recruitment of women and minorities. Industry must find better ways to encourage the entry of women and minorities into scientific and technical careers. One program that Monsanto is involved with is called *Inroads*. This program effectively places minority undergraduate students who possess intellectual ability, scientific aptitude and an interest in pursuing science as a career in our laboratories during the summer. They gain exposure to actual scientific research and begin to experience the intellectual and aesthetic thrill of discovery. Moreover, they learn about the discovery and development of products first hand. This not only provides these students with information about the scientific world, but it also increases their self-esteem and self-confidence.

Another area for the activity of U.S.-based companies is in the support of education For example, scientists from Monsanto Company have worked with high school biology teachers to develop a curriculum unit on biotechnology. Thus, the latest findings in this exciting new technology have been made available to high school science teachers and through them, to their students, some of whom will become future scientists and engineers These kinds of programs are important if we are to counter the trend toward ever greater scientific and technological illiteracy in the U.S.

On yet another front, Monsanto has formed a partnership with The University of Missouri--St. Louis and the St. Louis area public schools. This partnership is called the *Bridge Program* . Its goals are designed to raise levels of skill and interest among disadvantaged students in the public schools, to increase the numbers of these students who go on to college and to motivate them to pursue careers in mathematics, science and technological fields. Monsanto contributed $500,000 to this program

In other areas, Monsanto offers financial support to a range of projects. We support the Science Fair, various workshops for science teachers, the development of novel exhibits for the St Louis Science Center, the purchase of desk-top personal computers for the St Louis public schools, as well as special public lectures on science for the non-scientist.

It may be especially important to reach students at the elementary level Monsanto supports the development of new curricula at this level. We also help to expose elementary students to our facilities by inviting them for presentations. In addition, our scientists often go out to make presentations to science classes throughout the St. Louis area. They also act as mentors to help students develop suitable science fair projects. It is probably at the elementary level that we would have the most impact in inviting females and minorities to consider science as an interest and potential career direction.

Corporations will have to develop programs which address the special needs of women employees who often have dual or triple roles at work and at home. Daycare and eldercare provisions are a minimum. In addition, special programs for the continuing education of older employees will be essential because it is likely that their services will become more and more important with the decline in the number of younger entrants into the workforce.

Changes in Public Attitudes and Policies

But companies cannot resolve these issues by themselves. Everyone has a vested interest in finding solutions to the pressing problem of developing scientific and engineering talent and indeed to the problem of obtaining a more highly educated general population. The threat posed by this issue to our standard of living and the defense of our way of life should not be underestimated. As never before, the U. S. must compete in a truly international marketplace of products and ideas. We simply cannot afford to become a second rate nation.

Some of the changes which must occur to address this issue include the following:

(1) The public must be helped to understand that science and technology are the driving forces of our civilization. Science is essential if we are to maintain our high standard of living, as well as the freedoms that we cherish. We must continually push forward with the development of new technologies.

(2, The choice of science or engineering as a career must be seen as at least as prestigious as medicine, law finance.

(3) The government must foster science and science education at a higher financial level than in the recent past. In addition, governmental agencies must regulate the products of technology with laws based upon good science, verifiable data and accurate interpretations and not on emotional, irrational or anti-technological arguments. Government must take an active role in advocating technology and technological development, helping the public to derive accurate risk/benefit assessments.

(4) We must find new ways to encourage the entry of women and minorities into technical careers. Science careers must be considered to be a viable option for anyone with the ability and interest, regardless of race or gender.

Companies like Monsanto are committed to success in the international marketplace. The achievement of such long-term success is an enormous challenge, given the intense competition from abroad. For science-driven companies, the quality of the technical labor pool is critical. We are committed to the development of novel strategies for recruiting the best of those who are trained in our universities, regardless of race or gender. Moreover, we are committed to doing our part to help to fill the pipeline with those who might never before have considered a career in science

Mr. WILLIAMS. Thank you very much.

Dr. Richard Hope is with MIT, the Massachusetts Institute of Technology at Cambridge. He is Executive Director of Quality Education for Minorities Project. Dr. Hope, it is nice to have you with us.

STATEMENT OF DR. RICHARD O. HOPE, EXECUTIVE DIRECTOR, QUALITY EDUCATION FOR MINORITIES PROJECT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS

Dr. HOPE. Thank you very much.

Mr. Chairman, Mr. Coleman, I appreciate the opportunity to appear before you today to discuss ways of improving math, engineering, and science education for minority students. I'm going to talk very briefly about the role of minorities in meeting our nation's need for scientists and engineers, and describe the Quality Education for Minorities Project, which I direct. I will share with you some examples of successful programs working to increase the number of minorities in the math and science fields, and conclude with brief recommendations.

I will submit this report, of course, and as usual, MIT presented the thickest report, I see, for which I apologize.

The background data I think are clear, in fact, Mr. Chairman, as you well articulated, the problems of science today. We are suggesting that the answer to this challenge, quite simply, must come from America's minority populations, in part. Demographers tells us that the college age population will decline in the 1990's, exactly at the moment when we need more college trained scientists and engineers. The nation is beginning to comprehend that the vast untapped potential of minority students lies not as a threat to greatness, but as the best hope for America's revival.

Demographic trends are changing the face of America. Right now, more than 20 percent of the citizens in our nation are non-white. By the best estimates indicated, by about the year 2020, one-third of the nation will be American Indians, Asian, Black, and Hispanic.

The Quality Education for Minority Project was founded on the goal to develop an action plan, due for release late this year, to improve minority education along the entire length of the educational pipeline. The action plan will be aimed specifically at improving the education of our nation's educationally under-represented minority populations.

Mr. Ray Marshall chairs our advisory council, a council including such members as Senator Edward Kennedy and Senator Jeff Bingaman.

We have conducted nine hearings around the country with parents, teachers, students, directors of various types of intervention programs, with minority leaders around the country, and there have been a series of basic principles that we are receiving from these hearings that will serve as, in part, the basis for these recommendations.

One of the most obvious is that we must be early. We believe this is a pipeline issue and that we must, to look at the number of

Ph.D.'s, we literally have to look at the number of youngsters going into kindergarten and what is happening to those youngsters.

Secondly, we must mobilize the resources available from minority communities themselves. There are considerable resources in the communities that can serve as support to this educational enterprise.

Third, we must restructure educational systems at all levels, including higher education, to promote, rather than to discourage minority students.

Fourth, we must make the curriculum more responsive to the needs of minority students. For example, eliminating systems of tracking.

The best teachers should be available in those communities where there is the greatest need.

Sixth, we must improve what we call the total learning system. There is a concept of the urban school, that the urban school has to be more than a school itself. Schools must stand for the absent parent, the substitute for welfare departments, work with teen-age parents, deal with drug and sexual problems, and provide afternoon and daycare centers.

Finally we must improve school-to-work, "second chance" programs.

The National Science Foundation just completed a study which indicated that youngsters, in fact, could produce very effectively, and that minorities can attain high levels of achievement, and in fact are superior to their white counterparts, if given certain kinds of situations: one, where they find the study of the math, science and engineering enjoyable, as was indicated; two, they are enrolled in colleges that provide a range of programs and services designed to assist the youngsters; three, they participate during high school and after school in math and science programs; and four, that they had an opportunity to meet and even work with scientists. We find that mentoring, and their ability to meet with scientists and see the reality of that rather profound.

Lessons of this type of study are very simple but profound. When talented minority students are exposed to science role models, when they are properly prepared so that they can handle college level courses, when they have an opportunity to actually do science on a first hand basis.

In short, when they have the opportunities that their more affluent peers have, then they are quite likely to become scientists and engineers.

There are three recommendations I would like to mention very briefly. One, we would like to join with others who undoubtedly will urge you to increase financial support available to minority students, both as undergraduate and graduate students.

Secondly, I urge you to establish an incentive program to facilitate linkage between higher education and other schools. This includes such summer programs, in-service programs, camp programs, mentoring programs, et cetera.

Finally, we would like to urge that you closely consider the concept of residential academies for minority students of exceptional promise as a way of extending linkage between higher education and students at the pre-college level.

Our action plan will also propose a similar model, but one aimed at minority students, grades seven through twelve, from a mix of backgrounds and achievements.

We will seek to provide minority students the same quality high structured learning environment as available for more affluent youngsters.

Thank you very much.

[The prepared statement of Dr. Richard O. Hope follows:]

Draft April 27, 1989

Testimony by Dr. Richard O. Hope
Executive Director
Quality Education for Minorities Project

before the U.S. House Education and Labor Subcommittee on Post-Secondary Education

Kansas City, MO
May 1, 1989

Mr. Chairman and members of the subcommittee, I appreciate deeply the opportunity to appear here before you today to discuss ways of improving mathematics, engineering, and science education for minority students. I'm going to talk very briefly about the role of minorities in meeting our nation's need for scientists and engineers, and describe the Quality Education for Minorities Project which I direct. I will share with you some examples of successful programs working to increase the number of minorities in the mathematics and science fields, and conclude with a few recommendations for your consideration. I will also submit for the record a longer version of my remarks, which will contain somewhat more detail about each of these points.

Context

In a world of increasing international economic competition, the overall decline in the quality and interest of America's students in the mathematics, science, and engineering fields presents a frightening omen for our future. The economists tell us that we stand at an economic crossroads of momentous importance. To compete in the world economy, we can take the path of increasing our productivity, which leads to a higher standard of living and greater well-being, or we can take the path that results in lowered real wages and a standard of living we presently associate with third world nations. The preliminary evidence is disheartening: a widening gap in income in which over the last decade the poorest fifth of American families became eight percent poorer and the richest fifth became 13 percent richer; a decline in real earnings of unskilled workers; and a 23 percent increase in the working poor, who are increasingly finding their wages inadequate to maintain living conditions that most of us would find acceptable. It seems clear that we have already taken a first few steps down the path that leads to economic decay, social disintegration, and possibly political turmoil.

The alternative path, which leads us to increase our productivity to compete with other nations, depends to a great extent on the way we nurture and harvest our human resources. Unfortunately, the evidence from our schools and colleges is nearly as disheartening as the figures cited above. In 1987, according to the Committee for Economic Development, one million young people left high school without graduating, and most were essentially unemployable, deficient in the most basic skills needed in today's economy. Another 700,000 received their diplomas but were hardly more skilled than the dropouts. Indeed, fewer than 50 percent of that year's high school seniors read well enough to master moderately complex tasks, an a majority were unable to write adequately. CED estimates that each year's class of dropouts costs this nation $240 billion in lost earnings and forgone taxes over their lifetimes.

Focusing on science education, the news is perhaps even more dismaying. A recent NSF international comparison of mathematics and science skills among 13-year-olds in 6 nations shows American youngsters at the bottom, with Korean children scoring four times better than their American counterparts. A 1986 survey of fifth graders showed that our best science and mathematics students scored below the average Japanese student. A recent National Assessment of Education Progress test shows that half of American 17-year-olds cannot handle junior high level mathematics problems, and only 7 percent were ready for college science courses. The number of qualified mathematics and science teachers has been declining in the last decade, and a recent RAND Corporation study suggests that traditional teacher education programs will supply less than half of the 60,000 mathematics and science teachers we will need between now and 1992. An NSF study estimates that of the 4 million students who were sophomores in high school in 1977, less than 10,000 -- just 0.2 percent -- will earn doctorates in mathematics science, or engineering.

The gloomy news goes on, but the result of the mathematics and science education crisis is best foretold in the NSF estimates indicating that by the year 2000, there will be 45,000 fewer students with mathematics and science bachelor's degrees than we will need to maintain our present economic status, and by the year 2010, there will be 700,000 fewer workers with baccalaureates than needed to fill existing jobs. This is a challenge of the first order, and one in which America simply cannot afford to waste any of her precious human resources.

Demographic Changes

The answer to this challenge, quite simply, must come from America's minority population. Demographers tell us that the college-age population will decline in the 1990s, at exactly the moment when we need more college-trained scientists and engineers, as well as doctors, social workers, teachers, and policymakers. Minority students can fill that gap, and indeed, must fill that gap. At a time when our technological supremacy is under challenge from abroad, and when we are facing a massive shortage of engineers and scientists the nation is beginning to comprehend that the vast untapped potential of minority students lies not as a threat to greatness, but as the best hope for America's revival.

Demographic trends are changing the face of America. Right now, more than twenty percent of the citizens of our nation are non-White, and the best estimates indicate that by about the year 2020, one-third of our nation will be American Indian, Asian, Black, or Hispanic (Figure 1). This will occur not because of a decline in the majority White population, but because of a much faster growth rate among minority groups, as well as immigration. From 1985 to 2000, for example, the White population is expected to increase by less than 7 percent, while the Black and Hispanic population will increase by 23 and 46 percent (Figure 2). These figures remind us that if we take the world view that the modern international economy compels, then what we call "minority" peoples in America are, in fact, the majority population on this planet.

These enormous demographic changes in the United States have implications for all segments of our society, but nowhere will they be more immediate, more evident, and more important, than in education. Indeed, in our nation's schools, the future has arrived: right now, some thirty rcent of all kindergartners minority, and by the year 2000, a third of all public school students will be non-White (Figure 3).

Of course, the distribution of these students is far from even. The greatest concentration of minority students takes place in our urban centers, and in the West and Southwest. Today, minority students are in the majority in 23 of our 25 largest central city school districts, in the states of California, Mississippi, and New Mexico, and nearly so in Texas. In another 25 states, minority students make up more than 25 percent of the public school population. (Figure 4)

The question that we must answer is complex, but the implications are stark: Will these schools inspire and teach our non-White children to be the next generation of engineers, scientists, scholars, doctors, and policymakers that the nation needs so badly, or will schools continue to be so alienating and frustrating to minority youngsters that we end up squandering another generation of minority talent?

The urgency of this question was illustrated in the landmark study by the Hudson Institute, Workforce 2000. There we learned that by the end of this century, one in six members of the U.S. workforce will be minority, and that 30 percent of all new workers between now and then will be minority (Figure 5). There we also learned that these new workers will not only require better education in schools, but in college as well, for in the year 2000 half of all jobs will require some college, and 30 percent will require a bachelor's degree (Figure 6). Minority students will need better and more education than ever before.

Unfortunately for minority students, progress has been excruciatingly slow. Schools must cope with the severe damage to some minority families caused by poverty and the legacy of racism. Last year, approximately 43 percent of Black children and 40 percent of Hispanic children lived in poverty. Unwed mothers, half of whom were teenagers, bore 75 percent of the Black children born in 1986. Over half of all Black children and 30 percent of all Hispanic children live in single-family homes. As a result of these factors, as well as the lack of resources, the low expectations, and the often-deficient curricula we find in many urban schools, minority youngsters typically test six months or more below grade level in all areas by the third grade, reaching two years or more below grade level by the 7th grade. While there have been some improvements, high school dropout rates continue to be extremely high: 35 percent of all Black and 45 percent of all Hispanic 18- and 19-year-olds drop out of school (Figure 7). A study of 1980 high school graduates showed that six years later, White students had earned bachelor's degrees at twice the rate of Black students and three times the rate of Hispanic students (Figure 8).

Currently, about 18 percent of all students in higher education are non-White (Figure 9), with nearly half of all minority students in the two-year colleges (Figure 10). While estimates are difficult to obtain, it appears that fewer than 15 percent of minority students in community colleges successfully transfer to a four-year institution, and less than ten percent go on to earn bachelor's degrees. If one compares college enrollment figures with degree attainment numbers, it becomes clear that there are high levels of attrition in higher education for minority students, especially Blacks, as we proceed through the undergraduate and graduate levels (Figure 11a-f).

It is important to remember that we are not just losing students as we proceed through the educational pipeline: we are losing scientists, engineers, mathematicians, and science teachers. This particular loss is not limited to minority students. Increasingly, White students are showing a disinterest in pursuing graduate studies, especially in the mathematics, science, and engineering fields.

Much of this loss has been made up in our universities by intensive outreach to international students, as well as a welcome increase in doctorates awarded to Hispanic, Asian, and Native American students, although this reflects at least in part population growth. This is especially true in the mathematics and science fields, where from 1978 to 1987 Whites earned 300 fewer doctorates (- 3 percent), while Hispanics earned 132 more (+83 percent), Asian-Americans earned 165 more (+ 60 percent), and Native Americans earned 28 more (+ 133 percent). These rates are much higher then the overall growth in doctorates for these groups. (Figures 12 -12e). This happy news is bolstered by a recent NSF study showing that high-ability minority youngsters are more likely to persist in their pursuit of science careers than White youngsters. Unfortunately, these gains are tempered by the disheartening drop in doctorates awarded to Black students, both in science and engineering fields (20 percent) and overall (26 percent -- Figure 13). In 1987, only 765 doctorates were awarded to Black students, including just 2 in computer science, 3 in chemical engineering, five in physics, and none in electrical engineering. Nearly half of all doctorates awarded to Blacks in 1987 were in education (Figure 14).

What I have tried to make clear from this brief overview is that the education of our nation's minority students represents a great challenge to our schools, as well as other social institutions, but these youngsters also represent our best hope for the future. While we must proceed with efforts to increase the number of White students entering mathematics and science fields, the needs are so great that our economic security can only be ensured by providing minority students the opportunity and preparation needed to consider, enter, and succeed in a science, mathematics, and engineering career.

The Quality Education for Minorit' Project

It was with these pressing issues in mind that a unique partnership was formed in 1987 by the Carnegie Corporation of New York, the Massachusetts Institute of Technology, and the University of Texas at Austin. The Quality Education for Minorities Project founded with the goal of developing an Action Plan, due for release late this year, to improve minority education along the entire length the educational pipeline. The Action Plan will be aimed specifically at improving the education of our nation's educationally underrepresented minority populations: Alaskan Natives, American Indians, Blacks, Mexican-Americans, and Puerto Ricans.

The project is based at MIT, with a small staff supplemented by researchers based at the University of Texas at Austin. UT Austin is the home institution of Dr. Ray Marshall, the chairman of our national advisory group, the Action Council for Minority Education, which includes Representative Ben Nighthorse Campbell and Senators Edward Kennedy and Jeff Bingaman. We also established a Resource Group of 16 educators to work most directly with staff in the development of the plan. The Resource Group is directed by Dr. Shirley McBay, the Dean for Student Affairs at MIT and QEM Project Director.

It seems to me that ther are five aspects of our effort that will provide a unique and important perspective to the ongoing education reform process:

First and most importantly, the QEM Action Plan will be prepared for minority students and communities and under minority leadership. Most of the other education reform reports, and many of the actions they have inspired, have tended to overlooked the needs of minority students. We and the Carnegie Corporation felt that the time had come for minority educators to present our sense of what needs to be done for minority students.

And I don't mean just Black students or just Latino students. While the needs and circumstances vary greatly among each of the groups with which we are concerned, they share common goals: to have control over the education of our children, to eliminate our present two-tier system of education and provide educational equity for all, and to inspire a sense of self-worth and pride in our children while enabling them to succeed in the majority culture. Our report will deal with the needs of all underrepresented minorities in our schools.

Second, we are viewing the problem from what we call the pipeline perspective. That is, we recognize that it is impossible to effect real improvements unless we take a comprehensive approach and eliminate barriers along the entire educational pipeline, from pre-school to post-graduate levels.

If we want more minority Ph.D.s or college graduates, if we want more minority doctors and lawyers and business executives, if we want more minority teachers and social workers, we must start at the beginning of the pipeline and make changes along its entire length. Only a comprehensive approach to reform can seal all of the leaks and remove all of the barriers.

Many groups have focused on pieces of the problem, but few, if any, have taken a comprehensive approach to quality education for minorities.

Third, our strategy is to focus on what we know works. While there are no magic bullets and no simple formulas for success, there are teachers that teach and students who excel despite even the greatest odds. We have traveled the nation learning from programs that help minority children succeed in school, and we intend to base our recommendations whenever possible on such examples.

Fourth, we recognize that while such programs are important, and that we need to expand the ones that work, we must not ignore the fundamental and systemic changes necessary to the overall educational system. So we will be calling for a variety of institutional changes along the pipeline, from the way that schools and colleges are accredited to the way that teachers are tested to the way that students are tracked, to provide the same basic opportunities for minorities that are available to majority students.

Finally at the conclusion of the planning process, that is, after we release the Action Plan at the end of 1989, we plan to relocate the project, most likely in Washington, D.C., and to establish a nonprofit organization there to implement the

strategies we are recommending. One of the specific steps we intend to take is to set up demonstration projects in five to six locations around the country, including both urban and rural areas, where we will focus on two critical areas: the production of more minority teachers and university faculty and the development of residential academies that can provide the kind of educational opportunities for minority students that are presently available only to the wealthy.

We will also have a strong research arm, we hope to provide evaluation services to existing intervention strategies, and if possible we hope to provide funding for such existing programs.

Over the past year, we have been traveling the nation seeking the advice of educators, policymakers, minority leaders, parents, and students about ways to improve education for minority students. Out of nine regional meetings with more than 350 presenters, dozens of individual meetings, and through many, many letters and telephone calls, a growing consensus is developing about what needs to be done. While the specifics are sometimes controversial, the principles seem clear. I'd like to share seven such principles with you now.

The first and most obvious principle is that whatever intervention steps are taken they must begin early. Early intervention in nutrition, parent education, day care, and preschool education is essential. It has lasting effect, and, as the Committee on Economic Development demonstrated, is extremely cost-effective. Each dollar invested in prenatal care, for example, saves about $3.38 in the cost of care for low birthweight babies. Each dollar spent on preschool education, they estimate, saves about $4.75 in the cost of special education, public assistance, or future crime.

Too many minority youth begin school behind, lacking the health and nutrition l care and achievem t skills enjoyed by their more affluent peers The evidence from programs such as Head Start shows that early childhood education plays an enormous role in academic development in later years. It may not be an exaggeration to say that potential minority ph D.s are lost for lack of a pre-school education.

We believe that, therefore, that early childhood nutrition and education programs such as WIC and Head Start must be fully funded. We must provide day care, with a significant child development component, to low-income parents. And we must provide parent training and support, building the roots for home-school part rships.

Second, we must mobilize the resources available from minority communities themselves. The exodus of middle-income minority families from the inner cities, the departure of minority professionals and shop-owners and teachers, the less visible role of the black church, and to some degree, the very success of integration, at least for some, have all served to dissipate the community institutions and networks that formerly served as informal safety nets for children from the poorest circumstances Where minority children are succeeding in school, one almost always finds support and participation from parents, local business, and local community organizations.

Recognizing the shared responsibility of all, we must work to increase family and community involvement in education. Minority leaders must work to revitalize such networks, especially in the areas most devastated by poverty, substance abuse, and crime.

Third, we must restructure educational systems at all levels, including higher education, to promote, rather than discourage the education of minority students. To achieve this goal, we must introduce a great deal more flexibility, decentralization, and most importantly, accountability into the system. Schools, principals, and teachers should have the authority and resources to respond to the unique needs of the students they serve, but at the same time, should be accountable for results That includes the ability to promote and fire based upon the impact educators have upon our children The need for better accountability is illustrated in its extreme by the New York elementary school principal who suffered from emotional and substance abuse problems for years without serious sanction from the school board until he was arrested for possession of crack. But in a more subtle sense, lack of accountability allows teachers to remain in the classroom or on the college campus, poisoning youngsters with racism low expectations, or lack of vision about the potential of minority youth.

Just as we must restructure the system to provide incentives for teachers, we must restructure the system to provide incentives for students It should be clear to students from an early age that education can pay off, either through employment or through an affordable college education In 1984, 30 percent of the students at historically black colleges and universities who received federal aid came from families with incomes below $6,000 annually These are the truly neediest of the truly needy. But instead of providing the financial support they need to stay in school and reverse the cycle of poverty, we ask them to take on a loan burden bigger than their family's annual income. No wonder that the dream of college seems hardly worth the effort to some children. And when the only jobs a child can imagine is flipping hurgers at MacDonald's or Wendy's, the incentive to learn calculus is greatly weakened. Programs that offer tuition guarantees, such as New York's Liberty Scholarships or Eugene Lang's "I Have a Dream Foundation," can help youngsters understand the payoff for their efforts. Programs that offer youngsters a chance to participate in the world of work, such as California's Partnership Academies, in which students are guaranteed work by local businesses when they graduate, can help show that their learning has meaning in the real world.

Fourth, we must make the curricula -- what we teach, as well as how we teach it -- more responsive to the needs of minority students. and we should begin by eliminating tracking that steers children as young as ages 6 and 7 irreversibly away from academic pursuits. Research shows that heterogenous classrooms, along with nontraditional teaching techniques such as cooperative learning, grade clustering, and peer tutoring can reach students we now wri off academically.

We need to expand the amount of schooling we provide to our children, especially to minority children. We will propose that 11-month school years be mandatory every third year, providing time for students to catch up if they are behind or to enrich their present knowledge if they are not.

We must give teachers more flexibility to use texts, lesson plans, and other resources that are better able to instill a sense of pride and self-esteem in the children in their classroom.

We must give all children, and especially minority children, the chance to learn the same kinds of higher order skills -- and by that I mean the ability to frame and solve problems, to use knowledge, to communicate effectively, to think critically -- as most of their more affluent peers in the suburbs are learning. Such skills are now critical to opening doors for students who want to go on into technological or scientific careers, but experts tell us that in the future all workers will need these higher order skills More to the point, as Ted Sizer of the Coalition of Essential Schools tells us, "A good education for the least is a good education for the best A good education for those that have not much is a good education for those to whom great advantage has been given, and a high quality education for minorities is a high quality education for all." At Coalition schools, and at successful schools in other places, educators are developing a set of core skills that all children -- and not just the elite -- will learn in the humanities and in the sciences. I would like to be clear that to us, that core knowledge must include an understanding and appreciation of a multi-cultural, multi-lingual society.

We must revise the way we test knowledge, so that we can learn not whether students are good at taking tests, but rather whether they are actually able to use the material they are learning Our tests must be used to cultivate, and not to weed

And given the threat to minority children from malnutrition, drug or alcohol abuse, and pregnancy, we must incorporate health education materials into the curricula beginning as early as grade three We must abolish the mandatory use of federal categorical funds to create special "pull-out" courses that label children as failures As proposed in the recent report from the National Center for Education and the Economy, schools should have the option of using those dollars in more flexible ways that keep children together, rather than separate them.

We must have in place a bilingual education policy that builds upon the student's first language to achieve proficiency in both that language as well as in English, and promotes the learning of a second language for all students. When possible, content classes should be available in a student's first language until English proficiency is reached

Fifth, the best teachers should be available to those who need them the most and we should improve preparation for all teachers. All too often, it is the least experienced teachers who are assigned to the lowest-achieving schools. Through financial and administrative incentives, we must recruit the best teachers to the toughest schools We must redouble our efforts to recruit more minority teachers, including college loan forgiveness, and lateral entry from business, government, and the military.

And we must revise radically the way we train teachers, to improve the ability of minority and majority teachers alike to work with a multicultural, multilingual student body

Sixth, we must improve what we call the total learning system. In the words of New York financier and civic leader Felix Rohatyn, "Urban schools have to be more than schools." Schools have to stand in for absent parents, substitute for welfare departments, work with teenage parents, deal with drug and sexual abuse, provide afternoon and evening day care, and undertake a host of other extra-curricular activities that are a far cry from the glee club and track team that occupied schools in bygone days. Schools must take a much more active role in coordinating social services, emulating the most successful models already in place, such as the cities in schools programs. Schools must remain open for much longer hours and provide activities for children as well as some educational programs for their parents. To further improve the total learning system, we must pay much closer attention to informal learning situations, including youth-serving agencies, museums, science centers, civic and community organizations, and churches, as well as summer, after-school, or Saturday learning programs. Such experiences should include enrichment and acceleration activities including hands-on science.

And finally, we must improve school-to-work, "second chance," and on-the-job learning opportunities for minorities. Minorities suffer serious economic problems because of disproportionately high school dropout rates and are less likely than majority students to go to college. The absence of effective school-to-work transition systems is one of the weakest American labor market institutions relative to other countries, as documented in the Grant Commission's <u>The Forgotten Half</u>. Similarly, minorities participate heavily in various "second chance" systems for people with limited education or other labor market problems, and are much less likely than white males to participate in the best on-the-job learning systems.

These seven principles, and the recommendations they inspire, will be the foundation of the Action Plan we will be releasing next December. We certainly would welcome the opportunity to work with all of you and your staffs in the coming months as we flesh out our Plan, and we look forward to sharing copies with you when we release it.

Examples of Successful Mathematics, Science, and Engineering Programs

Earlier, I referred to an NSF study that indicated that high-achieving minority students were more likely to persist in their pursuit of science careers than their White peers. In that fascinating study, they identified several characteristics of these successful students: 1) they find the study of mathematics, science, and engineering enjoyable and rewarding; 2) they enrolled at colleges that provide a range of programs and services designed to ease the transition from high school to college; 3) they participated during high school in after-school mathematics and science clubs, in honors courses, and in science activities; and 4) they had opportunities to meet or even work with scientists and engineers.

The lessons from this study are simple but profound: when talented minority students are exposed to science role models, when they are properly prepared so that they can handle college-level courses, when they have an opportunity actually to do science on a hands-on basis -- in short, when they have the same opportunities that their more affluent White peers may take for granted -- then they are quite likely to become scientists and engineers. When we make the right investment, we get an extremely high payoff from these youngsters.

As I mentioned, we have been traveling the nation over the past year talking with educators, parents, students, community leaders, and policymakers about examples of outstanding programs that promote a quality education for minority youth. Among the many programs we visited our heard about, I'd like to share some examples with you that accomplish ex-‿tly what we just described. I'll skip over two of the most celebrated and successful mathematics and science programs for minority youth, the Mathematics, Engineering, and Science Achievement (MESA) program and the Professional Development Program at UC Berkeley, which I will assume you already know well. and instead desc ibe briefly th : others, beginning with a program sponsored at MIT.

Minority Introduction to Engineering and Science (MITES) Program, Cambridge, MA

MITES is a six-week summer residential program at MIT for 40 minority high school students who have mpleted their junior year. Now in its 15th year, the program's main objective is to introduce highly qualified, disadvantaged minority students to careers in engineering or science. The program has been highly successful in bringing minority students t IT, and more importantly, in keeping them there or at other outstanding universities. In 1986, 16 of the 40 MIT students ent ed MIT in the class of 1991, and virtually all of the others went on to other institutions. More importantly, 92 percent of all MITES alumnae who entered MIT either graduated or are still enrolled.

The MITES curriculum provides students with the practical and analytical skills needed to enhance their senior-year course work and ready them for college work. Rigorous courses in mathematics, physics, biochemistry, humanities, and design are offered by MIT faculty, practicing professionals, graduate students, and high school teachers, with resident tutors available to assist with homework. In addition to their academic coursework and lab work, students take seminars on study skills and time management, meet with top scientists and policymakers, spend one day each week touring industrial or public sector agencies involved in mathematics and science, and meet with campus library, admissions, financial aid, and police representatives to learn more about the college environment.

What MITES represents is an extremely intensive, and quite successful outreach by higher education to minority youth with great potential for success in science and technology. Youngsters are exposed to hands-on science, meet potential role models, and are provided a friendly process for making the transition to higher education -- exactly the elements found to be crucial in the NSF study.

Massachusetts Pre-Engineering Program for Minority Students (MASSPEP) Boston, MA

MASSPEP is a comprehensive program working with more than 650 minority middle and senior high school students, as well as undergraduates, in the Greater Boston area. The program provides students with practical experience in applying mathematics and science skills and concepts through independent science and technical research projects, role models working in engineering and math-science based professions, and academic and technical environments to help them understand what engineers and scientists really do.

For middle school students, MASSPEP provides a summer, as well as a Saturday Science Laboratory, offering the chance to engage in the exploration, planning, design, and "doing" of science and technology. For high school students, MASSPEP offers the In School/After School program, which provides participants the chance to work on independent and group science and technical research projects, provides academic counseling, tutorials, and study skills in mathematics and science, field trips to laboratories and research centers, and the opportunity to meet role models as speakers and mentors. MASSPEP also offers a summer residential program for 40 high school students on a college campus and a summer technical internship program that places students in paid positions with high-tech companies in the Boston area. For college students, MASSPEP offers the Graduate Research Development Program, supported by NASA, that helps prepare minority undergraduates for graduate school through counseling, research skill development, and GRE exam preparation. These students also serve as mentors for MASSPEP high school participants.

A survey of 63 graduates of the high school program showed that 95 percent of them were enrolled in college, with more than half majoring in engineering, science, or pre-med. What MASSPEP illustrates again is the importance of providing research experience and mentoring for minority science students, but it also demonstrates the importance of early exposure to science. The MASSPEP middle school program captures students while they still have a chance to take the courses they need to enter college or pursue a science career. This theme of early intervention is crucial, and is also amply illustrated in my last example, Project C.A.U.S.A.

Comprehensive Activities to Upgrade Science Activities, Rio Piedras, Puerto Rico

Project C.A.U.S.A. is a new program sponsored jointly by the Ana G. Mendez Educational Foundation, which is a private university in Puerto Rico, and the Puerto Rico Department of Education. It is an example of the potential of university/school partnerships in producing young scientists and engineers from even the most adverse economic circumstances.

For the last three years, C.A.U.S.A has provided an intensive Saturday enrichment program for talented, low-income Puerto Rican 9-12th grade students. The courses are offered at three local branches of the Mendez Foundation, where students receive instruction in science, mathematics and English, enjoy laboratory and research experiences, and meet with guidance counselors to help them set and reach personal and career goals. Students continue their enrichment at six-week summer programs, and C.A.U.S.A has established links with mainland universities and sends students to summer programs here. One of the most important elements of C.A.U.S.A is the in-service training it provides high school science teachers in summer institutes, helping prepare them in content areas as well as the development of hands-on enrichment programs for their students.

C.A.U.S.A.'s 260 students have shown extraordinary promise. 95 percent who have entered the program have remained until graduation, and all who have graduated have entered college, with 85 percent majoring in science or engineering. Thirteen have been admitted with full scholarships to major mainland universities. I must share with you the testimony of one young C.A.U.S.A. participant at our own hearing in San Juan, who told us how she, a poor girl from a small town in Puerto Rico, had decided to become an astronaut, thanks to Project C.A.U.S.A.

Recommendations

In closing, I'd like to share with you three brief recommendations for your consideration.

To begin, I'd like to join with others who undoubtedly will urge you to increase the financial support available to minority students both as undergraduates and graduate students. An undergraduate education at MIT will cost ???? next year, and as a result of budget pressures, the self-help level was raised to ???? for the 89-90 academic year. The financial and psychological barrier this can place before a talented young minority student is enormous, and all too often, final. At the graduate level, too many of our potential minority scholars are deflected to the private sector or business school by the prospect of large debt and low salaries. Only about 5 percent of all graduate students now receive federal fellowships and traineeships. Increasing the Pell Grant funding for undergraduates, and a boost in funding in particular for the various NSF and NIH fellowships for minority graduate students would ease the financial burden on students and would also signal a renewed commitment by the federal government to the training and nurturing of minority scientists.

One potential application of graduate funding opportunities is illustrated in a program that we will be proposing in our Action Plan, the National Minority Faculty Development Project. This program will identify potential minority scholars in their junior year of college, and then provide counseling, research opportunities, and support services designed to ease their way into graduate school. The project will be developed in a consortium with major research universities, who will guarantee admission to students meeting the very high standards for retention in the program. These students will receive support, mentoring opportunities, and full scholarships throughout graduate school, with funding derived from the host institution, private, and public sources. The goal as now planned is to produce 8,000 new minority scholars by the end of the century, which, for comparison purposes, would roughly double the number of Black scholars we might expect under current trends. We hope that we can turn to you and other members of Congress for support as we develop the program.

Second, I urge you to establish an incentive program to facilitate linkages between higher education and our schools. As the examples I shared with you earlier illustrate, collaborations between teachers and students at the precollege levels and the faculty, staff, and students of our colleges and universities are among the most powerful tools for change, and are practically essential for success in turning around a troubled school system. We know that science-based university outreach activities work, including summer programs, in-service teacher education, research opportunities, campus orientation programs, and mentoring, and we know that a small amount of federal seed money could go a long way toward establishing such programs at institutions that are poorly endowed, especially those in urban areas.

Finally, I'd like to urge that you closely consider the concept of residential academies for minority students of exceptional promise as a way of extending linkages between higher education and students at the pre-college level. Residential mathematics and science academies for gifted students are currently in place in six states, most notably the North Carolina School of Science and Mathematics, but recent efforts to expand such programs into new locations have faltered due at least in great measure to lack of state funds.

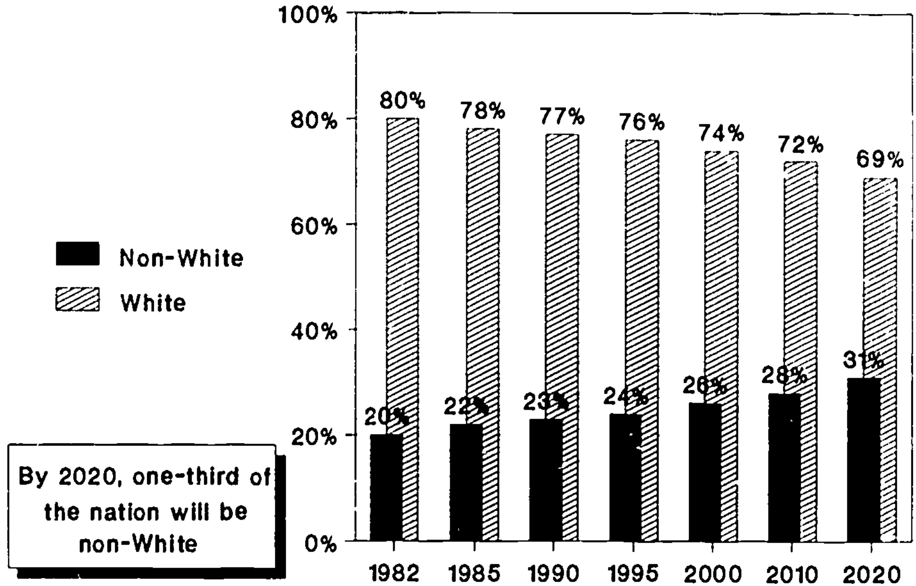
As mentioned earlier, our Action Plan will propose a similar model, but one aimed at minority students, grades 7-12, from a mix of backgrounds and achievements. We will seek to provide to minority students the same high quality, highly structured learning environment now available to affluent, chiefly White students, at our most prestigious private schools. There are four points to be made about such academies: first, they will provide gifted minority students now languishing in inferior schools the opportunity to be challenged and the exposure to a world outside the inner city. Second, they will remove students with talent from destructive home and community environments which may be holding them back, and mix such students with their more affluent minority peers. Third, they will provide apprentisceship opportunities for students that will be of value to those who choose to enter the working world after high school as well as those who go on to college. And finally, they will provide shelters in which effective learning strategies can flourish and develop into models for the larger school systems. We see such academies again being the product of university, school, private sector, and public sector resources, drawing upon the most effective and dedicated talents available to develop a pool of minority scholars, scientists, and teachers who will serve as a beacon of hope and inspiration for their peers.

I urge you to consider ways of assisting in the development and implementation of such academies, as part of a long-term strategy to utilize the enormous human resources contained in the minds of our Black, Hispanic, and American Indian youth.

I thank you for your time and attention, and look forward to working with the subcommittee in the future.

Figure 1

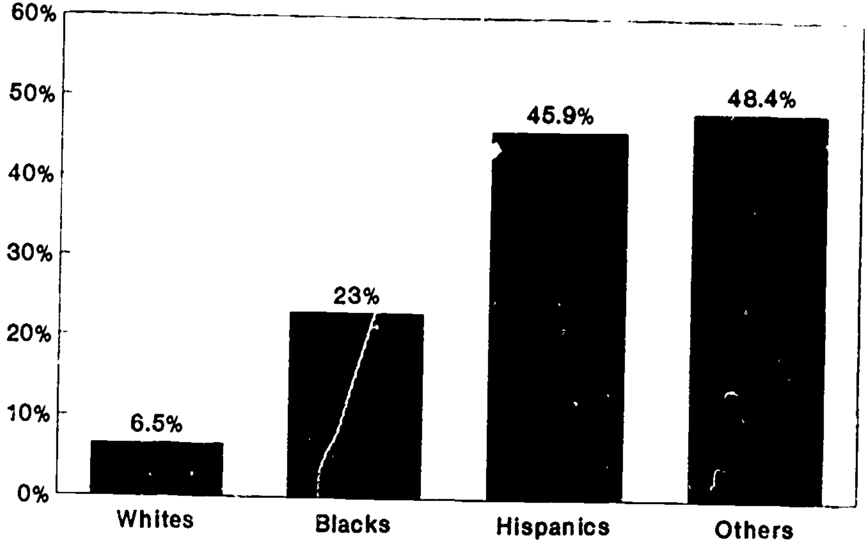
Minority Population Growth



Source: Current Population Reports

Figure 2

Projected Population Increases: 1985-2000

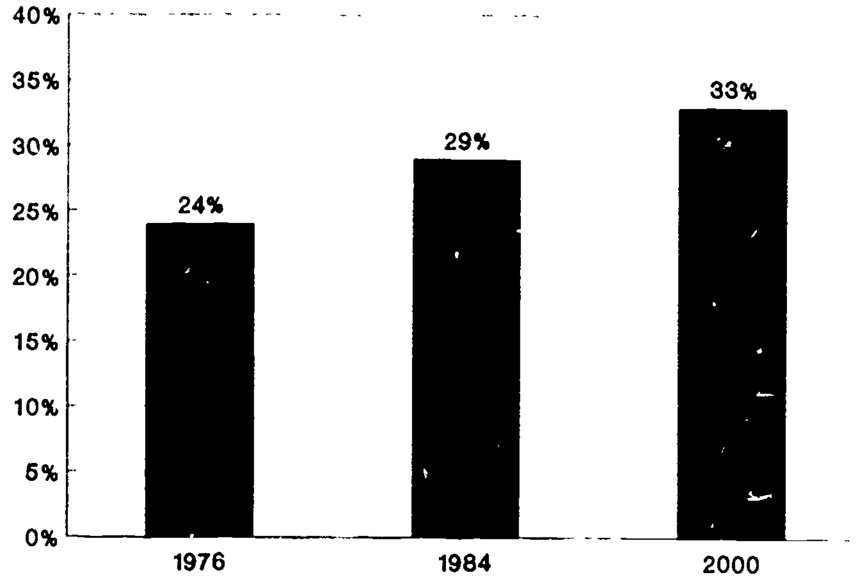


Source: U.S. Census Bureau

100

Figure 3

Minority Students in Public Schools



Sources: <u>The Condition of Education</u>,
<u>All One System</u>

Figure 4

MINORITIES ARE MORE THAN 50% OF THE PUBLIC SCHOOL POPULATION

- in California
- in Mississippi
- in New Mexico
- close in Texas
- in 23 of the largest central city school districts

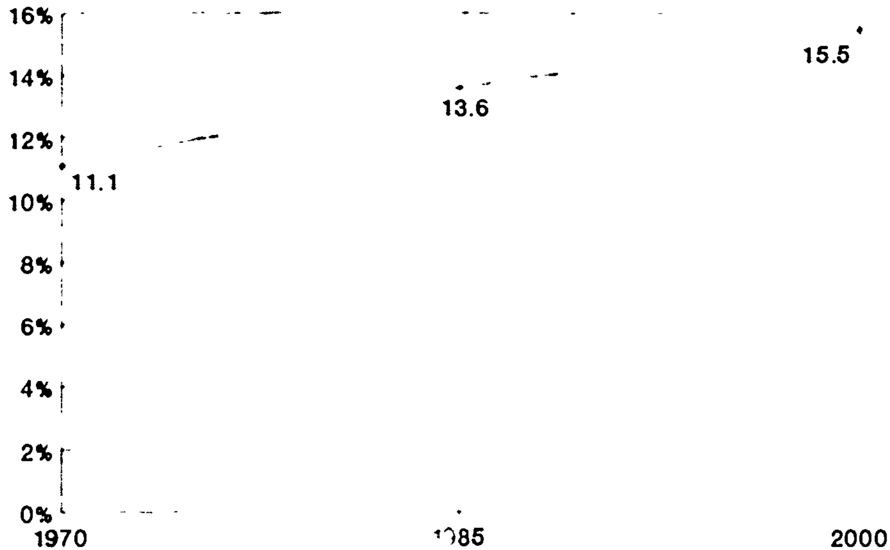
MINORITIES ARE MORE THAN 25% OF THE PUBLIC SCHOOL POPULATIONS

- in 25 States

Figure 5

Changes in the Workforce

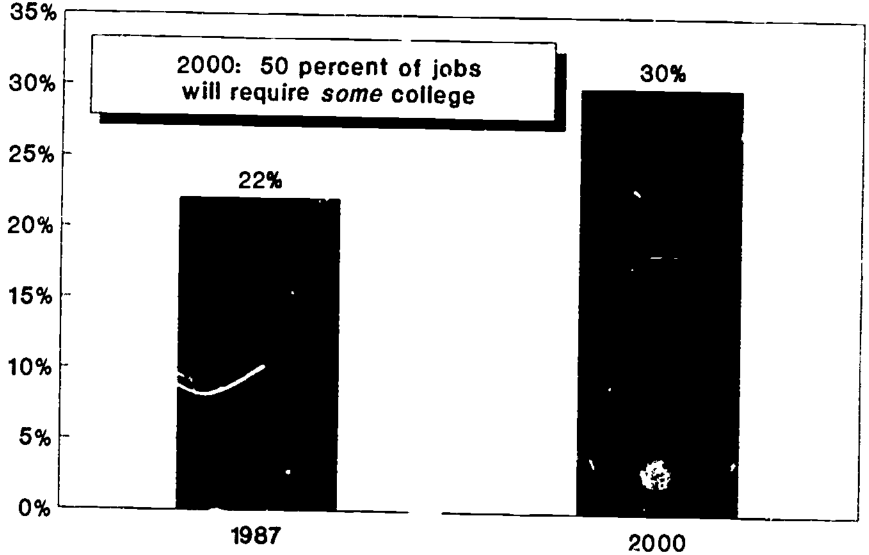
Minority Percentage of U.S. Labor Force



Source. Hudson Institute

Figure 6

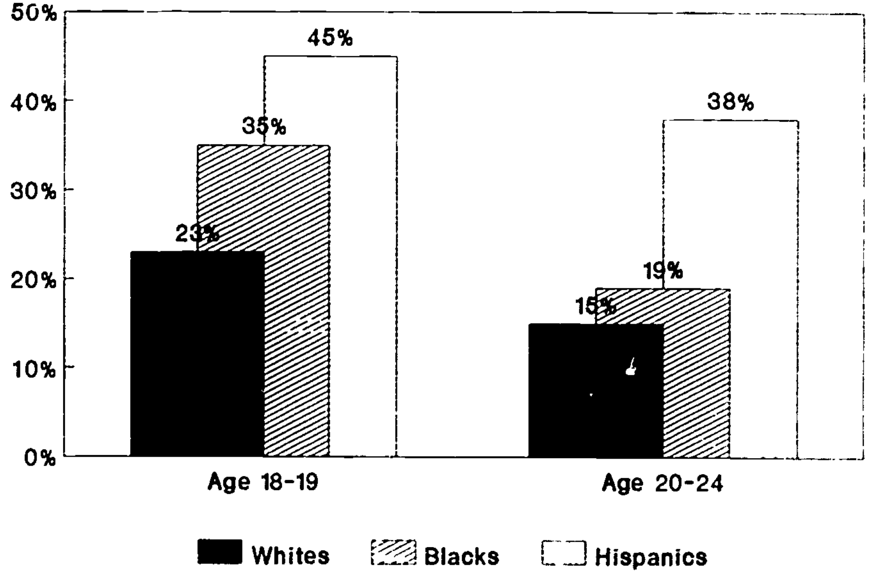
Growing Need for a College Degree
Jobs Requiring a Baccalaureate Degree



Source: Hudson Institute

Figure 7

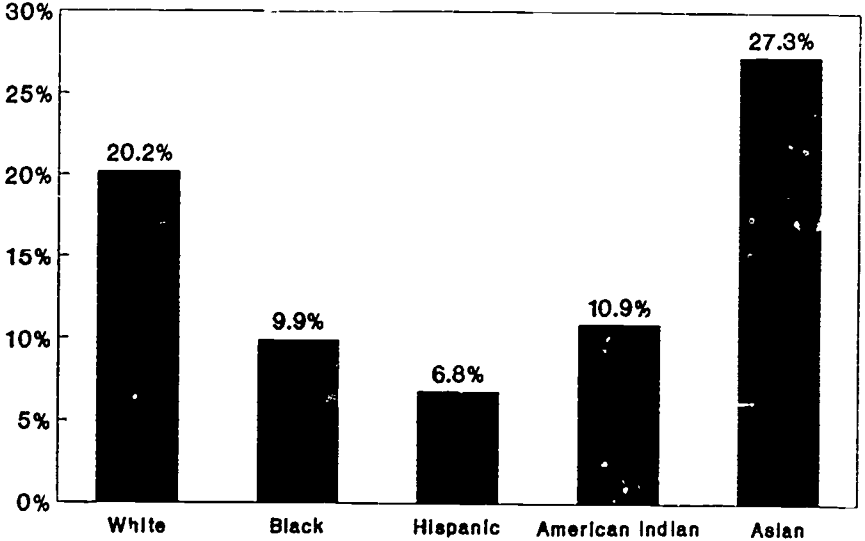
High School Dropout Rates, 1986



Source: The Condition of Education 1988

Figure 8

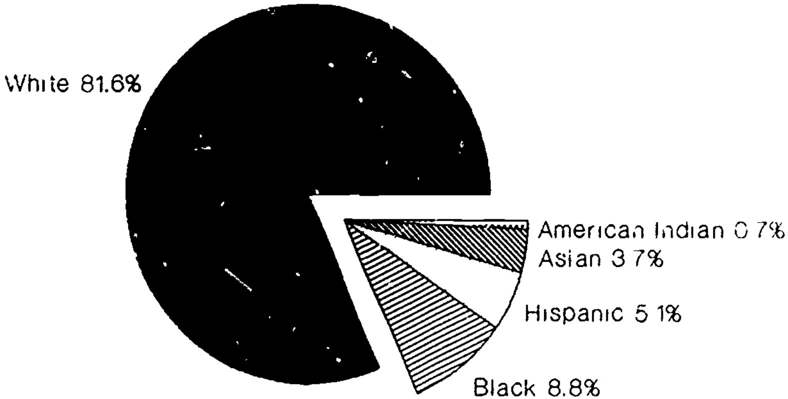
1980 High School Graduates
Percent With Bachelor's Degrees by 1986



Source: High School and Beyond

Figure 9

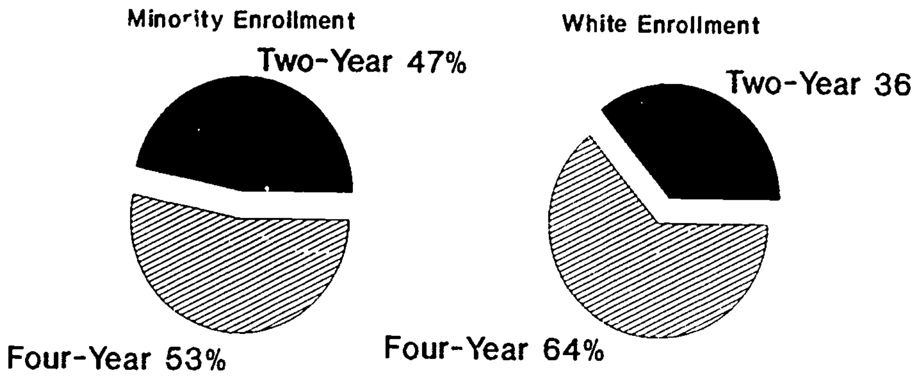
College Enrollment by Race, 1986



Source: Minorities in Higher Education

Figure 10

Enrollment by Type of Institution 1986

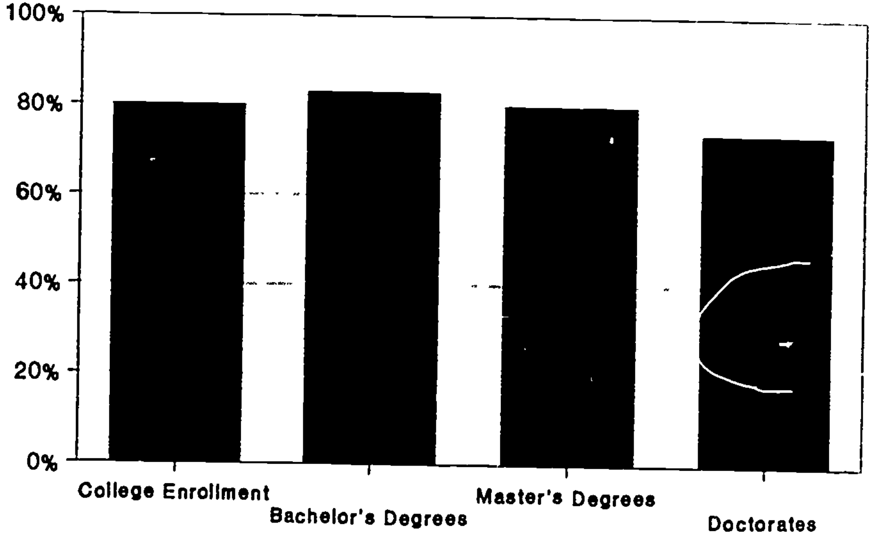


Nearly half of all minority college students are at two-year colleges

Source: Minorities in Higher Education

Figure 11A

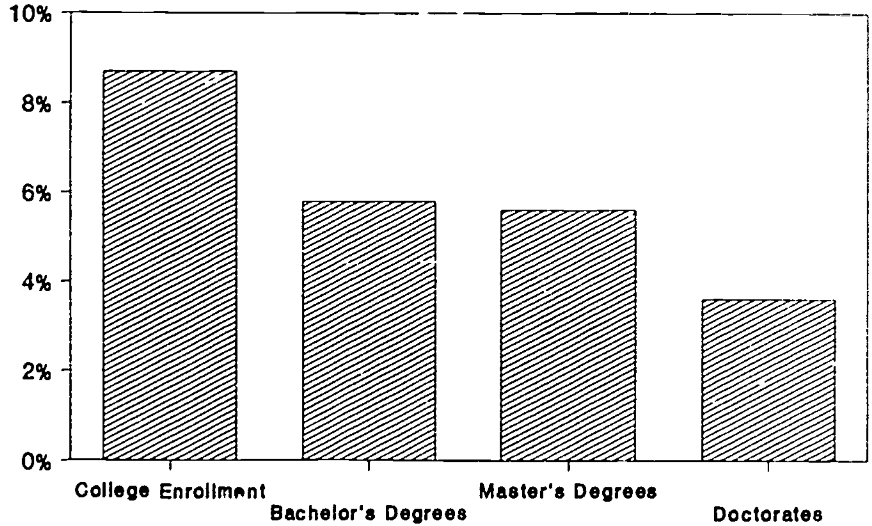
1984 Share of Total Enrollment and Degrees Earned, Whites



Source: Digest of Education Statistics

Figure 11B

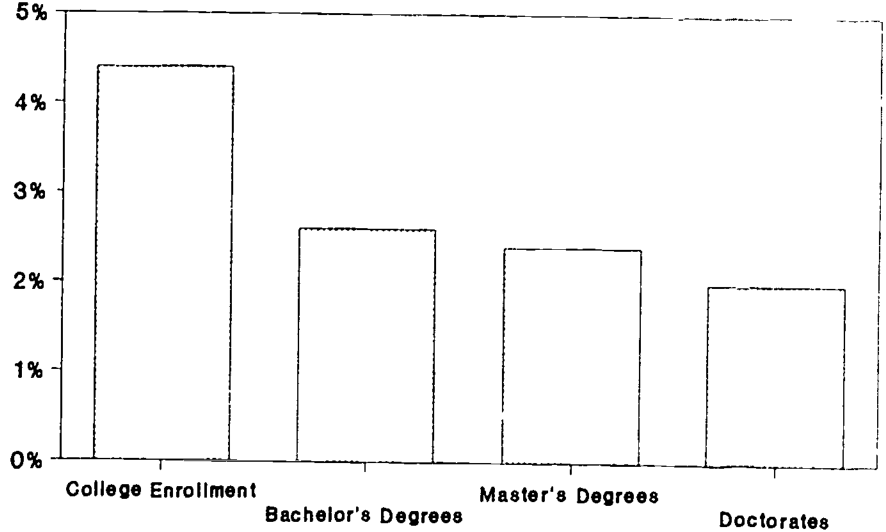
1984 Share of Total Enrollment and Degrees Earned, Blacks



Source: Digest of Education Statistics

Figure 11C

1984 Share of Total Enrollment and Degrees Earned, Hispanics

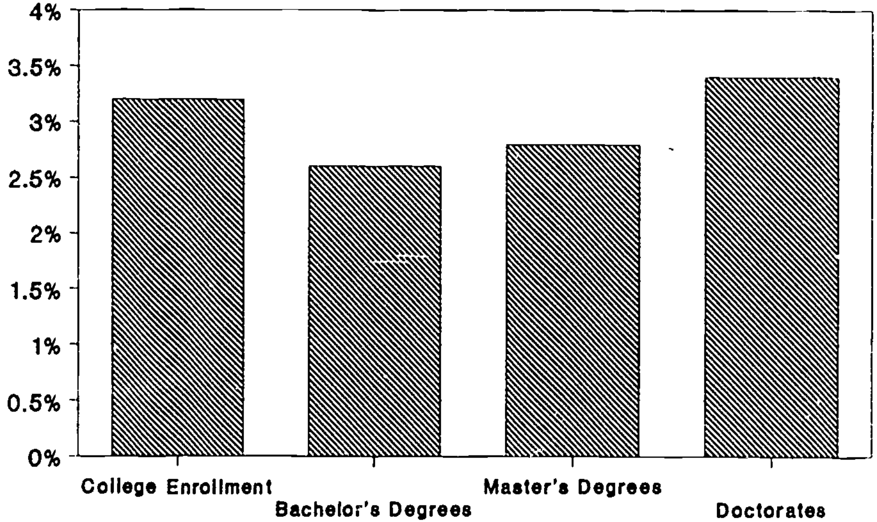


Source: Digest of Education Statistics

111

Figure 11D

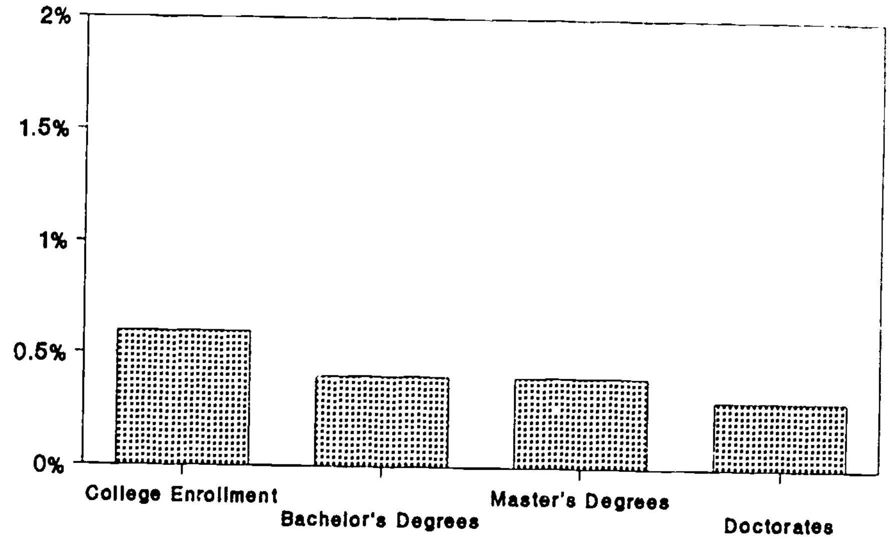
1984 Share of Total Enrollment and Degrees Earned, Asians



Source. Digest of Education Statistics

Figure 11E

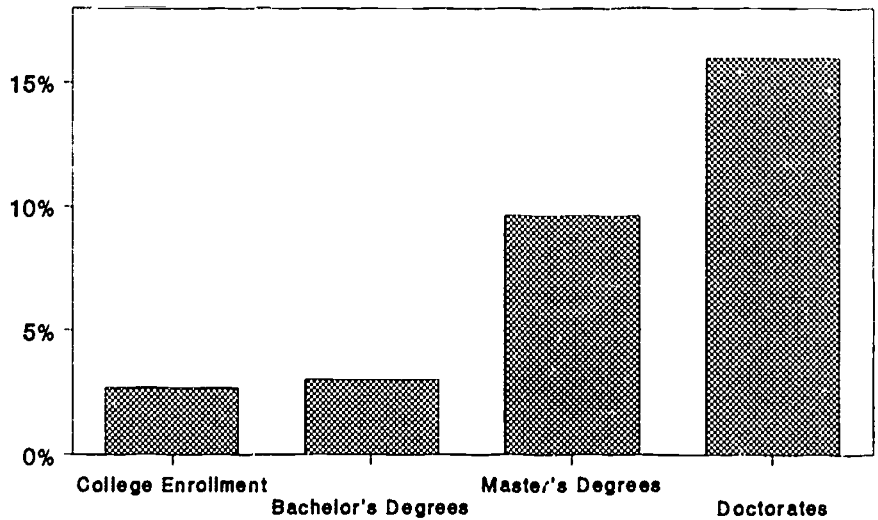
1984 Share of Total Enrollment and Degrees Earned, American Indians



Source: Digest of Education Statistics

Figure 11F

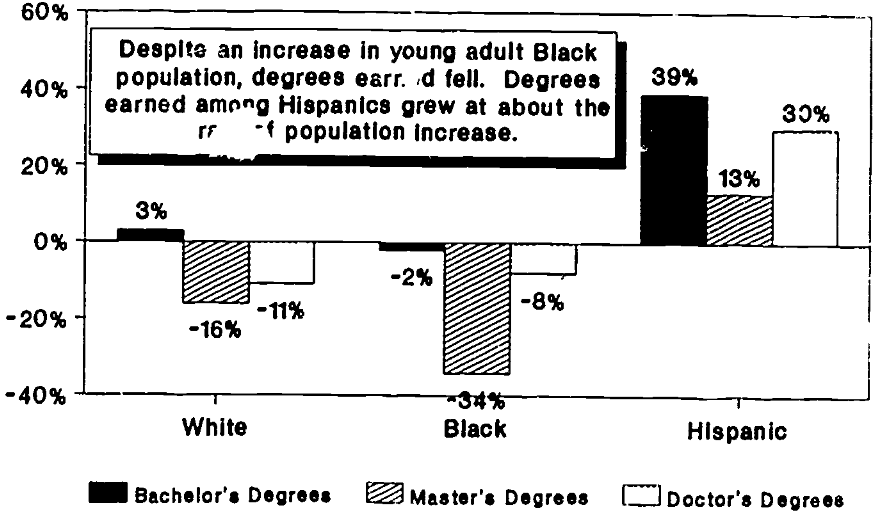
1984 Share of Total Enrollment and Degrees Earned, Foreign Students



Source: Digest of Education Statistics

Figure 12

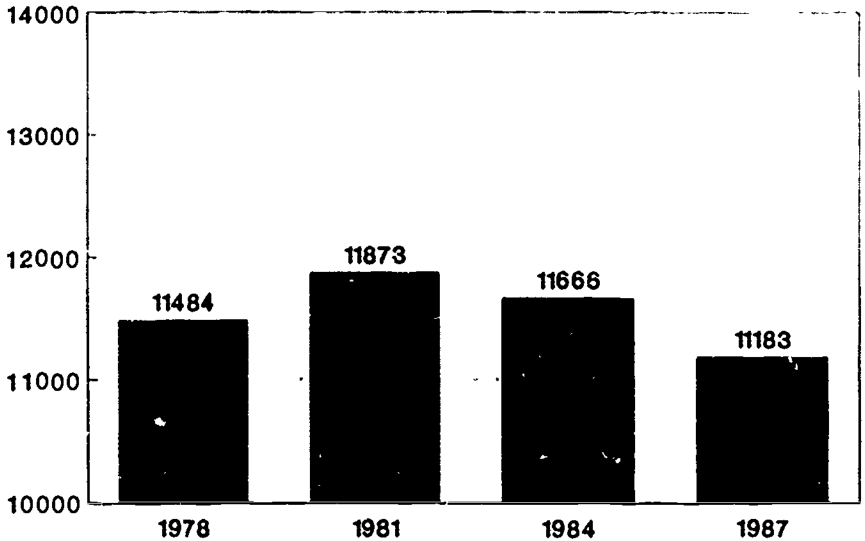
Change in Degrees Earned 1977-1985



Source: The Condition of Education

Figure 12a

Science and Engineering Doctorates
Whites, 1978-1987

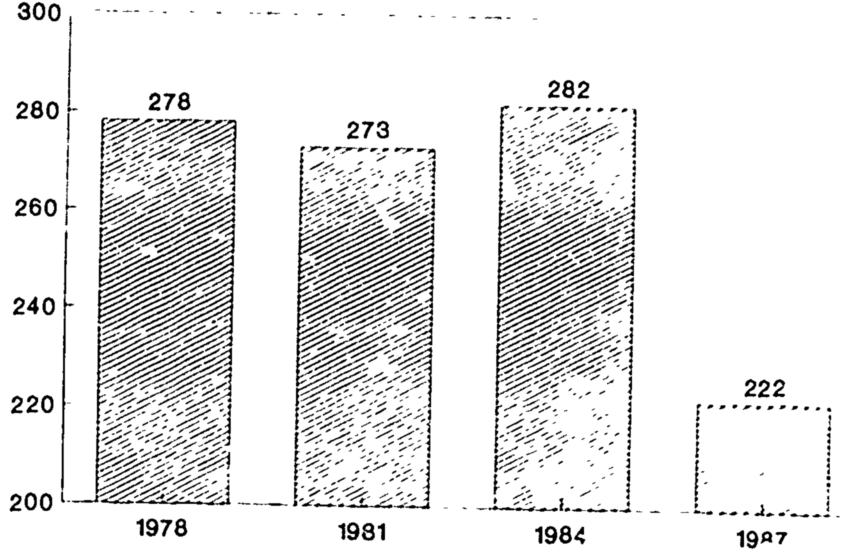


National Research Council

Figure 12b

Science and Engineering Doctorates

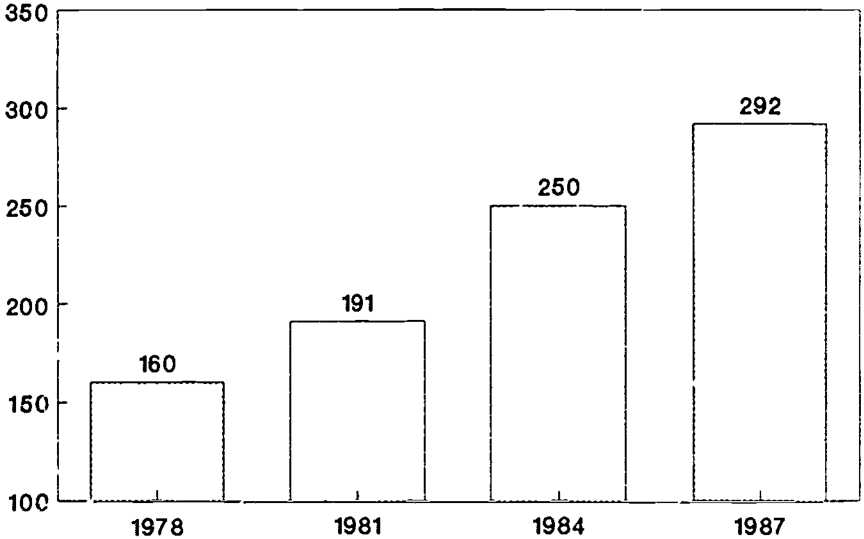
Blacks, 1978-1987



National Research Council

Figure 12c

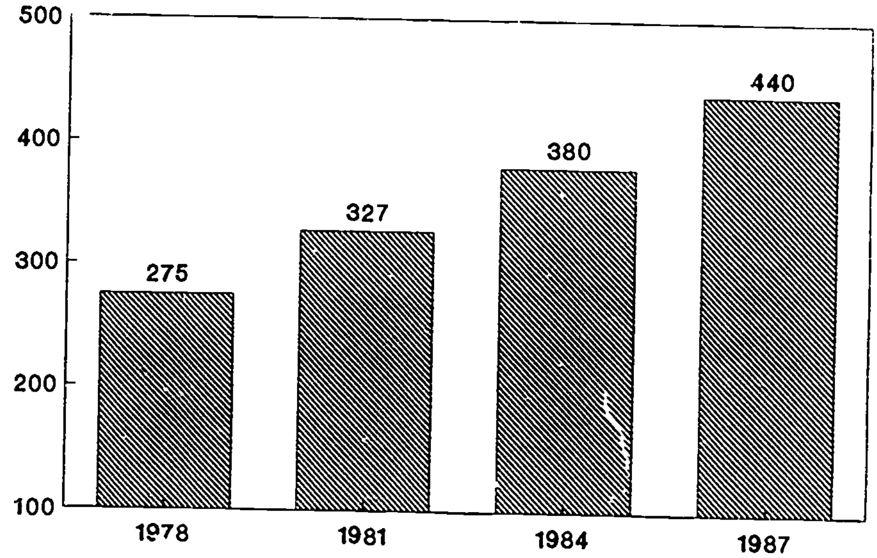
Science and Engineering Doctorates
Hispanics, 1978-1987



National Research Council

Figure 12d

Science and Engineering Doctorates
Asian-Americans, 1978-1987

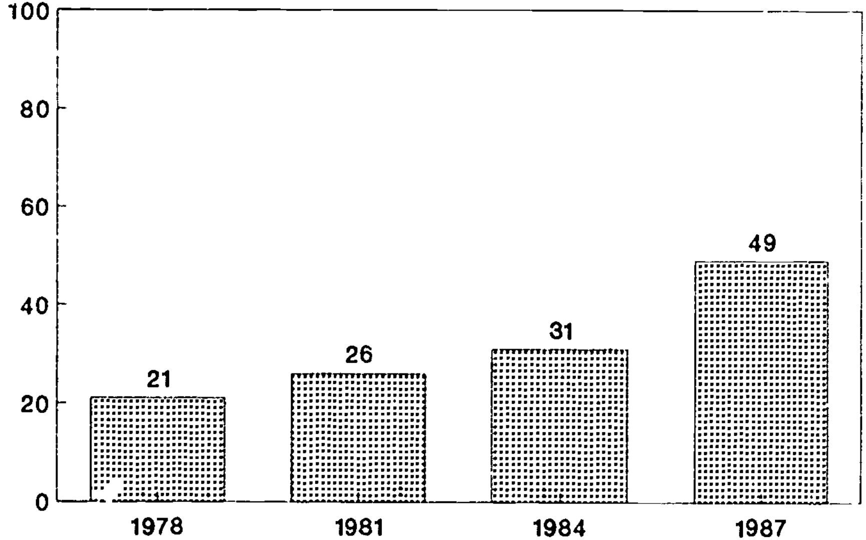


National Research Council

Figure 12e

Science and Engineering Doctorates

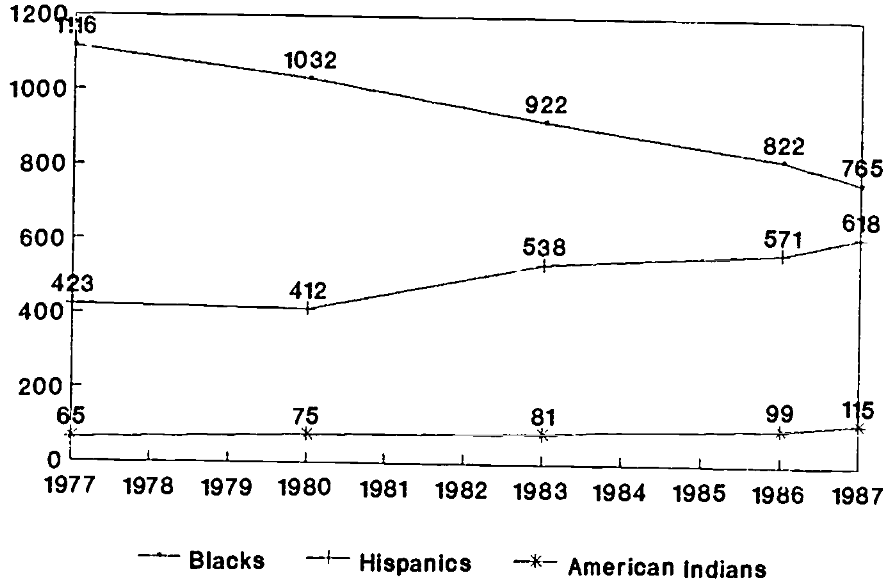
American Indians, 1978-1987



National Research Council

Figure 13

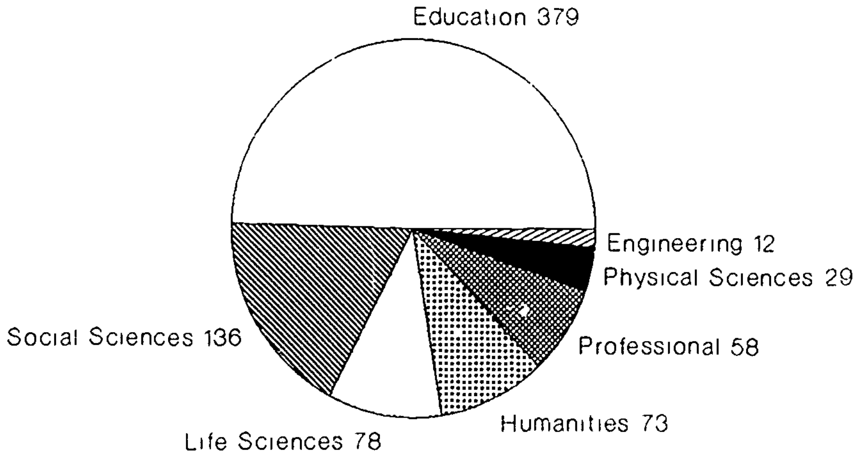
Doctoral Degrees Earned



Source: National Research Council

Figure 14

Fields of Doctorates Earned by Blacks 1987



Source: National Research Council

Figure 15

RACIAL DISTRIBUTION (PERCENT) OF FULL-TIME FACULTY AND ADMINISTRATORS IN HIGHER EDUCATION

	Faculty			Administrators		
	1975	1983	1985	1975	1983	1985
Whites	91.7	90.7	90.8	90.8	89.7	88.4
Blacks	4.4	4.0	4.1	7.0	7.1	7.6
Hispanics	1.4	1.5	1.7	1.7	1.7	2.0
American Indians	0.2	0.3	0.3	0.3	0.4	0.4

Figure 16

Underrepresentation of Minority Teachers
By Student Proportions, 1986

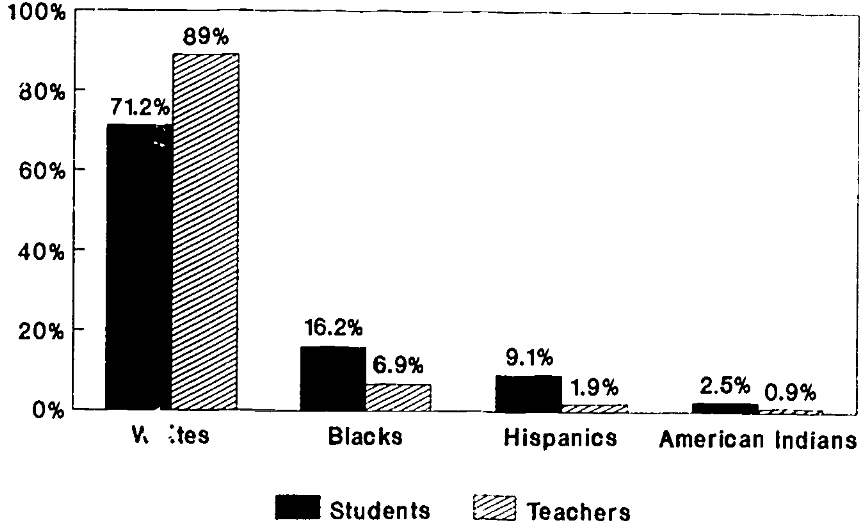


Figure 17

OEM TARGET GROUPS

ALASKAN NATIVES

BLACKS

AMERICAN INDIANS

MEXICAN AMERICANS

PUERTO RICANS

Figure 18

QEM ORGANIZATION

- MIT
- Carnegie Corporation of New York
- Resource Group (Shirley McBay)
- Action Council (Ray Marshall)
- Staff at MIT and UT Austin

Figure 19
NUMERICAL GOALS OF THE QEM PROJECT

1. Eliminate the gap in the h'gh school graduation rate that now exis... between mino ·s and whites.

2. Increase two-fold the number of minority high school graduates who successfully complete a college preparatory curriculum.

3. Increase three-fold the number of minorities receiving bachelor's degrees.

4. Increase four-fold the number of minorities receiving bachelor's degrees in mathematics, science, and engineering.

5. Increase five-fold the number of minorities receiving bachelor's degrees who enter the pre-college teaching profession.

6. Increase three-fold the number of minority Ph.D. recipients, especially those who enter university teaching and who ear·· degrees in mathematics, science, and engineering.

Figure 20

KEY ACTIVITIES TO DATE

- Regional meetings (New York, San Antonio. Los Angeles, Chicago, Anchorage, Albuquerque, Atlanta, San Juan, Atlanta and Boston)
- Washington meetings with National Organizations
- Action Plan Drafts under way
- Computerized data base
- Task Forces and Commissioned papers
- Meetings with scholars and practitioners to review recommendations
- Speeches and articles

Figure 21

LESSONS LEARNED

- Role of Teacher Expectations
- Harmful Impact of Tracking
- Importance of Linkage Between Systems
- Importance of Culturally Relevant Curriculum
- Importance of Parental Involvement
- Role of Self-Esteem and Confidence Building in Children
- Importance of Qualified Teachers
- Importance of Having Minority Teachers and Professors
- Fostering Greater Student Retention
- Mentoring in Higher Education
- Attracting and Rewarding Good Teachers

Mr. WILLIAMS. Thanks to each of you. Mr. Coleman.

Mr. COLEMAN. Again, thank you. All of your testimony was very interesting.

Dr. Montague, let me say that I noted in your testimony that in some cases financial support will be essential between corporate America and the outreach program, which all of you have indicated is necessary. I think it is something that we need to address and look at in depth, but the fact of the matter is, that you identified it, as a representative of a very large research-oriented corporation, which leads credence to the fact that we need to really develop this aspect as well.

Also, note, as Dr. Campbell did, that we have national security issues heavily involved with what we're talking about here. Because of our national security restrictions on classified data and information, we need to produce more American scientists to be able to go into these fields. This is extremely important for this country to recognize.

Dr. Hope, I just would say that what we're hearing from you is, that not only are we passing up America's opportunities for scientific betterment, we're passing up large segments of American students, Blacks in particular, and minorities. When you think about all of the people in this country in 1986, who received Ph.D's, and the number of Blacks was—421 of the 820 recipients of Ph.D's went into the engineering, science, math Ph.D. programs and graduated with a degree—14 in the whole country in engineering, 25 in physical sciences, 70 in humanities, 163 in social sciences. We're just simply not reaching a large number of people of American citizenship that we need to, and we need to address that problem.

Then I was handed this, which reflects what you've said here. The Asians that are coming here, for example, are recruiting themselves back. They are holding out after they get a U.S. education, instead of going to work for Monsanto or somewhere else. The companies are enticing them back to work for Korean companies, Korean governments, Korean corporations. So we have the worst of all worlds now. We are, in fact, training them, not retaining them, and they are leaving us, competing with us at the same time.

I thank all of you for coming here today and providing your important testimony. I will review all of it very closely.

Mr. WILLIAMS. Dr. Hope, visit with us another couple of minutes about the proposal for, what do you call them, residential academies for minority students who would go on and become scientists or engineers or mathematicians.

Dr. HOPE. We're finding that one of the issues, and all you have to do is read the newspapers and see the problems of the communities that many of the youngsters live today. These youngsters we are finding, one or two trickle in to MIT, are absolutely bright, absolutely talented, and could have tremendously successful careers if simply given the opportunity.

What we're suggesting is, and this is not anything new, but what we're suggesting on a much larger scale, is that minority youngsters be given an opportunity to have a live-in experience where the best of all possible teachers, health care, daycare—we would like to have these residential environments near the minority communities so that you have a close relationship between the communities. But at the same, it would be a secure time, be healthy for the youngsters, and youngsters would also have an opportunity to link with the higher education community. For example, MIT or Stanford, could have university faculty rotating in and out. Lawrence Livermore could have some of their scientists coming in to these residential academies, having allowed the youngsters a hands-on experience.

Mr. WILLIAMS. What age youngster, or year in school, do you envision as being the participants of this?

Dr. HOPE. In talking with most of the headmasters—for example, I spoke to the headmasters out in Albuquerque not too long ago, of independent schools, and the attempts—in North Carolina, there is one program where they have youngsters in a residential environment for science. Generally, the seventh grade, beginning at the seventh grade through the twelfth grade is the residential component.

In addition, now of course, there would be early intervention relationship associated, because we would like to see the parents involved in the residential situation, that they should not view it as a kind of reservation situation, if I can refer—say to the Native American experience, but that would be a very positive situation.

Mr. WILLIAMS. Would this supplement or supplant the students' normal schooling?

Dr. HOPE. During those years, yes.

Mr. WILLIAMS. It would supplement it?

Dr. HOPE. No, it would be there, their schooling for the year.

Mr. WILLIAMS. So, high school students would attend full time these residential academies.

Dr. HOPE. That is correct, from the seventh grade through the twelfth grade. At least that is the way we would like to begin.

Mr. WILLIAMS. Our thanks to each of you. We very much appreciate your good counsel here this morning.

I will ask our second panel to join us: Shirley Hill, Cynthia Yocum, Kent Kavanaugh, Hal Gardner, and Dennis Wint.

Each of the members of our first panel were kind enough to try to follow our time constraints, and we encourage each of you to do the same so that everybody can be aptly heard and people can make their next appointments with some ease.

We will first hear from Dr. Shirley Hill, who is the chairperson of the Mathematical Sciences Education Board at the University of Missouri. Dr. Hill, it is nice to see you and look forward to your testimony.

STATEMENT OF DR. SHIRLEY HILL, CHAIRMAN, MATHEMATICAL SCIENCES EDUCATION BOARD, UNIVERSITY OF MISSOURI, KANSAS CITY, MISSOURI

Dr. HILL. Thank you. Thank you very much Mr. Chairman, Mr. Coleman.

I will limit my remarks this morning to mathematics education, and I would like to say first that there is much that is good and healthy in American school mathematics. There are many classes in which superb teachers use innovative techniques to give students rich mathematical experiences and understanding. But despite such pockets of excellence, signs of weakness still abound.

I believe that nothing less than a major restructuring of the entire system of mathematics programs in the schools is necessary if our children are to receive the mathematical knowledge, and the confidence to use it, that they will need to be prepared for the 21st century.

I would like to place what I see as the problems in five broad categories. They are first, low achievement, whether we talk of it in either comparative or absolute terms; second, the serious and growing deficiencies in supply relative to demand; third, an increasingly obsolete cu riculum and outdated instructional practices; fourth, continuing changes in mathematics itself, its nature and its methods; and fifth, increasing levels of mathematic literacy demanded by modern life.

The achievement of our students has been well publicized and has been mentioned here today. I would like to point out that in addition to its standing comparatively, national assessments have shown that United States students do well in computational programs, but very poorly in problem solving and applications.

We have had a good deal of talk about the pipeline issue, so I will not say anymore about that except to reinforce the notion that at all levels we are filtering students out of that pipeline disproportionately, and it is minorities and women who are filtered out disproportionately.

That pipeline question, that supply and demand question, certainly suggests that we must learn to attract and retain minority and female students in mathematical studies. This is a matter I think not only of our economic well being, but of equity. Because as mathem tics is more and more a key to opportunity, equity finds common cause with our collective economic needs.

But even if we could solve all these problems mentioned, we still have a serious concern. I'm speaking here of the fact that our school curriculum in mathematics is becoming obsolete. It does not anticipate the changing nature and uses of mathematics. It looks backward and not forward to a new century, and it fails to take advantage, largely, of the available laboratory tools that are vital to doing mathematics today.

The essential organizing principles of what is a computational formula-driven curriculum are in very few substantive respects different from those of 500 years ago, 500 years. Even if we look at upper levels of algebra, geometry and calculus, we see a curriculum that is just about three centuries old, harkening back to Newton.

I think one of the barriers to needed support for change is indeed the public's misconceptions about what mathematics is. It is dynamic; it is not static. It is much more experimental and investigative than formula dependent, and indeed it is fun.

What we have here, in my opinion, is an inordinately complex set of very deep-seated problems. The need for solutions is urgent, but I certainly think they will not, and in fact warrant against, the attempts at short-term interventions at just one or two points alone, or to quick fixes. The problems are interdependent and I think the task is no less than to move an entire system in a set of coordinated, cooperatively planned efforts.

There are many fine, truly outstanding projects today in this country. They are based on good ideas, and they are demonstrating impressive successes. But when we look at the magnitude of the entire problem, our efforts are inevitably fragmented, piecemeal, and uncoordinated.

We do need mechanisms to form networks, coalitions, and finally, an agreed upon set of national goals and standards. I think an important contribution in recent months has been the publication of what is the first, ever, set of national curriculum standards proposed by the National Council of Teachers of Mathematics.

I think there are several necessary conditions for making and sustaining, and I would like to stress sustaining, systemic change.

First, and absolutely basic, is a broad public support, which is built on a foundation of understanding.

Second is achievement of a consensus among all concerned sectors and stake-holders on directions and goals. Our present efforts are largely incoherent.

Third is agreement about a set of universal standards.

Fourth is a coordinated program of national leadership and action toward reaching the goals and standards around which we develop the consensus. National leadership, in my view, is not synonymous with Federal leadership, but the Federal role in creating a climate for support and, indeed, a portion of financial support for research must be a key ingredient.

I would like to propose that there are two instrumentalities that exist today. There are many, but two that I know of that I think that can serve as models for national leadership.

One is the Mathematical Sciences Education Board of the National Research Council, whose program is one of establishing linkages and coordinated leadership toward needed reform. This Board has the active support of a good many government agencies. Among the co-sponsors of the MSEB is, in addition to private foundations, the National Science Foundation and all of the mission agencies that were mentioned in earlier testimony.

The other is the National Board for Professional Teaching Standards, whose goal is the improvement of student learning in general through high and rigorous standards for a true profession of teaching. A recent report of the Mathematical Sciences Education Board at its end said that the key ingredient for everything we are talking about must finally be the teacher.

As I heard previous testimony about intense need for recruitment of top talent, of what will inevitably be a highly competitive position of bringing these talented mathematicians and scientists into various agencies and into science, I must confess that I had a very [illegible] concern. As I see that happening. I see the shortage of mathe[illegible]ics teachers and science teachers increasing in such competitive stance.

I would want to urge industry and government to take a long view in this respect and not eat our seed corn. We cannot afford to attract, even in the face of these intense needs, all of our best talent away from the teaching profession.

The two boards I mentioned have much in common. They both have very diverse membership with not only professional expertise, but public sector membership as equals. They both are concerned with outreach to inform and listen to many constituencies and the public at large. They both conduct research and development which will provide state-of-the-art programs, and they both have a true commitment to the ultimate goal, the better education for all of our citizens and children. They work for the public interest and not narrow objectives. And they are finally about cooperation and are, in these two instances, already working together.

I personally have very high hopes for the current efforts, and those that I think will be set up in place in the next few years, and I'm optimistic about solving these problems. It will certainly not be easy, but I think it can be done.

Thank you very much.

[The prepared statement of Dr. Shirley Hill follows:]

TESTIMONY OF SHIRLEY A. HILL

BEFORE THE U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON EDUCATION AND LABOR

SUBCOMMITTEE ON POSTSECONDARY EDUCATION

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE. My interests in the issues before the subcommittee in this hearing are directly related to my professional life in teacher education as Professor of Education and Mathematics at the University of Missouri-Kansas City, in national policy in mathematics education as the Chairperson of the Mathematical Sciences Education Board of the National Research Council, the operating arm of the National Academies of Science and of Engineering, in the teaching profession as a member of the National Board for Professional Teaching Standards. Thus my testimony will be confined to mathematics education at all levels and to mathematics teaching as a profession.

It is at no risk to suffer the fate of the boy in the fable who cried "Wolf", that I say that mathematics in this country is in a serious crisis. The evidence mounts that our students are ill prepared to confront the challenges of an information age, when much of that information is quantitative; of a global economy dependent more and more on mathematical and computer models; of a technological future whose bedrock must be mathematical and scientific knowledge ; on an everyday world in which the demands for mathematical literacy and number sense are significantly higher than ever before in human history.

To put it the simplest and most straightforward terms, our mathematics achievement levels in the United States are unacceptably low (in absolute or comparitive terms), our curriculum is obsolete, and our textbooks and especially our tests are woefully out-of-date.

The consequences of the crisis as it relates to the health of our labor force are becoming well known in the boardrooms and on the line in industry and corporate America. The deleterious affects are not just in the so called "high-tech" industries. They are recognized in the financial as well as the scientific sectors, in the service industries as well as in manufacturing. and alarmingly in the military

But this is a crisis not fully comprehended by our broader public. There is little awareness of how pervasive mathematics is, or of the nature of its modern face and its dynamic quality. There is a very limited perception of the really astonishing applicability of mathematics, its "unreasonable effectiveness" as one mathematician put it many years ago. Mathematics is part of an "invisible culture", and this is a reflection of a curriculum that scarcely ever mentions any mathematics newer than that of 300 years ago. No other subject could get by with so obsolete a curriculum.

The media have not been particularly helpful when they persist in presenting the concerns of a large profession as a parochial argument among "nerds" and "professors". The inability to get a message of concern across to the public is a constraining factor in needed reform. For a necessary condition for change , especially if it is to be sustained, is public support and understanding. What is needed now is a broad-based national consensus on new goals and directions for mathematics education at all levels and for all students. To achieve such a consensus requires national leadership around standards, in the context of local and state implementation and control.

Within the last few months two publications provided the first steps in the process of national leadership. One was the report, EVERYBODY COUNTS, issued by the National Research Council. It sets out the problems in stark terms and outlines a plan for attacking the problems in coalitions, networks, linked projects , and a coordinated national dialogue to build consensus. The other publication is a first-ever set of national standards developed by the National Council of Teachers of Mathematics in CURRICULUM AND EVALUATIONS STANDARDS FOR SCHOOL MATHEMATICS These standards represent goals and guidelines, and a yardstick by which local schools and districts can measure their programs. Such standards for a forward-looking mathematics program in the schools can be a rallying point for the entire effort in reform.

But these are first steps although giant ones. They must be followed up and they must garner a broad base of support. In reality, what we have is an enormously complex set of interrelated problems. They will not yield to quick fixes or simplistic though splashy solutions. They will not yield to limited focus or intervention at just one or two points. The many current efforts are often thoughtful and excellent, but inevitably fragmented and geographically limited. What is needed is systemic change. The task is to change an entire system. This will mean coordinated effort, cooperative programs in which all factors, textbooks, tests, curriculum, teaching, teacher education and school management evolve in parallel and related ways toward widely accepted goals.

This means new paradigms of funding, of leadership, of coalition-building, of coordination. Out must go defense of turf and self-interest, in must come joint effort and shared responsibility and risk, and shared credit as well. Can we do this on a large scale? My only answer to that questions is, "WE MUST".

There are two basic reasons that we must develop a program of excellence in mathematics education. One is to build a strong work force and sustain a viable, competitive economy. Here the well-being of society as a collective is at stake. The other is to assure the widest individual opportunity.

In a technolog cal age, the foundation for problem solving is mathematical. Mathematical models are used now , not just in the physical sciences and engineering, but in the social sciences, the life sciences, business and management, finance and medical research. At less sophisticated levels, much of postsecondary training in business, government and the military demands technical training, most often grounded in mathematics. Training in computer-based manufacturing, in office work, in advanced weaponry, in systems management has serious mathematical prerequisites. Few college majors have no required mathematics components. Yet an inordinate amount of collegiate resources in mathematics are expenoed on remedial work In fact, it should not always be called "remedial" because the problem is often that the students were never exposed to the mathematics needed for collegiate-level mathematics courses.

The second compelling reason for excellence in mathematics education is that more and more, mathematics is a key to opportunity. By the same arguments raised above, individuals who can think for a living and can think mathematically are more in demand. Mathematics opens doors. To drop out of the study of mathematics is usually to close many doors... sometimes forever.

Even in everyday life, mathematics is more pervasive than ever before. The level of numeracy , or mathematical literacy, demanded by the complexi ies of modern life go well beyond the era when shopkeeper arithmetic and the quantitative and measurement needs of agriculture were sufficient for most people. Yet C curriculum largely reflect those times.

Humans are more than jo workers. There are other aspects of our lives in which a higher level of mathematical literacy is advantag us. To be enlightened consumers we need to understand data and statistics as represented in advertising, we need to comprehend rates of interest and mortgages, complex investments Otherwise, we are vulnerable and dependent on others. As an informed electorate, we understand polls and survey processes, we are asked to

-7-

vote on issues as diverse as acid rain and AIDS in which research and solutions will be couched in terms of mathematical modeling. Many large public issues have substantial quantitative aspects and measurable consequences.

The grounds for positive reform of mathematics education have a dual character: individual opportunity and societal economic well-being. In mathematics education, equity finds common cause with collective social economic health. To quote EVERYBODY COUNTS, "Mathematical illiteracy is both a personal loss and a national debt."

This has been a broad-brush picture of the crisis. Let me now provide some supporting data in the context of supply and demand. The demand for mathematical knowledge is incr sing. Perhaps more critically, the demand for the kind of thinking and pr solving skill central to doing and applying mathematics is increasing. Ma matics provides good training in higher-order thinking skills.

The report WORKFORCE 2000 states that "The fastest growing jobs require much higher mat. language , and reasoning capabilities than current jobs, while the slowly growing jobs require less." The most critical basics today are literacy, numeracy and logical reasoning. Publications by the Mathematical Association of America have shown that a very large fraction of college majors require some mathematics . Translating this to high school mathematics prerequisites, an analysis by the Math-Science Network shows that most jobs and careers demand at least three years of high school mathematics and many that do not require a college degree still require at least two. The report EVERYBODY COUNTS, which makes the case that all American students can and should learn mathematics, recommends that students study mathematics every year they are in school.

Turning to the supply side we face some grim data. I will discuss some of these data in terms of the pipeline and the sources for the supply in the pipeline. I will begin at the end of the pipeline with data on production of Ph. Ds in the mathematical sciences (mathematics, statistics, operations research, etc.). Between 1973 and 1987, the surveys of the America Mathematical Society and the Mathematical Association of America show a drop in the Ph.Ds from nearly 1000 to about 750. But when we sort out U.S. citizens we find that the decline is far more precipitous- from over 750 to about 350. The band of non-U.S. citizens in the graph is widening while the band representing U.S. citizens is narrowing and by more than 50%. Should we be concerned about this? Many of the foreign students return to their homelands so the number that can be employed by U.S. universities and industry and government is even less than the decreasing production figures would suggest. There is one agency that surely is especially worried about these figures. That is the National Security Agency. the largest employer of mathematicians in the country. One other band in the graph is worth noting. The number of/U.S. female recipients of the mathematical sciences doctorates in the period from 1973 to 1987 has remained at about 100 per year, at best less than 1/3 the total number of U.S. recipients. The good news is that the percent of the total has increased. The bad news is that the actual number has not. To break out the most recent data on Ph. Ds, we find these subsets: white males, 74%, white females, 19%, non-white males, 5%. non-white females 1%.

What is not seen in the usual graphic presentation of the data is our greatest failure. During the last 15 years, the total number of blacks and Hispanics receiving doctoral degrees in the mathematical sciences has averaged less than 10 per year. That is 10 in absolute number not percent.

The pipeline problem begins much earlier when students discontinue study of mathematics in school. (Its genesis is probably even earlier, when children are allowed to lose interest in a subject their natural sense of wonder and curiosity causes them to love initially.) In fact, the leak in the pipeline is general and not specific to the top talent. If we look at the numbers of students in mathematics study from ninth grade through graduate study we find that the half-life is one year, i.e. on average we lose half the population every year.

There are many reasons for this gushing loss from the pipeline. For me the saddest is the loss of motivation, the change of attitude that seems to come as children progress up through the grades. The process of "doing" mathematics at any level, real mathematics not the boring exercises of computation and formula memorization, is enjoyable, stimulating and even fun. Good teachers and surveys convince us that virtually all young children like mathematics. They do it naturally, discovering patterns and making conjectures based on observation. Natural curiosity is a powerful teacher for mathematics Why is it that as children become socialized by school and society, they begin to view mathematics as a rigid, of externally dictated rules governed by standards only of accuracy, speed and memory? Attitudes go from enthusiasm to apprehension, even fear and revulsion. This need not happen; it should not happen. And good new programs sprouting up in many places today show that it does not happen.

Many teachers can teach in ways that sustain motivation in mathematics. Most want to. They need examples of good models, they need good materials and ideas, and most of all they need the instruments of testing and assessment and evaluation to be brought up to date, so that they are not a drag on the ability to change and to improve instructional techniques and add new content. Currents tests and the public testing mania are the greatest barrier to reform in mathematics instruction.

In an apt metaphor, Robert White, the President of the National Academy of Engineering, described the central role of mathematics in the economic growth of the country. He said, "Mathematics must become a pump instead of a filter in the pipeline."

When mathematics filters students out of the pipeline it does so disproportionately for women, blacks and Hispanics. Mathematics has been perhaps the worst curricular villain. When it acts as a filter, it not only filters students out of careers but frequently out of school itself.

As data have shown, mathematics has been in extreme terms primarily the province of the white middle-class male. The cold water of reality should hit when we compare that fact with the demographics for the rest of this century. The proportion of the population that is non-white is growing dramatically. If mathematics has drawn almost solely from the white male population then it will have a smaller and smaller proportion of the students to draw from. The report WORKFORCE 2000 states that "White males, thought of only a generation ago as the mainstays of the economy, will comprise only 15% of the net additions to the labor force between 1985 and 2000." The little syllogism has a clear conclusion. We need far more mathematical expertise and general literacy. We have only succeeded in attracting from the white male population in sufficient numbers. But that share of the total population is in decline. Conclusion: We MUST learn to attract and retain minorities and women in mathematics study. We know it is possible. Many well publicized programs show that minority groups and females can be interested in mathematics and achieve at very high levels. We need the will and the base financial support to widen these excellent models to more areas and schools.

Not everyone will want to become a mathematician of course. But most should aspire to careers and professions that represent opportunity. Most of those will require some mathematical ability and skill. Furthermore, everyone needs numeracy. In another striking metaphor from EVERYBODY COUNTS, it is noted that in the United States we have been reasonably successful at tapping and channeling the highly visible talent springs which develop without special support from formal schooling .. but now we must raise the entire water table.

While the problems are daunting, we are not just sitting around wringing our hands. There are many, many excellent programs and projects but it isn't enough. There is an inevitable fragmentation and unevenness about the movement to change, to reform. It suffers from a lack of coordination and a fundamental consensus about directions and goals. If the basic need is to change an entire system simultaneously, then the components of the system need to be changed along parallel paths and in a coordinated pattern. In our decentralized system of education in the United States, this is especially hard to accomplish. We need national leadership but in its limited jurisdiction that cannot be solely federal leadership. National leadership rather than mandates needs to be voluntary.

Two boards on which I serve seem to me to be examples of how national leadership can be effected. The very reason that the Mathematical Sciences Education Board was formed at the National Research Council was the recognition by the mathematics community itself that its organizations alone could not bring about needed change. What was needed, they felt, was a group that represented very wide-ranging interests in mathematics education. Thus the Board is a diverse group consisting not only of mathematicians and mathematics teachers (though there are a fair number of these), but also of school administrators , chief state school officers from two states, scientists, and members from the public sector, e.g. representatives from business and industry, from the school boards'associations, from the leadership of the National PTA. The business of the Board is all about linkages, reinforcing, publicizing good programs, augmenting ongoing projects, brokering partnerships, establishing networks, in short coordinating a wide-ranging effort at reform. It exists to encourage coordination, communication and coalitions, to discourage redundancy and to help fill gaps. One of its major efforts is outreach, in the belief that a broad base of understanding and support will be needed to effect lasting change. Its report EVERYBODY COUNTS was intended as a public preface to its role in garnering support for the CURRICULUM AND EVALUATION STANDARDS referred to earlier and to its initiation of a national dialogue throughout the country to try to achieve a consensus on new goals and directions for mathematics at both school and college levels. That process has begun.

What we need to accomplish an ambitious program is the participation of every group with a stake in the problem. To get this we need many groups to call attention to the effort. It is not always easy to get an audience even when you are asking that audience for its opinion.

The MSEB does more than publish reports, establish outreach and solicit opinion. It is actively engaged in the implementation of several plans that attack a number of factors central to the problems I have outlined.

I will mention some of these projects and my office would be happy to provide details on any that are of particular interest to you. An ongoing series of projects relates to the need to revise radically the mathematics curriculum of the schools. Because the use of technology, computers and calculators calls into question the organizing principle of computation and symbol manipulation around which the traditional curriculum was structured, we are engaged in an examination of several strands around which a curriculum for the next century could be organized. These are selected to represent several of the "big ideas" of mathematics, e.g. uncertainty, change, dimension, shape and quantity. The strands could be woven together to illustrate mathematics as the science of patterns.

In addition, we will be releasing a guide to reform that should be helpful to localities that want to revise their mathematics curricula. Our view is that our role is an "augmented grass roots" form of curricular change, with guidance for local and state efforts toward a flexible set of standards but retaining **local** initiative and decision-making.

Another ongoing project is directed toward the revitalization of collegiate mathematics. We are conducting it jointly with the Board on Mathematical Sciences of the National Research Council.

Two important projects now funded and set to be launched are one entitled "Making Mathematics Work for Minorities". It will begin with a set of regional planning conferences. The other is a project to establish coaltions at state level. It is envisioned that these coalitions would bring together at state level the diverse constituencies represented by MSEB.

Taken all together, the several programs represent the intent of the National Research Council to engage in an unprecedented study of the mathematics enterprise from pre-kindergarten through the graduate school, and to offer leadership in a broad based coalition toward reform.

The organizations that represent the mathematics and mathematics education communities are also concerned with standards for teaching mathematics. MSEB will help to coordinate the work of the National Council of Teachers of Mathematics and the Mathematical Association of America in the development of a set of standards for mathematics teaching. We believe that we can present a consensus of the entire community on what these standards should represent.

I believe that in the last analysis, the key to positive change is in teaching. In the preface to EVERYBODY COUNTS, my co-chairmen in the development of the report, Phillip Griffiths, the Provost of Duke University and J. Fred Bucy the retired CEO of Texas Instruments and I stated, "whatever any of us do as individuals or through organizations to improve education, we see our role as supporting the efforts of the central person who can bring about meaningful and lasting change: the teacher."

It is for this reason that I have such high hopes and expectations for the goals of the National Board for Professional Teaching Standards. To have and maintain high standards, to recognize teachers who meet these standards, to have these standards defined and set by the professionals themselves with the help and cooperation of public members, to provide the sort of environment in which professionals can work and reach their goals of student learning; all of this will surely enhance the profession of teaching, but most importantly, it will make a difference for America's children.

The goal of assessment in five years is a short time to do such a large task and do it right. But we must have impact on the large numbers of teachers who will come into the profession in the 1990's as well as encouraging those many , many teachers who continue to provide excellent teaching year after year . I work with teachers as well as with students who are candidates for teaching. When I describe the vision and goals of the National Board for Professional Teaching Standards, there is an almost universal positive response and excitement. The overwhelming majority welcome the Board and what it represents. Especially among members of the Board who have worked for many years to improve education, there is a sense of new mission and dedication.

As chair of the Assessment Committee, I sometimes feel overwhelmed by the awesome task we have set ourselves... an assessment that breaks new ground but is built on the best research and development that exists or can be done. This job must be done right and it will only be credible if it is truly based on good teaching performance. There are few existing paradigms for performance-based assessment. But current experiments are very promising. The key to success is adequate research. In this the Congress can help and play its legitimate leadership role. This effort could well be the linchpin for bringing American education into the position of excellence our children deserve.

The report, EVERYBODY COUNTS, states that our national goal is to make U.S. mathematics education the best in the world. The 87/88 ANNUAL REPORT OF THE NATIONAL BOARD FOR PROFESSIONAL TEACHING STANDARDS states that Board certification is a means to many ends: better teaching, better schools, better graduates, a better America. Our goals are similar, our efforts are complementary. Both

Boards represent mechanisms for national leadership that bring together diverse constituencies in common cause. Both work together with, not in isolation or in competition with, other groups and both make a practice of seeking opinion from many sources. Neither represents a narrow special terest. It seems to me they are exactly the kinds of national leadership dels that can actually make a lasting difference in American education.

Mr. WILLIAMS. Thank you, Dr. Hill.

Cynthia Yocum is an elementary school teacher at Hall Elementary School over here in St. Joseph, Missouri. It is nice to have you with us.

Ms. YOCUM. Thank you.

Mr. WILLIAMS. What grade do you teach?

Ms. YOCUM. I'm a sixth grade teacher.

Mr. WILLIAMS. I, too. That is what I did before—

Ms. YOCUM. I've taught several different levels, but right now I'm in the sixth grade.

I want to thank you for inviting me to be a part of such a distinguished panel. I want you, first of all, to take your hats off that you came on with, and become a sixth grader now, so I'm not so nervous and I can talk to you more freely.

Mr. COLEMAN. Let me say that many congressman haven't attained that level yet, present company excluded, of course.

Ms. YOCUM. Okay, don't be hitting each other; don't be calling each other names so we can get this done.

STATEMENT OF MS. CYNTHIA YOCUM, TEACHER, HALL ELEMENTARY SCHOOL, ST. JOSEPH, MISSOURI

"Like it or not, science education is where the future of our country lies, and you don't want your child left behind." I made this statement to a group of parents, and this came from a person who, in previous years, had a very poor science teacher. I had the opportunity to attend a class called Air and Space Science for Elementary Teachers that was funded by the National Science Foundation. We've heard that a lot this morning.

I didn't take the class because I was interested in the material that was being taught. I took the class because it was five hours graduate credit and it was going to be free and they were going to give me a little money on the side. As a teacher, we are always looking for those things.

So, I took this class While I was there, I gained much valuable information. Probably the most valuable I gained was the fact that the teacher doesn't have to always know the answers. Up until this time, I had been very afraid to teach science. I had taken every out of teaching science possible, because I didn't think I knew the answers that were necessary, and therefore, if there wasn't time in the day for a certain subject to be taught, it was science.

But through this class I found that it is okay if you don't know the answers. You can find them someplace. I also found that if you do laboratory work and it doesn't turn out with the results you expect, you can do it again and change the variables and you learn a lot of things in the meantime.

So, I decided that if this is okay to take place in a college class, then it would definitely be okay to place in my elementary classroom. I felt much more comfortable going back to my classroom with that attitude.

In the fall of 1985, I went back to my class and decided that I couldn't allow myself to be the weak link in the chain that joins children and science education. I, therefore, have taken a number of different classes, most of them have been through grants. They are classes that have been funded by someone else. I've been at minimal expense for several of these and they dealt with science education.

My concern is for the teachers who haven't had the positive experiences that I have had, who have not had the opportunity or have not taken advantage of the opportunity of some of these classes that are offered for elementary teachers. They make the choices not to.

The greatest problem with science in the elementary classroom is the fear of teaching science. My problem stemmed from elementary school, myself. I don't remember one single class in science being taught. I had some excellent teachers, but they weren't very good science teachers. Therefore, I didn't have a very good role models to follow.

I see many problems in the field of science, the greatest being the fear of teaching science, that we simply do not have the knowledge. Other teachers just simply express that they don't have the interest to teach science. Another is the lack of time We have schedules that we have to follow, and working science into our schedule is one problem, but another problem is we have a 30-minute planning time set aside each day, and by the time we find our supplies and get them all set up for our labs, we most generally run out of time.

Probably the greatest problem we have in elementary school is the expense of the materials and supplies and the necessary equipment. My school has set aside $50 a year for science. We have 450 students in our building, and it is very difficult to have an effective program when you don't have the necessary equipment available to us.

These are a few of the most blatant problems that I see. The solutions don't come very easy for us, as I'm sure you're well aware. The problem begins with teacher education, teacher training. I'll take the blame for that, just like any other teacher would, I think. Education has been hit several places here, and I'll be the first to agree it does take—and it begins in elementary school.

I'm going to be taking a class during the summer, again it is through a grant, and this grant is going to approaching several science concepts as though the teacher has absolutely no knowledge of science. For the next several years, until we've brought science educated students up through the system, maybe that is path that teacher training in science education needs to follow, as though the people who are participating don't have a science knowledge, so they become more comfortable with the subject matter itself.

Another solution that was given to me was that possibly we need to increase the requirements for teachers, that they need to have maybe a B.S. in Arts and Science. One of the best teachers in my school says that without that type of a degree, she wouldn't have the necessary knowledge to have stepped in and taught what she has been teaching.

The favorite solution that was given to me was that we need to put our classes into departments, with the best science teacher teaching science. This comes from teachers who are not comfortable with teaching science. There are lots of arguments against that. One would be the scheduling problems that we would have. Another would be that we are causing children to grow up too quickly, that they are going to be faced with those things, that we are taking them out of a safe and secure structured environment, and they are going to be having those things soon enough when they reach the middle school.

The people who make the decisions don't always come up with the things that are going to be best for the children, the things that are the easiest to put into practice is what we most often see.

Teachers who like to teach science also have many frustrations with the system. Probably the most often thing you're going to hear is that we are required to teach certain things. We have objectives that we have to teach. Part of the Teaching Act states that we have to state the objective orally as well in writing, and when we do that, we take the discovery away from the students. We're telling them what they are going to be learning, instead of letting them find out for themselves what they are going to be learning.

A suggestion was made by a high school teacher that in elementary schools they should have many hands-on activities that deal with the science concepts, keep the enthusiasm alive and then send them on to middle school where they can teach the objectives and the students are more ready to learn those objectives. Therefore, they are still enthused when they get there and they have lots of good experiences with science when they reach them.

Until the general public, especially parents, realize the importance that needs to be placed on science education, I don't think that we're going to have a very easy solution to these problems. The public holds the purse strings that control the funding as well as the power to ask for the excellent education that each child deserves. The public, as well as teachers, need to realize the importance of the statement I made in 1985, like it or not, science education is where the future of our country lies, and you don't want your child left behind.

[The prepared statement of Cynthia K. Yocum follows:]

TESTIMONY FOR THE SUBCOMMITTEE ON POSTSECONDARY EDUCATION
BY CYNTHIA K. YOCUM
SIXTH GRADE TEACHER, HALL SCHOOL
ST. JOSEPH SCHOOL DISTRICT
ST. JOSEPH, MISSOURI

May 1, 1989

" Like it or not, science education is where the future of our country lies, and you don't want your child left behind." I made this statement to some parents who did not understand why, all of a sudden, when their child reached fifth grade, there was so much importance placed on the area of science. This was probably extra confusing for those parents who had previously had children in my class. This was new territory for me also. Up until that year I had been the world's worst science teacher. If there was something that had to be left out in a school day because of lack of time, it was science. I did not understand science and I was very afraid of it. "The teacher never wants to let the student know she doesn't have all the answers" was how I had felt up until the summer of 1985.

If I was going to be making statements like I did to that group of parents, I could not afford to be the weak link in the chain. In the summer of 1985, I had the opportunity to take an Air and Space Science for Elementary Teachers class on the campus of Northeast Missouri State University. I didn't take the class because I was particularly interested in the subject content, but because it was a five hour graduate level class that was completely funded by the National Science Foundation. During this class we had a lab and I became amazed at how much fun you could have learning all the information I had missed in elementary school, high school, and, yes, even college. We had experiments that didn't turn out the way they were expected to turn out, but we didn't panic. I decided if these things could happen to a college professor of science, then it would be okay if they happened in an elementary classroom. This began my transformation as a science teacher as well as a teacher of all other subjects.

I went back to my classroom in the fall of 1985, and transformed it into a space laboratory. We did many experiments and activities that had to do with space, but also had basic science concepts. I did not have much knowledge in the area of science, but I was having as much fun as my students learning. If we ran across questions I didn't know the answers to, we would search together. Many times the students would come up with the answers before I did, but we still learned. Still most of the science concepts we covered were aerospace things.

In the fall of 1986, I made a move to a much larger school district where there was a "science curriculum" with specific "objectives" to be taught. I discovered very quickly I was going to have to broaden my horizon to more than aerospace. I had lots of homework to do because if I expected my students to understand these things, I first needed to understand. I continued with aerospace activities and each spring would have an open house for the parents to see some of these activities. My principal, Leo Blakley, attended one of these and considered it as a mini-science fair. I had never thought of it as that, just as something fun for the students to do.

Later in the spring of 1988, Mr. Blakley received some information on a School Science Improvement class to be held that summer. This class was funded by a grant and in order to participate, the principal had to recommend the teacher. Mr. Blakley thought it might be a good idea for me to participate in this class, but he also included the stipulation I would share my information and organize a science fair for Hall School. I agreed to this and became a member of a very fun class. In this class I was exposed to physics, chemistry, biology, and earth science. I had taken these classes as an undergraduate, but had only put in my time without much understanding taking place. During that summer, these classes increased my understanding of many concepts. I also had access to many things I could use in my classroom. As part of my assignment I had to go back to my classroom and have my students draw a picture of a scientist. I also had to keep a journal of all the things we did in our science class.

The 1988-1989 school year began with many things to be accomplished. The very first day of school, my students were given a blank piece of paper and ask to draw a picture of a scientist. Most of the pictures turned out as expected with men wearing lab coats in a laboratory.

It was my good fortune to be selected to represent my building at another science class. The class was titled Kindergarten-Sixth Grade Science and Math. This class, again was funded by a grant. This was probably one of the most useable c[illegible] had ever taken. We spent three hours a night doing experiments we could take back and do in our classrooms. Imagine adults crawling around on the floor acting like children. Our assignment was to choose at least one of the experiments and have our students do it. These experiments were total student involvement and not merely observation. The students loved this and looked forward to the days after my class because I always wanted to try at least one the very next day. The students, both boys and girls, loved the experiments and could often be heard to ask if they could go home and try it some more to see if they could make any improvements. Students asking for homework, especially in science, was very exciting for me. I had lots of information to add to my journal as well. This group of students became my group of "guinea pigs" because of the many things we tried for the first time.

In the fall of 1988, I began the planning of Hall School's first science fair. It was decided we would include third through sixth grades and it would be a science/consumer fair. The students were required to participate since school time would be allowed for work on their projects. The students could work in groups of two or they could work individually. The students were given a time line as to when each part of their project should be completed. The science/consumer fair was held in January of 1989, with approximately 160 projects completed and around 250 students being involved. Each participant received a ribbon plus some positive feedback. In our award ceremony, we invited the primary classes to come and had our winners present their projects so the younger children could become excited and look forward to when it was their turn to participate. All students came away from the experience feeling very good about themselves.

Because of our success I was asked to write a grant for teachers on how to organize a science fair. The grant was not funded, but the school district felt it would be valuable so they are funding the making of the video.

We have continued our school year with many hands-on activities. The class's favorite unit so far was our unit on electricity. I had written the unit as part of my assignment in the School Science Improvement Projects class.

In December I asked my class to draw a picture of a scientist at work. The drawings had greatly changed from the ones they did at the beginning of the year. They, for the most part, drew pictures of themselves doing experiments on the floor We had at least gotten rid of part of their sterotype.

I have set aside the last part of the school year for the part I like best, aerospace. My class is very excited and looking forward to this. We are making hot air balloons, studying air pressure and the principles of flight, making glidders, launching rockets, and planning our first aerospace day.

I am also in the planning stages of organizing a Young Astronauts Club for fifth and sixth graders. The interest in this area is great.

When I came to Hall School, I was asked to be the building coordinator of Starlab, a portable planetarium. I knew absolutely nothing about the constellations, but I thought it might be something fun to learn about. I was then asked to help write curriculum for the district. The purpose of the curriculum was to help other teachers become more comfortable in using Starlab.

Where does the future take Cindy Yocum, science teacher? I will be taking advantage of every opportunity that arises to increase my knowledge in the area of science education. I will be taking a class during the summer that will further change my classroom next year. I have learned to never allow an opportunity to pass me by because that opportunity might carry along with it something that will completely change my life or the lives of my students. The links I'm adding to my student's chains are becoming stronger with each of these opportunities.

I have evolved into a teacher who loves to teach science. My knowledge is still lacking, but I am constantly learning. My concern is for those teachers who have not had the positive experiences. Some have not had the opportunity or have not taken advantage of the opportunity to become involved in the excellent science classes available to teachers.

As part of teacher training, students are required to take so many science classes, but, if the student does not have a good science background, the science phobia is allowed to grow. Teachers, often, were not taught science when they were elementary students, and, therefore, do not have many good role models. It appears to me that the problem begins in elementary school.

Along with teachers being afraid of teaching science are many other problems. Some teachers have expressed they simply do not have the interest. Time also plays a big factor. Not only time to work it into the daily schedule, but time to prepare for the class. Most teachers have only a 30 minute planning period, and by the time everything is rounded up there is no time to try the experiment first. Some of the equipment and supplies needed for science are very expensive. My building is allowed fifty dollars a year for science. It is difficult to have an effective program when the necessary equipment is not available.

The problems are simple to point out, but solutions do not arrive so easily. Teacher education seems to be the logical place to begin. I will be taking a class during the summer that is approaching several science concepts as though the participants have no science knowledge. For the next several years, until we bring science educated students up through the system, this is possibly the path teacher training in science education should follow. Another solution might possibly be to change the requirements for teaching so that each teacher would need a B.S. in Arts and Science. One of our best science teachers at Hall says she would not have had the necessary background without that type of a degree. This solution would create another problem. With increased education should come an increased pay schedule compounding the already great problem of funding. A favorite suggestion, especially from those who do not feel comfortable teaching science, is to departmentalize with the most qualified person teaching science. This, in turn could create more problems to deal with. Some of the arguements against this might be scheduling, or the removal of the child from a "safe" structured environment. The people who make these decisions don't always come up with the solution that has the child's best interest at heart, but one that might be the easiest to put into practice.

Teachers who enjoy teaching science have many frustrations with the system. Many feel too much emphasis is placed on teaching the "objectives." Part of the requirement of the teaching act is to state the objective both orally and in writing. If this is done, then discovery by the student is removed. Some feel the objectives should be removed from the elementary school altogether. The suggestion was made by a high school teacher for elementary schools to concentrate on many hands-on activities that deal with science concepts, thereby keeping the enthusiasm alive. Then send them to middle school where the objectives could be taught and the student more ready to learn. A teacher's favorite time of the year is after achievement tests have been taken. This is when we do things that couldn't have been justified earlier because they were not part of the objectives for that grade level.

Until the general public, especially parents, realizes more emphasis needs to be placed on science education the road appears to be long and rough. The public holds the purse strings for the necessary funding, as well as the power to ask for the excellent education each child deserves. The public, as well as teachers, need to believe my statement made in 1985, "Like it or not, science education is where the future of our country lies, and you don't want your child left behind."

Mr. WILLIAMS. Thank you very much.

Kent Kavanaugh is also a teacher, at Park Hill Senior High School in Kansas City.

STATEMENT OF MR. KENT KAVANAUGH, TEACHER, PARK HILL SENIOR HIGH SCHOOL, KANSAS CITY, MISSOURI

Mr. KAVANAUGH. Thank you, Mr. Chairman, Mr. Coleman.

I am an advanced chemistry teacher who teaches in an affluent suburban high school. Approximately 43 percent of the Park Hill School District lies within the city limits of Kansas City, Missouri. I will give testimony to the problems as I see them in my classroom and in the educational field. Our educational efforts are beset by a number of hurdles affecting our ultimate successes and failures. In an attempt to address these problems, I have found that they are best approached from three separate categories: students, teachers, and resources.

Students: Because the drop-out rate in the United States is about one out of four, or higher, I will only see about 75 percent of the possible number of students who could take science classes. Of those remaining three, a high percent, have been turned off to science before they enter high school and will take the minimum science requirement for graduation. I have to spend a good percent of my time in the classroom convincing my students that they can succeed in science, that science is for everyone and not just the elite.

Only about 30 percent of my advanced chemistry students are girls. If I can get them to take the first year of chemistry, they go on to take more science. It is getting them into the science room in the first place that is the challenge. We need to attract more minority students also into the sciences and in the math fields.

The high ability student that I see is, by far, better informed and better prepared than a decade ago. But this group is not a reflection of the average student in the our classroom today. Today's students are born into a world of minimum effort and a desire for instant gratification. They have been exposed to too much passive entertainment which can be obtained with a push of button, 24 hours a day. There are times when I feel I must be as much an entertainer as a teacher. The American work ethic is virtually non-existent in the classrooms today.

The average student will either be from a single parent family or from a family where both parents work outside the home. The student will often lack the support and encouragement of the family base. I find my role in the classroom become more and more one of a pseudo-parent, as well as an educator. I think many of today's parents look to the school to not only educate their children in the three R's, but to teach them about morals, ethics, commitment, and to shift the basic role of the family to the educational system.

It is true, we should support and reinforce these ideals in the classroom, but we cannot instill them or make them a high priority in their lives. One of the major problems in education, and therefore, science education, is the lack of parental involvement.

The average science student has gained his or her basic education from the fill-in-the-blank tests and assignments. I realize the limitations of fostering independent thought or critical thinking at the elementary level, but this approach does not have to be perpetuated at the secondary level. Many of the students I see think that science education is looking up the answers in their textbooks without reading the assignment. To instill problem-solving skills in the average science students in my biggest challenge and goal.

Of the teachers: We are not attracting high quality of science majors in the educational field. The single most important step that can be taken to improve science and math education for the 21st century is to raise the monetary consideration for the math and science teaching profession. The average age of the secondary science teacher is 43 years. This means that at a time when our country is entering the technological arena of the next century, a large percent of our current science teachers will be retiring. There is an extreme shortage of science teachers today. This problem will be catastrophic by the 21st century if we continue to assume that the laws of supply and demand work everywhere except in the field of education.

We must attract bright, highly qualified students into the fields of math and science teaching. This is not possible when the first year chemistry teacher will earn approximately $7,000 less than the same educational entry position in industry. Unfortunately, those who are attracted to education are often in the lower one-third of their graduating classes in science and math.

A great many science teachers must maintain another job to financially survive. The month before I left for Washington, D.C., to receive the Presidential Award, I averaged 40 hours a week at my job, not my teaching job, my second job as an analytical chemist for the Mobay Corporation of Kansas City. I must work at two or more jobs to make ends meet and to try to pay for the college tuition for my son, who graduates this spring. Because of this, I often come to school physically and mentally worn out. I am not the exception, I am the rule.

One of the biggest frustrations I feel in education is that because I have reached the top of my salary schedule and years service to my school, I cannot get any increase in salary for another three years. No matter how hard I work, no matter how well I do my job, I can't increase my salary. There is little monetary incentives to do or be the best that you can be in education. This is one area where education can learn from industry. This is my sixth year with my secondary job, working summers and part time. I have received increases in wages, consideration, and responsibilities in those years. I do not view this job as a financial dead end, which is the way I often see my career in education.

As for the resources: As in most areas of education, it appears that there will always be a limited number of resources for classroom instruction. I have found that industry can play a major role in contributing to classroom supplies. What is considered as material no longer suitable for industrial needs is a godsend for education. School districts should form partnerships with community businesses and resources. Because of a partnership that my science department has formed with the Mobay Corporation, we have been able to improve science education in our districts and others. But many science classrooms are not located where these resources are available.

The science textbooks get larger, the contact time between student and teaching gets smaller, labs give way and are reduced in the name of safety and available resources. If these problems do not find solutions, our future as a leading nation in the world is very dubious.

If we do not make the science teaching fields ones which are competitive with industry, we can only expect more reports like, "A Nation at Risk" or the "International Science Report Card." The role of the United States in the 21st century can only be that of a second or third rate country, because the general population will be scientifically illiterate and unable to function in an advanced technological world. The very apex of democracy, the voting booth, will be of little salvation for an American population that has little understanding of the scientific issues they will be facing in the coming century.

Thank you.

[The prepared statement of Mr. Kavanaugh follows:]

TESTIMONY

to

HOUSE SUBCOMMITTEE
ON POSTSECONDARY EDUCATION

May 1, 1989

Kent Kavanaugh
Park Hill Senior High School
Kansas City, Missouri

I am an advanced chemistry teacher who teaches in an affluent suburban high school. Approximately 43% of the Park Hill School District lies within the city limits of Kansas City, Missouri. The area is centered around I-29 in the vicinity of Kansas City International Airport. The high school is about 20 minutes north of downtown Kansas City and about 20 minutes northeast of the Fairfax industrial area. The Park Hill District includes rural, suburban, and small town communities, in close proximity to urban and industrial centers. The district operates nine schools with a total enrollment of approximately 6,600 students.

I will give testimony to the problems as I see them in my classroom and in the educational field. Our educational efforts are beset by a number of hurdles affecting our ultimate successes and failures. In an attempt to address these problems, I have found that they are best approached from three separate categories: students, teachers and resources.

Students: Because the drop-out rate in the United States in about one out of four, I will only see about 75% of the possible number of students who could take science classes. Of these remaining three, a high percent have been turned off to science before they enter high school and will take the minimum science requirement to graduate. I have to spend a good percent of my time in the classroom convincing my students that they can succeed in science, that science is for everyone and not just the "elite".

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162

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Mr. WILLIAMS. Hal Gardner is the Executive Director of the Missouri Education Satellite Network, a consortium called Midlands Star Schools Consortium at Columbia. It is nice to have you with us, Mr. Gardner.

STATEMENT OF MR. HAL GARDNER, EXECUTIVE DIRECTOR, MISSOURI EDUCATION SATELLITE NETWORK, MIDLANDS STAR SCHOOLS CONSORTIUM, COLUMBIA, MISSOURI

Mr. GARDNER. Thank you, Mr. Chairman, Mr. Coleman.

I want to point out that the material in the folders, the brochures that I've given you, is primarily a listing of schools, sites, locations and places where things are happening by way of satellite delivery. That is a relatively new area. The Education Satellite Network is an intervention vehicle, primarily. It is a tube, a conduit. It is so much plumbing into which, I hope, that all kinds of things that we're hearing this morning can be poured.

The Education Satellite Network is a service of the Missouri School Boards Association and has been in operation since March of 1987. In that relatively short period of time, the concept of satellite-delivered instruction, enhancement in service, professional growth programming, as well community teleconferencing, has caught the imagination of educators and the public throughout Missouri and the nation.

The Network has been the recipient of two Federal grants—it is currently providing a major portion of service to public schools in Missouri—and will be receiving state monies from the proceeds on a new taxation on the rental of video cassettes which has been earmarked for distance learning. By the way, that will provide about $5.3 million dollars each year in the area of technology and education, which is a significant first in this state.

Education Satellite Network is the lead organization for Missouri's participation in the Star Schools Program, a program that was sponsored by Senator Kennedy last year, and enabled about $19 million dollars, to be distributed nationally to four consortia.

Our consortium, the Midlands Consortium, is comprised of Missouri, Oklahoma, Kansas, Alabama, and Mississippi. It is with this most recent funding that the Education Satellite Network has been able to build its own studios and facilities and hire the personnel required to produce and transmit programming throughout the consortium states and the Americas.

While there are a variety of kinds of programming services made available to schools, this testimony focuses on science and mathematics instruction as it applies to secondary education in selected Missouri downlink receiving sights during the 1988-89 school year.

The '89-'90 school year will show growth, causing the present-day numbers to seem somewhat insignificant, except, of course, to the students taking the courses this year. They simply wouldn't have had an opportunity had it not been for satellite delivered physics calculus, analytic geometry, and a number of other science related teleconferencing opportunities.

I read, now, just a portion from our program guide of a particular success story, how the Missouri students taking courses by satellite stacked up with others across the country. Very well, indeed, if Clint Rybak is any indication. Rybak takes advanced placement physics, a satellite delivered course offered through the Education Satellite Network in Oklahoma State University.

He is a junior at Cooper County Consolidated High School in Pilot Grove, Missouri. Recently he scored an 83 percent, a top score among 471 students enrolled, on advanced placement physics test conducted by Oklahoma State University. The average score ranged from 34 to 50 percent. The physics class is aired to Pilot Grove students from the Oklahoma State University transmission facilities and is under the guidance of Cynthia Castle. Advanced placement physics by satellite reaches 170 schools in 13 states.

"We have been very pleased with the satellite program in our school districts," said Richard Mandall, superintendent in the Pilot Grove School District. "It permits us to provide both physics and German classes to our students, classes that otherwise would not have been possible. Our teachers are also making extensive use of other programming available on the network, and integrating it into their regular classroom activities."

Advanced placement physics by satellite is a one-year advanced placement course designed for high school students with solid math backgrounds. It aims to help students appreciate the physical world around them and to prepare them for college physics. While this is an introductory course, it also meets the College Board requirements for advanced placement. Advanced placement physics is taught by Dr. Peter Shoal at OSU.

A.P. physics by satellite is just one of a number of instructional courses now offered by the satellite network. Others include advanced senior English, calculus, German, and pre-calculus. Plans for next year include offering courses in trigonometry, Russian, Spanish, advanced placement chemistry, basic English, economics, and American Government.

Kansas State University will develop a genetics course that will become available in the Fall of '87. We have two schools right now being piloted this summer. They have already received kits of beetles and other miscellaneous supplies that they will be doing some genetics experimentation on this summer. That will lead to a full course implementation come Fall.

Finally, teachers and teaching partners will advance their understanding of many issues in the field through distance learning via satellite. Through a number of teleconference activities sponsored by agencies all over the world, including NASA, the National Science Foundation, and the National Diffusion Project.

Our hopes are that those of you in this room, those engaged in the employment, the education, and training of students in technology areas, science and math, will take advantage of the new and viable mass of satellite receiving sites located throughout, not only Missouri, but throughout the nation, and that we can join in the effort to bring an enlivened approach to science and math teaching in our nation's schools.

Thank you.

[The prepared statement of Hal Gardner follows:]

Missouri School Boards Association
EDUCATION SATELLITE NETWORK

OTA Testimony

Hal Gardner
Director, Satellite Communications
MSBA/ESN
2100 I-70 Drive, Southwest
Columbia, Missouri 65203
314/445-9920

Monday, May 1, 1989

The Missouri School Boards Association (MSBA) developed the Education Satellite Network (ESN) to provide more equitable access to education for all students in Missouri. ESN offers a unique learning resource to school districts by providing enhancement and enrichment programming, in-service and staff development programs, as well as instructional courses for high school credit via satellite.

The Education Satellite Network consists of member schools located across the state of Missouri -- a "network" of satellite downlink sites offering a convenient and cost-effective communications service to not only schools, but government agencies, business organizations, and private industry.

In September, 1987, MSBA/ESN was awarded a $319,050 federal grant to assist certain rural counties in parts of Northern and Southeastern Missouri in obtaining satellite receiving equipment for distance learning. The grant is an historic one; awarded by the National Telecommunications Information Administration (NTIA), it is the first of its kind anywhere in the United States.

As a member of the Midlands Consortium, a five-state consortium consisting of Alabama, Kansas, Mississippi, and Oklahoma, MSBA was awarded federal grant money in October, 1988, as a result of the "Star Schools" legislation. This money is being used to fund the expansion of the Education Satellite Network, including construction of a production studio, addition of an editing suite at the Department of Elementary and Secondary Education (DESE) studios in Jefferson City, the purchase of a production van and a mobile Band uplink truck, and the production of several staff-development and in-service teleconferences in cooperation with the DESE.

As a recipient of this federal funding, Missouri is receiving national attention as a provider of satellite learning. Schools in Missouri are taking advantage of this unique resource, increasing educational opportunities for all students.

Topics for teleconferences and programming range from Science Awareness to The Legislative Branch Under the Constitution. Participants are able to interact via phone lines with the speakers despite the difference in location, phoning in questions and comments and getting an immediate response from the presenter in the studio.

Currently there are 67 active members participating in the ESN program, representing over 30,000 students; 15 sites are pending installation. We anticipate a substantial increase in membership in Missouri after July 1 due mainly to the distribution of funds collected through SB 709. A minimum growth of 90% is projected, reaching as high as 225% by September 1, 1989. We are also expanding our services to reach schools nationwide.

Through services such as the Education Satellite Network, students are able to participate in programs covering such topics as physics, calculus, analytic geometry, various foreign languages, and chemistry. For many rural schools, satellite delivered broadcasts are their only opportunity of offering such courses; geographic and monetary limitations restrict many districts from providing advanced-level mathematics, science, and foreign language courses.

Satellite-Delivered Science and Math

ESN Member OSU Course enrollment for School Year 88-89:

Bismarck R-IV		PreCalculus 7	
Braymer C-4	AP Physics 5		
Climax Springs	AP Physics 4		
Cooper Co. C-4	AP Physics 5*		
East Buchanan C-I	AP Physics 10		
East Carter Co. R-II	AP Physics 6		
Holden R-III	AP Physics 13		
N. Harrison Co. R-II	AP Physics 8		
Princeton	AP Physics 4		
S. Harrison Co.	AP Physics 16		
W. St. Francois R-IV	AP Physics 5		AP Calculus 6
ESN TOTALS:	AP Physics 76	PreCalculus 7	AP Calculus 6
OSU TOTALS:	AP Physics 471**	PreCalculus 92	AP Calculus 28

* Clint Rybak, HS junior at Cooper Co. C-4 scored 83% in AP Physics exam. (average score ranges from 34 to 50 percent)

** AP Physics by Satellite reaches 170 schools in 13 states.

OSU Added Math/Science Course Offerings for 89-90 School Year:

AP Chemistry by Satellite

Trigonometry/Analytic Geometry by Satellite (former PreCalculus)

Applied Economics by Satellite (Fall semester only)

Spring 89 Science Teleconferences:

NASA: 3/21 "Technology & Your Classroom"
Applications of NASA's aerospace research to industry and classrooms. Featured NASA Ames Research Center and its new supercomputer, the Numerical Aerodynamic simulator.

LESN: 4/4 "Joint Missions in Space" (co-sponsor, Challenger Center for Space Science Education)
Discussions on past, present and future of the Soviet and American space programs. Featured student-moderated, in-studio panel of 12 Soviet and American students, grades 4-12.

4/ "Fueling Man's Flight to the Future" (co-sponsor, Martin Marietta Corp)
Featured manufacture of the space shuttle's external propellant tank (grades 6-12). Live interaction with scientists and engineers.

NATIONAL DIFFUSION NETWORK:
3/1 "Science Awareness"
Science segments for elementary & secondary students
"Marine Science. For Sea"
"Starwalk" (astronomy, grades 3 & 5)
Hands-On Elementary Science" (grades 1-5)

SCISTAR: 5-Part Series from Talcott Mountain Science Center ($25 fee)
Produced for middle and high school students
11 ESN member sites participated

3/13 "Electronic & Computer Music"
Dr. Robert Moog, inventor of the Moog Synthesizer
3/20 "New Champion Among Women Comet Discoverers"
Dr. Carolyn Shoemaker, discovered more comets than any other astronomer
4/3 "Searching for Extraterrestrial Intelligence, Science Fact, Not fiction!"
Dr. Jill Tarter, fr NASA's Ames Research Center
5/1 "Life in an Undersea De
Dr. Eugenie Clark, featured in 10 Nat'l Geographic
5/15 "Sonar and the Animal World"
Dr. Julia Chase-Brand, mammalogist & animal behaviorist

SCISTAR: Free Teleconferences:

3/6 "Title II Projects"
Boston Project: Harbor Explorations
New York Project: More Math for More Females"

To be rescheduled: "Project Prism," a Maine project

Star Schools Proje^ts:

OSU: "Distance Education: Is the Sky the Limit?"

4/6 Part I: Kevin Smith, ,t President of the International Council on Distance Education. Looked at meeting the curriculum needs of today's classroom.

4/13 Part II: Dr. Glenn Kessler, Director of Media Services, Fairfax County, VA, on making technology understandable.

4/20 Part III: Will Kitchen, President of Tele-Systems Associates, Inc., Bloomington, MN, on supporting effective distance education programs.

4/27 Part IV: Features simultaneous audi. conference with national and international distance educators, plus a presentation from the MIT Media Laboratory.

K STATE:

5/1-5 "Genetics: An Enrichment Program for HS Biology Students"
Five-part series, 45 min. each
Two MO Pilot Schools: Fox C-6 at Arnold & Fulton. Schools received lab experiments prior to teleconferences. Fox C-6 running cable to biology lab. Experiments including plants and live beetles are underway.

5/10 "It's a New World: Science, Language & Math Motivational Workshop"
Staff development for jr. high/middle school educators & guidance counselors.

5/23 "What is COMETS"
5/25 "Resource Panel and Open Forum"
9/26 "Wrap-up with COMETS and open discussion"

"COMETS" (Career Oriented Modules to Explore Topics in Science" (3-Part series for educators of grades 5-9) Funded by the National Science Foundation. Show students that science study has practical applications. Encourage early adolescents, both girls & boys, to consider a science-related career. Use community resource people to help teach science lessons and stimulate student interest in science. Spice up science lessons and increase student interest in science.

Science & Math Programming

THE LEARNING CHANNEL: (Spring '89)

The Challenge of the Unknown (math & problem solving, 7 half-hrs)
College Entrance Exam Math Review (math portion/SAT, 5 half-hrs)
Computers at Work (15 half-hrs)
Earth, Sea & Sky (concepts of earth science, 30 half-hrs)
For All Practical Purposes: Contemporary Math (26 half-hrs)
High School Algebra Review (basic principals, 1 half-hr)
Intro to Logic, Probability, Statistics & Geometry (1 half-hr)
Life in the Universe (US space prog. NASA/produced, 13 half-hrs)
Math Review for the ACT (1 half-hr)
Civil Service Exam (1 half-hr)
GED (1 half-hr)
GMAT (1 half-hr)
GRE (1 half-hr)
SAT-PSAT (1 half-hr)
Math TV (high school math series, MTV style, 8 half-hrs)
The New Literacy: An Intro to computers (30 half-hrs)
Oceanus: The Marine Environment (30 half-hrs)
Planet Earth (7 one-hrs)
Principles of Accounting (30 half-hrs)
Real Life Math: Decimals (1 half-hr)
Real Life Math: Fractions (1 half-hr)
Review of Arithmetic (basic arithmetic principles, 1 half-hr)
Science Fiction, Science Fact (NASA, 1 hr)
The Search for Solutions (fun science/prob solving, 9 half-hrs)
A Touching Way to Teach Math (for teachers/parents, 2 half-hrs)
Universe (NASA, 1 half-hr)

THE DISCOVERY CHANNEL: (May Program

Arctic IV (Canadian scientist/North Pole)
Australia Naturally (insects/animal science)
Beyond 2000 (scientific & technological interest)
The Big Ice (scientists/Antarctica)
Natural World (research/science/environment/animals, etc)
The Nature of Things (technology/animal communication/nature)
Profiles of Nature (animal science)
Secrets of Nature (animal science)
World Showcase (solar energy/weather/robots)

Mr. WILLIAMS. Our final witness on this panel is Dr. Dennis Wint. Dr. Wint is the president of the St. Louis Science Center. Doctor.

STATEMENT OF DR. DENNIS M. WINT, PRESIDENT, ST. LOUIS SCIENCE CENTER, ST. LOUIS, MISSOURI

Dr. WINT. Thank you, Mr. Chairman, Mr. Coleman.

I am honored to speak to you this morning and share with you my thoughts about science education, and I will address the role of science centers as partners in the formal educational institution and also focus my comments primarily at the elementary school, which is where I see the greatest need lies. If we have not excited and motivated students in science at the elementary level, it is unlikely, as we have heard, that they will become interested in high school or college.

We are not only concerned about the issues of enough qualified scientists and mathematicians and chemists and teachers, but also the adequately educated population to deal with living in a complex scientific and technological society. In the past, the welfare of the nation has been relatively secure with the few exceptionally well-trained men and women. This is no longer the case because of competition from other industrialized nations.

As documented in many reports, the general agreement for the decline of pre-college science education includes too little time spent on the teaching of science, insufficient curricular materials that demonstrate the importance of science through application, improved learning through the interest and the involvement of the student, cultivate the student's problem solving skills and personal investigation, and the decline of the number of qualified science teachers. I add a fourth, a lack of parental participation in demanding an effective science program within our schools.

One nationwide study indicated that students in grades one through six spend an average of 85 minutes per day on reading, 45 minutes on mathematics, 25 minutes in social studies, and 20 minutes per day on science. Out of 25 instructional hours per week, students only spend one hour on science.

As we have heard from Cynthia Yocum, science instruction in the elementary school is resulting in a curriculum that is underfunded in terms of equipment and supplies. It is taught by a woman who is generally without the content background and is uncomfortable with the subject matter; who relies on the textbook for science instruction; who receives little support from the school administration; and who spends only one hour per week in the study of science.

The impact on students is not surprising. We are turning students off to science in the elementary grades before they have ever entered high school and taken their first serious course in science. A national study of student attitudes reveal that by the end of the third grade, 50 percent of the students are no longer interested in taking science—50 percent, third grade. By the end of the eighth grade, only 21 percent have a positive attitude. For elementary students, science too often means learning names, facts, and scientific principles with a teacher or the textbook serving as the authority;

for students have little understanding of the physical and the biological world, do not understand the process of scientific investigation nor experience the excitement of scientific discovery.

You can think of in this way: Your child comes home and has said, "Dad, I learned how to play basketball today. They gave me a textbook and the first chapter was on how you dribble. You take the basketball and you push it down on the ground and it will come back up. You can push it back and forth and that is dribbling. You can walk and dribble, but you cannot walk without dribbling. At the back of that chapter was a test, and I answered all of those questions correctly. The second chapter was on how to shoot a foul shot."

That is the way we too often teach science. Parents would never tolerate this in the basketball program, but we do tolerate it in our science education program.

It is estimated that the elementary students spend about 70 percent of their waking hours in activities that are not related to watching television or going to school. That is an excellent opportunity to capitalize on science centers, botanical gardens, zoos, aquaria; to supplement, reinforce and to extend the educational experience.

While the science centers represent only 18 percent of all museums in the nation, they account for 45 percent of the attendance. The St. Louis Science Center, with only 13,000 square feet of public space, had an attendance in 1988 of 1,073,000 people, making us the fourth most popular attraction in the state, sharing honors with the baseball Cardinals, the St. Louis Arch, and the St. Louis Zoo.

When one includes zoos, botanical gardens, arboretum, planetaria, nature centers, the total attendance exceeds 150,000,000 visitors annually, which equals the combined attendance of professional football, baseball, and basketball.

Science centers translate science from the scientist to the general public. They are examples of informal learning institutions that supplement and reinforce the lessons of the classroom through the richness and diversity of the hands-on participatory exhibition in education programs. Science centers are effective partners, instilling the sense of excitement, enthusiasm, motivation, and personal investigation and satisfaction. They also serve as a place where after school the parent and the child can learn together in a joint learning experience.

Science centers have four important criteria that make them unique partners: One, they emphasize the primary object. When you come to the science center and see the Gemini VI space capsule, it is the real Gemini VI. It is not a fabrication. It is not a photograph. It is the real thing.

Two, they emphasize the primary experience. We want you to practice science, yourself. Not watch someone else do it, not read it in a textbook, not watch a movie, but actually participate in the science process

Third, they are positive learning environments that are suitable and accessible for all people regardless of race, age, educational background.

Lastly, they are voluntary places to learn. There are no grades. There are no diplomas. As Frank Openheimer, the late director of the Explorat ium in San Francisco said, "No one ever flunked a science museum."

Science centers focus not only on cognition, but the effective domain, the attitudes of our audience, to promote an interest in science, and become knowledgeable and informed of the scientific processes which effect our daily lives.

Science centers can serve as an effective partner in the education of children and the entire community.

Thank you.

[The prepared statement of Dr. Dennis M. Wint follows:]

SCIENCE EDUCATION: THE CHALLENGE AND THE FUTURE

COMMITTEE ON EDUCATION AND LABOR

SUBCOMMITTEE ON POSTSECONDARY EDUCATION

U.S. HOUSE OF REPRESENTATIVES

May 1, 1989

Presented by:

Dennis M. Wint, President

St. Louis Science Center

5050 Oakland Avenue

St. Louis, Missouri 63110

I am honored to speak before you this morning to share with you my thoughts about science, mathematics, and engineering education and the ability of our educational system to prepare our Nation with a scientifically and technologically literate population. I will address the role of science centers as partners with the formal educational institutions, and will focus my comments on the elementary school where I see the greatest need. If we have not excited and motivated students about science in the elementary school, it is unlikely they will become interested in high school or college.

Since the launching of Sputnik in 1957, the United States has placed an emphasis on science education through the formal educational institution, our schools. However, by nearly all measures of success, we are experiencing a national crises. The United States is lacking in two critical areas:

- The recruitment and training of enough qualified scientists and teachers to maintain the Nation's prosperity, and

- The adequate preparation of the general population with enough scientific concepts and information to use the process skills needed by every person to function in an increasingly complex scientific and technological society, and to function in their daily lives, their work, and their role as decision makers.

For the first time in the history of the United States, this current generation of students is less well educated than the previous generation.

Dr. Paul Hurd, Professor Emeritus of Stanford University, has stated "We are raising a generation of Americans that is scientifically and technologically illiterate."

The defi encies come at a time when highly skilled workers are needed i many accelerating new fields, when there is a proliferation of comp'ters and computer controlled equipment into every day aspects of life, where there is an increase in occupations related to science and technology, and where technology is transforming a ho.t of occupations.

In the past, the welfare of the Nation was relatively secure with a few exceptionally well-trained men and women. This is no longer the case because of competition from other industrialized nations. The world is seeing a redistribution of training capabilities and the resources needed for future growth.

The report Nation at Risk stated "Knowledge, learning, information, and skilled intelligence are the new raw materials of international commerce and are today spreading throughout the world as vigorously as miracle drugs, synthetic fertilizers, and blue jeans did earlier. Learning is the indispensable investment required for success in the 'Information age' we are entering."

The report continues "... the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves".

Since this important report in 1983, there had been many reports prepared by the National Science Foundation, National Academy of Sciences, the National Assessment of Educational Progress, and others which have further documented the scope and seriousness of the problems facing our communities and Nation. There is general agreement the leading cause for the decline of pre-college education includes:

- Too little time spent on teaching of science;

- Insufficient curricular materials that demonstrate the importance of science through application, improve learning through the interest and involvement of the student, cultivating the student's problem solving skills, and personal investigation

- The decline in the number of qualified science teachers,

and I add a fourth,

- The lack of parental participation in demanding an effective science program within our schools.

For nearly a decade, the enrollment in science courses in high school and college has been decreasing, and students are less motivated to study science. "If a reasonable degree of scientific and technological literacy is an expectation of a high school education, it is not being achieved," states Paul Hurd.

Schools have not provided quality science education at the elementary level necessary to interest students in pursuing science at the high school and college levels, and to understa the scientific and technological changes affecting our daily lives.

On a nation wide study, students in grades one through six spend an average of 85 minutes a day on reading, 45 minutes on mathematics, 25 minutes on social studies, and 20 minutes per day on science. Out of 25 instructional hours per week, students spend only about one hour on science instruction.

Science instruction in the elementary school is also compounded by other problems including: lower allocation of education resources to elementary schools versus high schools; larger percentage of women teachers at the elementary level; lack of college level science courses in the training of elementary teachers; sexual stereotyping in women which has resulted in a larger percentage of women teachers uncomfortable and ill equipped with the teaching of science; and a shortage of qualified science teachers.

What emerges is an elementary science curriculum that is under funded in terms of equipment and supplies, is taught by a woman who is generally without a content background and uncomfortable with the subject matter, who relies on a text book for the science instruction, who does not receive the necessary support from the school administration, and who spends only about one instructional hour per week on science.

The impact on students is not surprising. We are turning students off to science in the elementary grades, before they have entered high school and taking their first serious course in science. One national survey of student attitudes toward science revealed that by the end of the third grade, nearly 50 percent of the students are not interested in taking any additional science. By the end of the eighth grade, only 21 percent of the students have a positive attitude about science.

One of the major reasons for the lack of interest in science results from the emphasis on memorization and recall skills. For elementary students, science too often means learning names, facts, and scientific principles with the teachers and/or textbook serving as the authority. Students have little understanding of the physical and biological world, do not understand the process of scientific investigation, or experience of the excitement of scientific discovery.

Parents must expect more from the educational programs in our schools. And parents must be willing to provide the time and support for learning that takes place in the home and community, in addition to learning which takes place in the schools.

The problems we are experiencing have no quick fix. However, there are solutions which can be explored and implemented to help resolve the problem.

If one reviews the time children spend their waking hours, one sees the following:

- 11,000 hours or 13 percent in school
- 13 ' or 17 percent watching television
- 55, or 70 percent in other activities that are not rela d to school or watching television

This 70 per nt not spent in school or watching te vision is an excellent op tunity for other learning to take p e, such as in a science center, botanical garden, zoo, or aqua. ium. The important role of these institutions is to supplement, reinforce, and extend the education that takes place in our schools. These institutions are an effective partner through instilling a sense of excitement, enthusiasm, motivation, and personal investigation and satisfaction.

The National Science Board Commission on Pre-college education in mathematics, science, and technology stated th exposure to scientific concepts and processes at an early age is critical to later achievement. The "...top priority must be on providing more effective instruction in grades K-6."

The commission report continued:

> "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 nature trails and built model airplanes and telescopes is infinitely better prepared for, and more receptive to the mathematics and science of the classroom."

While science centers represent only 18 percent of all museums in the Nation, they account for 45 percent of the audience. For example, the St. Louis Science Center with only 13,000 square feet of program space had an attendance in 1988 of nearly 1,075 000 visitors, making us the fourth most popular attraction in the city, with the baseball Cardinals, the St. Louis Arch, and the St. Louis Zoo. If one includes zoos, planetaria, botanical gardens, aquaria, and nature centers, the total attendance exceeds 150 million visitors annually, which equals the combined attendance of professional football, baseball, and basketball.

Science centers translate science from the scientist to the public. They are examples of "informal educational" institutions that are effective agents of the education of children in the fundamentals of science.

The experience in a science center supplements and reinforces the lesson of the classroom because of the richness and diversity of the exhibitions and educational programs. It is also a place where after school the parent and child can learn together in a joint learning experience.

Science centers have four important characteristics that make them unique partners in the education of children and the general public:

1. The primary object

2. The primary experience

3. Positive learning environment

4. Voluntary place to learn. There are no grades or diplomas. As Frank Oppenheimer, the late director of the Exploratorium in San Francisco, said "No one ever flunks a museum."

Science centers not only have classes for children and adults, but they sponsor in-service teacher workshops. Nearly 90 percent of the science centers have programs especially for teachers, and 33 percent cooperate with colleges and universities to offer training for degree programs.

Through a recent grant from General Education and administered by The Association of Science-Technology Centers known as ASTC, 50 science centers are participating in the program "Science Teacher Education at Museums" (STEAM).

Science centers provide a wide range of program services including:

1. Training and support for television science programs including 3-2-1 Contact and NOVA

2. Career motivation programs for young girls and minorities

3. Programs for the gifted

4. Curriculum and materials development

5. Special programs eg,. museum camp-ins and overnights for school classes and scout groups

Most science centers also have an outreach component where educational programs and/or exhibits are taken to neighboring communities. The presentations may last an hour or two, or the science center staff may spend the entire day working with students during the school day and teachers thereafter.

A science center focuses not only on cognition, but on the effective domain, the attitudes of our audience, to promote an interest in science careers and to become knowledgeable and informed of scientific processes which effect our daily lives.

Congress can perform an important role in promoting science education through both the allocation of resources as well as assisting in setting a national agenda. I would like to suggest the following issues, not or less listed in order or priori'

RESEARCH ON SUCCESSES AND FAILURES OF INNOVATIONS:

Between the early 1960's and the mid-1970's, more money was allocated for the improvement of science education than in the history of the Nation. During the same period and continuing into the 1980's, science performance continued to decrease to the point that this Nation is at risk.

The allocation of adequate resources is very much needed, but we also need a new way of thinking about science education. We must clearly understand the factors contributing to the lack of success in order not to repeat the problems in the 1990's, eg, the "alphabet" curriculums and teacher training program, and capitalize on the advances in educational technology and the development of a partnership with community resources.

CLEAR DEFINITION OF THE PROBLEMS OF SCIENCE EDUCATION

While many reports exists which outline the problems facing the Nation, I feel there needs to be a more carefully articulated definition of the question. For example, is there a lack of qualified teachers or are jobs unavailable because of seniority and the unionization? The problems are complex, but without more carefully articulated questions, we will be unable to focus the limited resources to achieve the best possible results.

THE FEDERAL PRIORITY

The President, Congress, and the Nation must establish a national priority dedicated to the improvement of education in general and science education in particular.

An endorsement of a strong national agenda and the commitment of resources would set the stage for the Nation as a whole to address this fundamental concern. We must use our limited resources to think more creatively than only the "throw more money at the problem" and expect a successful solution.

Both the Department of Education and the National Science Foundation provide resources for the improvement of science education. I see a complementary relation, not a conflict between the two agencies and trust the funding for both will increase. As you may be aware, I am a member of the Science Education and Engineering (SEE) Advisory Committee of the National Science Foundation. We are working toward a funding goal of $600 million for SEE, $300 million for pre-college education, $200 million for undergraduate education, and $100 for fellowships and graduate education.

FOCUS ON THE HOME AND COMMUNITY RESOURCES

We need to develop the concept of the learning society, a society in which learning does not take place only between the ages of 6-18 in the confines of a school classroom, but throughout one's life in all parts of the community. This philosophy includes informal educational institutions as partners in the educational process.

The home and community are two of the most important and effective learning environments of the child. Parents must continue to learn about science in order to be effective teachers with the child. And more learning opportunities are needed within the community to support the learning of the home and school.

Science centers are effective agents in the education of audiences of all ages about science and technology. Financial support is needed to develop innovative educational programs, eg, the magnet school concept being planned with the St. Louis Science Center.

Thank you for the opportunity to speak before you about this important topic.

Mr. WILLIAMS. My thanks to each of you. Mr. Coleman.

Mr. COLEMAN. Thank you, Mr. Chairman. Let me say to Kent Kavanaugh, who, indeed, has been recognized for his outstanding teaching ability by being named the Presidential award winner for excellence in science and math. I hope you're not got getting burned out as I feel that your testimony is telling me.

He has annually produced outstanding people over at Park Hill, and many of them have applied to the academies as they want to do, or to go on to higher education.

We wouldn't want to lose a resource such as you.

You said in your testimony that most people are turned off by the time you see them in high school. Do you agree with the reasons why, that it is the methodology of the elementary and junior high classroom techniques, or are there other reasons?

Mr. KAVANAUGH. I believe it is a collage of reasons. I think what we've mentioned here, this testimony covers a lot of them. I think it is tradition to some extent, that the elementary teacher must be equipped to be chief bottle washer of the entire educational program. We've taken the philosophy that a little bit is better than nothing. We really do not prepare the elementary teachers, specifically, in the fields of science, to teach the technology base that we have to have for the 21st century.

Mr. COLEMAN. Is that a reflection of our entire process of training teachers and certification?

Mr. KAVANAUGH. It certainly is a reflection on the training of teachers. The certification of teachers is another problem that we're going to have to address. We are certifying teachers at the elementary, but specifically the secondary level, in sciences, that had little more than the blind leading the blind.

I think a personal story in this case is in point. My first position when I began to teach, they requested that I teach biology. I had five hours of college prep biology. Knowing that I probably would not be certified, I agreed and, of course, signed the contract. But I had ten hours of biochemistry. So I guess the state took a look at it and said, well, it begins with b-i-o, that is close enough, we'll give it to him. So the consequence, I was certified and found myself teaching high school biology with little less than five hours at the college level.

I realize the limits of a science teacher, and the critical need forces this type of certification. But it is only perpetuating the syndrome that we are hearing in this classroom right now. It is not a solution. It is a band-aid over a major wound on that same education process.

Mr. COLEMAN. Dr. Hill, I would want the record to show that, as the chairperson of the Mathematical Sciences Education Board, National Research Council, you referred to the report, Everybody Counts, which the Council recently issued, and as I told you privately the other day it was such an outstanding and extremely interesting report to read, it challenges all of us.

I wonder if, in that reform of the mathematical curriculum, you might tell us a little bit of what Federal role you envision your recommendations to impact.

What can we do as Federal congressmen to help, if you will, assist you and your colleagues? I'm trying to, as you say, turn the whole upside down and really generate some different methodology.

Dr. HILL. Well, I mentioned two quite distinct things, and let me be a little more specific, if I may.

One is, I think that the Federal role and through the Congress there is a critical role in really helping to build an encouragement climate for innovation. Then, you know, that is not very specific, but we can get down to the specifics of funding, of course, where there are particular kinds of things in research that the Federal Government can do.

I do not believe that the funding of experimental curricula, as totality as on a national level, to be either imposed or accepted or adopted at local and state levels is the way to go. I think we've tried that, and that really didn't work.

Neither do I think that having every single locality do it, go it alone and completely revise the curriculum, can possibly work. You do have the merits there of the ownership of individuals and teachers, but you have the demerits of—none of us have a critical mass of expertise to carry that off. I think there is a way that national leadership can be supportive and, in its research aspects, funded by the Federal Government in an, what we call and everybody counts it, augmented grass roots approach, where you do have support to develop the consensus I mentioned about goals and standards that everyone can accept, but on a voluntary basis.

Then, help of all kinds: materials, personnel. Really, almost in some ways, I think, often like the old agricultural field agent—help to individual districts who are interested, cross-working with other districts in their own localities in making a total revision—I'm speaking now of a mathematics curriculum. I think that is going to take lots of people, and I think that lots of groups come together and the funding would be in many, many, you know, packages, partnerships, complementary kinds of funding.

But I think in the long haul, we're going to have to try that route.

The mathematics curriculum itself simply must change. I mentioned how old it is. That in itself wouldn't be bad, except that mathematics has changed. We don't even see in our curriculum all the things that have been discovered and developed in the last few hundred years. It is an invisible culture. That is the urgency of the change in the program itself.

The methodology, I think—because I don't really distinguish the methodology from the content. It should be more experimental. It is has got to be hands-on. We now talk in mathematics about laboratories and equipment. Our equipment is primarily calculators and computers, but nonetheless, it is needed and it is a very experimental subject now—a big task.

Mr. COLEMAN. Thank you very much.

Ms. Yocum, thank you being so frank and honest about some of the shortcomings of the profession and to recognize that there are opportunities for teachers to take advantage of. We're certainly glad that you are doing that and preparing yourself to help prepare our youngsters.

Mr. Gardner, it is exciting what high technology can do to bring about what may be a current lack of classroom capability to be able to tie in with others in this nation and use the resources that we have.

Dr. Wint, let me ask you a question. Who funds your science center?

Dr. WINT. Our operating budget is largely the result of a special taxing district, composed of St. Louis city and county village tax that is voted by the citizens. We also receive quite a bit of money from corporations. We are in the middle of a $34 million dollar capital campaign, of which $20 million has been raised, nearly all that has been corporate support.

Mr. COLEMAN. I assume you have a very close working relationship with all the school districts, then, for field trips and so forth.

Dr. WINT. That is right. Not only in terms of students coming to us, but we go out to them, take our programs. We are also increasingly involved in in-service teacher training.

Mr. COLEMAN. I thank all of you for coming.

Mr. WILLIAMS. Dr. Wint, do you receive money from the Institute of Museum Services?

Dr. WINT. We have not been.

Mr. WILLIAMS. Have you applied for any——

Dr. WINT. Yes.

Mr. WILLIAMS. Let me be the devil's advocate for just a moment. All of you on both panels have said that science and math is fun. The American people don't agree, overwhelmingly don't agree. What happened?

Dr. WINT. It is in the wrong context.

Mr. WILLIAMS. What do you mean by that?

Dr. WINT. I believe someone before talked about the way we teach mathematics. A 500-year-old curriculum and a 300-year-old instructional methodology. I think we have done some of the same things in science, in that the context of the instruction is one in which the real essence of science is not experienced. It needs to be changed. I'm less concerned about the curriculum and more about the methodology in the instruction, where science becomes something that is real and fundamental to what we all need to do on a day-to-day basis.

Dr. HILL. I think that we see in mathematics the clear evidence of what happens. If you can get it with very young children, even the surveys that have been taken recently about attitudes towards subjects, they do like mathematics—and I'm sure science, too. They do find it exciting when it is hands-on, when they plunge in with materials and situations. They are very excited about it. Then, for some reason, through schooling and, I think, society and the attitudes of their parents, an apprehension is developed of fear and sometimes even a loathing, and that is passed along. There are a lot of myths that parents pass along. "I wasn't very good in mathematics, so you probably don't need to be, either." This is, unfortunately, too often true of the female parent and the female child.

We do make, in school, a subject that is inherently interesting, often very dull, memorize a lot of formulas, grind it out, I'll show you how to do one problem and then you do 50 more like it. That is dull for me. I would hate such a subject. I know that is not the subject that I, in fact, love.

So, I think school takes part of the burden of the blame that I think society, in general, has the wrong ideas about the subject and passes those along.

The Mathematical Sciences Education Board has a cooperative program now with the PTA, which I have great hopes for. The PTA is sending kits about mathematics and what you as a parent can do with your children and with your schools as partners, to every single PTA in this country. I think those kinds of things will eventually make a difference.

Mr. WILLIAMS. Let me suggest that some of what is happening today is only going to hammer in the dislike for math and science by the American people.

We are taking, in our rush to go back to the basics, we are requiring today's college students to take increased amounts of math and science, and they are unprepared to do it. They didn't know when they came through elementary and high school that in college there was suddenly going to be the installation of a new basic curriculum, and that they would have to meet it in order to graduate. Those people dislike math and science now, more than they ever did.

I think we're making a mistake, my friends, to suddenly incorporate those requirements on an unsuspecting student population unprepared to meet it.

But it is a typical American response. By the way, not a national response, but a local, the typical American local response.

Cynthia Yocum can't remember a single exciting science experiment all the way through school. And she probably came along when many of today's teachers did, just before or after America's advent into space, when one would think that there was a lot of excitement in the classroom.

We don't have the answer, obviously, either. But let me suggest to you that the answer will not be found at the Federal level, because Federal government only incidentally affects quality in the schools. Our job is one of providing access and equity.

We have, for better or worse as Americans, left it to the state and the localities to determine the quality of their schools. The Federal Government has then simply moved in and said, now, everyone has access to whatever quality school it is you decide you want in Kansas City, or Helena, Montana, or wherever it was.

We can, of course, affect quality at the Federal level, but the American people have seemed somewhat resistant to us doing that—perhaps, correctly.

Well, let me join my friend, Tom Coleman, in saying that your panel has indeed been very helpful to us. We appreciate it that you could come.

On our third panel: David Drew, Judson Sheridan, and Ed Wilson. Please come to the table.

Before this panel begins, I would like to make one additional, short comment about something that was said by the last panel, and this with regard to the competition between the private sector and America's school systems for people who would be teachers.

It is difficult to keep them down in the classroom once they've seen the Nova Project or Monsanto or G.E. That is not to say that each of those companies, Livermore, Monsanto, and G.E., and all the others, aren't very interested in having quality teachers teach. Of course, they are. But they also have to have good personnel for their operations, and there is a competition there that the public has not quite figured out how to resolve. It is very serious, as Dr. Hill mentioned in her opening remarks.

Let's begin with Dr. David Eli Drew, a Professor of Education and Public Policy from Claremont, California.

STATEMENT OF DR. DAVID ELI DREW, PROFESSOR OF EDUCATION AND PUBLIC POLICY, CLAREMONT, CALIFORNIA

Dr. Drew. Thank you. Good morning, Mr. Chairman. Good morning, Mr. Coleman.

Dr. Wint used the basketball metaphor, and I think I would like to begin my comments with a story about basketball that, perhaps, symbolizes the kinds of problems we're discussing here today. It is a story that Frank Layden, the former coach of the Utah Jazz, has told on several occasions.

He has talked about his difficulties in trying to instruct one of his basketball players in a certain maneuver. He set aside some time and he worked with this player about an hour a day for three weeks. The player still wasn't getting it. Finally, in great frustration he said to this player, you know, we've been working on this for three weeks. You're not getting it, and to tell you the truth, I can't tell if the problem here is ignorance or apathy. The player glared at him and said, I don't know and I don't care.

One way to summarize what we're discussing today, is that our young people don't know about science and most of them don't care about science. I've put together some data for this subcommittee and, in the interest of time, I would just like to present some of it.

The first figure I have—the figures in the report that I have presented to you begin after page 11—the first figure is very much like the one on this impressively done placard on the other table, about the Ph.D's awarded to foreign citizens. Mine is about foreign graduate students in the sciences and breaks it up into several disciplines. It compares 1980 and '85.

There already has been some discussion of the high percentage of foreign students in our graduate schools. My opinions about this situation were summarized very well in an interview—were expressed better—by Harvard professor, Sheldon Glashow, a Nobel prize winner in physics. This is what he said: "We import them. We import them from Iran, we import them from Turkey, and Taiwan, from whatever countries we can find. They stay in this country—more than half of them stay in this country—they take all the good jobs. I'm not attacking this, this is not a problem. This is the solution. These new Americans, who are a vital part of America today and are the technological backbone of the country, are the solution. Our people can't hack it." What really bothers me is that last comment by Professor Glashow, "our people can't hack it."

I will not repeat some of the data that you've heard before about the international comparisons. I've included some of that in my paper, and I believe I'll skip over that. Even when our educational system works for anglo middle-class male children, it discourages females and minorities from science careers. Mr. Williams mentioned a low percentage of women who achieve baccalaureates in the sciences. In Figure 2 of my paper, I've got some data about engineering Ph.D's. You'll notice, as expected, less than half went to U.S. citizens, 1,661. These are engineers, Ph.D's, in a recent year, 1986. Of those, only 139 were women, 25 Hispanics, 14 Blacks, 6 American Indians.

So, that is another dimension of the problem and, of course, these women and minority students represent the resource that we can use to remedy the problem.

You'll note that Figure 3 presents some data about the attitudes of young people towards science—in declining percentages during the school years who feel that science is fun or interesting or exciting.

Most of the data I have here are about college students and their choice of science and engineering careers. These are from the Cooperative Institutional Research Program or the Higher Education Research Institute. Also, in the interest of giving you as much data as possible, I have included, tentatively—and I'd like to request that I might be allowed to include in the formal record a statement by my colleague, Kenneth Green—Casey Green—who has written a paper I've included here, which has even more data about freshmen choice based on the freshmen survey.

Mr. WILLIAMS. If there is no objection, that will be included in the hearing record.

Dr. DREW. Thank you.

I'd like to add one other comment from my paper, one other topic, in the interest of time.

I believe that encouraging college students to go into science depends in part upon having professors who are actively engaged in research. I believe that you cannot examine the problems of science education at the undergraduate level without also considering how research is conducted, where it is conducted, and how Federal research funds are allocated.

Very briefly, I've argued elsewhere and in this paper that Federal research funds are very concentrated in a few institutions. This has been true for a number of years, and I have a pie-chart here that illustrates this, Figure 7, shows, for example, that almost 50 percent of Federal R&D funds go to 20 institutions.

We want our science funds to go to the best researchers, wherever they are. But I also present some data here that suggests that in the past 15 years, because of the tenure logjam in the universities, many of the brightest, best, young Ph.D's from the best institutions have taken jobs at second and third tier institutions; and that a small investment in research funds to those scientists at those institutions can greatly enhance our research effort, and more to the point for the reasons we are here today, can provide centers of science excellence, regional centers of science excellence, that can draw young people into science and where they can see professors actively doing research. I discuss a program called EPSCOR, the Experimental Program to Stimulate Competitive Research, that achieved just that in five states that get a low amount of Federal science funds. One of them that was successful, if not the most successful EPSCOR program, was in Montana and I describe that program here in more detail. It was under the leadership of Gary Strobel, a plant pathologist at Montana State.

So, we have a problem in terms of the number of young people who are choosing science as a career. Associated with that are these dismal statistics about the performance of our young people in international competition.

There are a number of possible solutions to the problem. I discuss several in the paper. In the interest of time here, I focused on the higher education data and an example of a higher education solution.

Thank you.

[The prepared statement of Dr. David Eli Drew follows:]

Preserving America's Scientific Preeminence

David Eli Drew[1]
Claremont Graduate School

Prepared for Field Hearings on

Math, Science, Engineering, and Education:
The National Need

Subcommittee on Postsecondary Education of the
Committee on Education and Labor
United States House of Representatives

Kansas City, Missouri

May 1, 1989

Preserving America's Scientific Preeminence

Good morning. I would like to review with you information and research findings about the flow of young men and women into what we call the "scientific pipeline." My own data and those of other researchers point toward three inescapable conclusions:

- o Far too few of our talented young people are choosing careers in science, mathematics, and engineering.
- o Those that do aren't being trained well enough.
- o It's not too late to turn this situation around.

In the latter part of the twentieth century, U.S. citizens and their leaders have worried about threats to America's role as a world economic power. Conservatives and liberals alike have agreed that scientific research, which lays the foundation for industrial innovation, is vital to the strength of our economy. In his best-selling book, The Rise and Fall of the Great Powers, Paul Kennedy argues that the United States may be on an inevitable downswing, like many prior world powers, and suggest that continued high-quality scientific research and development are a vital component of our strength.

Many Americans take for granted our leadership in science. They have come to expect that each year Americans will collect a lion's share of the Nobel prizes. The list of scientific discoveries and inventions by Americans is awesome, from Benjamin Franklin's kite-flying experiment about electricity to the pioneering research about the micro-computer by two young entrepreneurs in a garage in Silicon Valley. However, there is a very real danger that we may lose our grip on our role as scientific leaders just as we lost our number one status internationally in the automobile business. The main reason is that we have neglected the human resources that drive the system: young scientists.

When I think about the problems in the "scientific pipeline," I am reminded of a story that Frank Layden, a former coach of the professional basketball team, the Utah Jazz, enjoyed telling. He talked about his frustrations with one player's inability to learn a new maneuver despite extensive practice. Finally, he said to the player "We've been working on this every night for weeks. Yet you still can't seem to get it. Frankly, I can't decide if your problem is ignorance or apathy." The player glared at him and replied "I don't know and I don't care."

The problem is that our young people don't know about science and most of them don't care about science.

Let me show you one symptom of the problem. You may already know that substantial portions of the graduate students in science, mathematics, and engineering in the United States are international students. Figure 1 presents some data about the situation.

According to a recent article in a journal published by the National Academy of Sciences, "During the past few years, over 90% of undergraduates in engineering were U.S. citizens, but that proportion dropped to only about 45% for new engineering Ph.D.'s (about 4% of this latter group were naturalized, foreign-born citizens). Thus, the indigenous new Ph.D. population is about 40% of the total, even with efforts to restrict the number of foreigners admitted to graduate engineering programs."

These figures indicate our failure to train American students so that they can compete for slots in graduate schools with foreign students. But I don't believe the presence of international students in our Ph D. programs, in itself, is a problem. I agree with Harvard professor Sheldon Glashow, a Nobel prize winner in physics, who said

> "We import them. We import them from Iran, we import them Turkey, and Taiwan, from whatever countries we can find. They stay in this country--more than half of them stay in this country--they take all the good jobs. And I'm not attacking this, this is not a problem. This is the solution. These new Americans who are a vital part of America today and are the technological backbone of the country are the solution. Our people can't hack it."

For many decades, naturalized citizens have been among our top scientists. We have only to think of the influx of highly productive scientists and engineers escaping from Nazi Germany to illustrate this. The present influx of graduate students, including those recent immigrants from Southeast Asia, may, indeed, become the technological backbone of our nation's scientific and industrial effort. But, our own science education is in trouble when the future of our national research enterprise is so dependent upon the vicissitudes of immigration legislation. If new immigration laws should discourage these foreign scientists from remaining in our country after completing their education, the implications for national research and development could be devastating.

What really bothers me, and the focus of my presentation, is that last comment by Professor Glashow "Our people can't hack it."

He's right. The International Association for the Evaluation of Educational Achievement (IEA) conducted a study of science achievement in 17 countries. In the fourth and fifth grade, our ten year-olds tested about in the middle of the pack when compared with countries like Australia, Finland, Hong Kong, Hungary, Japan, the Philippines, Poland, Sweden, and Thailand. Our 14 year-olds tied for fourteenth place out of these 17 countries. Our high school seniors, tested separately in biology, chemistry, and physics, came in dead last, or close to it, depending on the discipline. The authors of this international study said about the United States "For a technologically advanced country, it would appear that a re-examination of how science is presented and studied is required." (1988, p.9)

Even when our educational system works for Anglo, middle-class, male children, it discourages females and minorities from science careers. For example, Figure 2 presents data on engineering Ph.D.'s awarded in 1986. As I've already noted, more than half were awarded to foreign students. Note the dismal percentages of women, blacks, and Hispanics.

There really are only two possibilities to explain these percentages. There's no scientific support for the first hypothesis, which is that young women and minority students are not as capable as Anglo males. There is considerable scientific support for the second hypothesis: Our educational and social systems consistently discourage talented students, particularly women and minorities, from successful careers in science. The silver lining around this particular cloud is that these previously neglected students represent a large source of tremendously capable future scientists.

Part of the problem is the attitudes and expectations held by some teachers about the capabilities of girls and of minority students. I teach about multivariate statistical analysis in our Ph.D. program at the Claremont Graduate School. I have encountered many students, especially women and minority students, who feared math and were sure they could not do it. (As you may know, most graduate students dread statistics and put it off as long as possible.) Most of these students find they are capable of understanding and conducting sophisticated statistical analyses like hierarchical multiple regression. In conversation, I often discover that their negative self-image goes back to an elementary school teacher with a sexist or racist attitude, a person who thought that "Girls can't do math" and managed to traumatize a student who now must be convinced about her real ability.

Many people have become aware of the extraordinary accomplishments of Jaime Escalante. This mathematics teacher at Garfield High School in East Los Angeles has successfully prepared many Hispanic and other minority students from poor families to take the Educational Testing Service Advanced Placement test in calculus. Last year's movie "Stand and Deliver" told this story well. But, the most important message from this experience is not that Jaime Escalante is an extraordinarily creative and successful teacher, although this certainly is true. The message is that many poor, minority high school students, who most educators might have considered incapable of mastering calculus, did just that when they were taught by such a creative instructor.

Are We Driving Students Away from Science?

Too few students are choosing careers in science, mathematics and engineering. Furthermore, the number who find science interesting seems to shrink as they progress through the school system. Figure 3, based on some important research by Yager and Penick (1986), presents data to illustrate this point.

According to Yager and Penick "The more years our students enroll in science courses, the less they like it. Obviously, if one of our goals is for students to enjoy science and feel successful at it, we should quit teaching science in third grade. Or perhaps we should try teaching it differently."

Carl Sagan recently commented that when he visits a kindergarten class "I'm in a class full of young scientists. They ask provocative, enlightening, insightful questions and clearly are enthused and excited about science." But when he visits a high school class, the students are much less interested. Somewhere between kindergarten and high school they have lost interest and enthusiasm. Some research suggests that the danger area may be junior high school.

Among those who locate the critical period in junior high school are James & Smith (1985) who observe:

> "There are some disturbing explanations for such a dramatic drop in positive attitude toward science at the seventh grade level. One possibility is that the seventh grade is often the first time that science is treated as a separate subject in a separate classroom. Further, it is usually required at this grade level. Seventh grade science may be one of the earliest attempts to require students to use self-directed problem solving techniques to a greater degree than earlier grades. Perhaps this additional rigor explains the response. Since K-6 science is frequently not graded, seventh grade may be the first time students work has been evaluated."

F. James Rutherford was the director of a project which prepared a report for the American Association for the Advancement of Science about the teaching of science and math in the United Sates. He comments "You have to know something is wrong when teaching something as exciting as science can result in most of us disliking it. (Connell, 1989)

The Cooperative Institutional Research Program[2]

This trend is reflected in data gathered from undergraduates. Without question, the best information available about college students comes from the Cooperative

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Institutional Research Program conducted by my colleagues at the Higher Education Research Institute at U.C.L.A. Each fall, a four page questionnaire containing items about demographic characteristics, high school experiences, careers aspirations, opinions and values is completed by a sample of well over 200,000 college freshmen. Follow-ups of sub-samples of each cohort are conducted periodically. These freshmen data have been collected each fall since 1966, making possible examination of trends over time. Figure 4 presents such trend data about freshmen interest in majors in biology, the physical sciences, and mathematics. The declining interest in mathematics is particularly disturbing and merits further examination. Figure 5 presents a closer look and also breaks the data out by gender. Mathematics is not attracting students. I think it's fair to say that if the Edsel division of the Ford Motor Company had been an academic mathematics department it would still be in existence.

Given that part of the problem may be the kinds of science and math teachers students encounter in their elementary and secondary education--and that part of the solution may be better teacher recruitment and training--Figure 6 from the CIRP freshmen data might be of some interest. It suggests that virtually all undergraduates planning teaching careers these days are education majors. Figure 6 indicates that this was not true twenty years ago. In other words, 15 or 20 years ago a high school student in physics was much more likely to be taught by a young teacher who had been a physics major in college. Today the same student might well have a teacher who has had more coursework in pedagogy than in math and physics.

There clearly has been a decline in the quality of science teachers as a side effect of the woman's movement. Increased career opportunities for women during the past two decades have meant that intelligent young women no longer are constrained to careers in teaching, nursing, and one or two other fields. The result is that the educational system has lost the "hidden subsidy" that resulted from the fact that so many bright young women who once chose teaching now feel free to choose other careers.

The Need for Role Models

The poor drawing power of the sciences at the undergraduate level relates to the lack of role models and cannot be examined without consideration of the manner in which research is funded and conducted. College students planning careers in science need to see and learn from professors who are excellent research role models. Instead, they read about increasing reported instances of scientific fraud. More to the point, they rarely are taught by instructors who are actively engaged in research and can model this process for them.

Many undergraduates at large universities are taught by teaching assistants. Recall the data in Figure 1 which indicated that about half the graduate students in many science and engineering disciplines are international students. The fact is that many of them do not have a full command of English. According to the National Academy of Science journal cited earlier "The majority of these foreign born engineering students come from countries where the language and culture are likely to be significantly different from those of most native-born U.S. citizens." (p. 78)

A more pernicious reason for the lack of good role models has to do with the contrast between the distribution of federal funds and the distribution of talented academic scientists. In my book, Strengthening Academic Science (1985), I discussed how this disparity is threatening the productivity of a generation of young researchers.

For many years now, federal funds for university research have been concentrated in a few institutions. Figure 7 presents information about National Science Foundation obligations. Note the substantial proportion of funds simply going to the top three institutions. Year a ter year, roughly half the federal support for basic research in many disciplines is awarded to the top 20 universities.

All those who favor a strong science effort want federal funds to be awarded only to the best researchers. And virtually all science policy experts agree that this can best be assured through peer review. But the data I reported in Strengthening Academic Science suggest that the top young researchers may not be at the top 20 institutions. Because of the demography of the academic world in the past 15 years--in particular the "tenure log jam" in which many leading institutions have virtually no job openings--the most talented new Ph.D.'s from the best departments who chose academic careers have taken jobs in second and third tier institutions. Thus, the best young physicists from Harvard, Berkeley, and Michigan have not been taking jobs at similar institutions but at schools like the University of Arkansas and North Dakota State University.

In my book, I reported analyses of surveys of 60,000 scientists and hundreds of interviews with scientists and administrators. The data revealed that the continued concentration of federal science funds may be destroying the potential productivity of these brilliant young scientists at second and third tier universities. Furthermore, these new Ph.D's then are unable to demonstrate to undergraduates what the research process looks like. And, of course, they are unable to engage undergraduates directly as participants in that research process. College students who hear young professors talk about the excitement of research, but note that those same professors are not conducting much research, are less likely to choose careers as scientists.

This situation is made more serious by the fact that there are vast numbers of students, many of them highly capable potential scientists, enrolled at these universities. We are talking here about AASCU-type institutions, about comprehensive universities. While some of the recent literature about future scientists focuses on the Ivy League and elite research universities and some discusses the Antioch or Claremont-type selective liberal arts colleges, the fact of the matter is that there are far more students enrolled in the large state universities. Thousands more of our young people are attending schools like Montana State, Kansas State, and the University of Missouri than are attending schools like Harvard, Stanford, and Oberlin.

Solutions to the Problem

I'd like next to suggest some possible solutions to this crisis in science education. First, let's consider measures that might draw more college students into careers in science, mathematics, and engineering.

The National Science Foundation has paved the way during the past quarter century with capacity building programs aimed at enhancing the research capabilities of scientists and institutions outside the top 20 schools. These programs have served a catalytic function by increasing the number of regional centers of science excellence, institutions that may indeed attract young people into science careers. Perhaps the three best known programs, presented in chronological order are:

- The College Science Improvement Program (COSIP)
- The Science Development Program
- The Experimental Program to Stimulate Competitive Research (EPSCOR)

I have great familiarity with these three capacity building programs since I directed evaluation studies and/or policy analyses of each of them (Drew, 1973; Drew, 1975; Drew, 1985). Lessons learned from evaluations of the first two programs laid the groundwork for the design of the more recent EPSCOR activities.

The College Science Improvement Program awarded millions of dollars to undergraduate institutions "to improve the quality of undergraduate science education." Our evaluation of its impacts found, for example, that undergraduates at COSIP-funded institutions were more likely to be planning careers in science and research. Furthermore, we examined the various funding mechanisms finding, for example, that funds intended to benefit the undergraduate directly e.g. undergraduate students projects, had considerably more impact than funds that were intended to have an indirect affect, e.g. funds for faculty sabbaticals.

The Science Development program of the late 60's and early 70's awarded well over $200 million to selected institutions outside the top 20 with the objective of creating new centers of science excellence. Our systematic evaluation of this program, conducted at the National Research Council, traced where the impacts were greatest and where they were negligible. One of the persistent findings from our case study field visits and the quantitative data was that creative leadership was a crucial factor in virtually every successful Science Development grant.

More recently, NSF's EPSCOR program funded scientists and institutions in five states that previously had received relatively little federal science support: Maine, Arkansas, West Virginia, Montana, and South Carolina. Under the leadership of John Talmadge and Joseph Danek, this program has converted relatively small investments by the Foundation ($3 million per state over a five year period) into dramatic projects, breakthroughs, and productivity.

The Montana program, one of the most successful, was directed by Dr. Gary Strobel, a plant pathologist at Montana State University. The "MONTS" program had many innovative features, including an extensive review of proposals by experts inside and outside Montana before they ever were sent to NSF for formal peer review. One illustrative result: a small $15,000 grant for anthropological research resulted in discovery of the largest collection of dinosaur bones in the world. Strengthening Academic Science (1985) contains a detailed description of each of the five state programs as well as a discussion of the planning activities in two states, North and South Dakota, that competed for funds but lost. The initial successes of this program in the five recipient states has led the foundation to fund a second round of EPSCOR grants in additional states.

Science Teachers

Role models are just as important for elementary and secondary school students. I recently heard Senator John Glenn give a vivid description of how his interest in science was stimulated by a high school teacher who invited Glenn to join him and his family on a summer vacation trip. Senator Glenn described with great enthusiasm how he saw steel being made in Pittsburgh and how they visited Niagara Falls where he watched the generators in awe.

If we are to improve the education of science students, we must improve the selection and education of science teachers. The power to change the dismal statistics presented in Figure 3 about the declining number of students who believe that science is interesting or fun or exciting lies with the teacher. An innovative and creative California junior high school science teacher, John Eichinger, recently commented "Honest curiosity, fallibility, and enthusiasm are the science teacher's most powerful tools."

Good teaching involves knowing what methods are effective. However, a recent national study by the Educational Testing Service (1988) found:

- o "Only 35% of the seventh graders and 53% of the eleventh graders reported working with other students on science experiments at least on a weekly basis.
- o "Over half of the third graders and more than 80% of the seventh and eighth graders reported never going on field trips with their science class.
- o "60% of the seventh graders and 41% of the eleventh graders said they never had to write up the results of science experiments.

I'd like to present two ideas about science teachers that may be controversial:

- o The teacher is more important than the curriculum in drawing students into science and training them well. I'd rather have a great teacher working with a poor book than a poor teacher working with a great book.
- o For the most part, good science teachers are born, not made.

These are exaggerations. Obviously, curriculum is very important in science education. And, obviously, we go to great lengths to teach people how to be good teachers. But, if these observations are even partially true, we must think carefully about how we can draw better young people into careers as science teachers.

In this context, I'd like to mention two innovative activities of the Teacher Education Program at the Claremont Graduate School. First, we have found that a very effective message to attract capable undergraduates from the Claremont Colleges and other selective institutions to graduate study in Teacher Education is to suggest that they might begin their career as a teacher. Some of them, indeed, may choose to remain teachers. But many professionals these days engage in two, three, or more careers during their lifetime. Spending five or ten years as a teacher before moving on to something else will benefit some talented undergraduates and our school systems.

Second, we have received funding from the National Science Foundation for a program in which engineers from industry enroll in the Teacher Education program, thus sending trained teachers to the schools who can speak and teach with authority about science, math, and engineering.

Conclusion

Prior to now policymakers have employed the model of the scientific pipeline depicted in Figure 8. I would propose that the present crisis in science education requires a new model of this pipeline, as depicted in

Figure 9. As you can see, the important difference is that our awareness of the present and projected needs of the scientific enterprise affect our approach to education and training at the pre-college and college levels.

In conclusion, we have a real problem in science education in the United States, a problem with important implications for the strength of our economy. Too few of our young people choose careers in science, mathematics, and engineering. In particular, we are failing to capture the talents of most young women and minority students. The achievement of our students suffers by comparison with those of other nations. However, we can turn the sit·ation around. It's a challenge worth accepting.

Footnotes

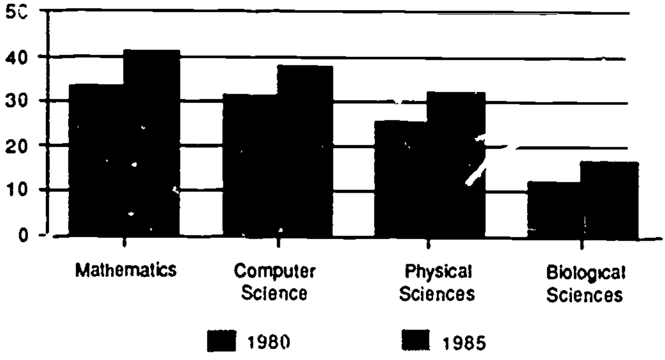
[1]David Eli Drew is a Professor of Education at the Claremont Graduate School, where he also holds appointments in the Executive Management and Public Policy programs. He is also a Senior Research Sociologist with the Higher Education Research Institute. For some time the focus of his research has been the management of scientists and the assessment of quality science. Previously he held senior research positions at the Rand Corporation, the National Academy of Science/National Research Council, and the American Council on Education. Earlier he held a faculty position at Harvard University, from which he received his Ph.D.

Mr. Drew is the author of four books, over twenty technical reports and monographs, and over thirty journal articles about science, technology, and education.

[2]I have appended to the written statement of my testimony a paper by my colleague, Kenneth C. Green, "A Profile of Undergraduates in the Sciences" which discusses these trends in great detail.

Fig. 1: FOREIGN GRADUATE STUDENTS IN THE SCIENCES

(percentage of total enrollment, by field)



National Science Foundation

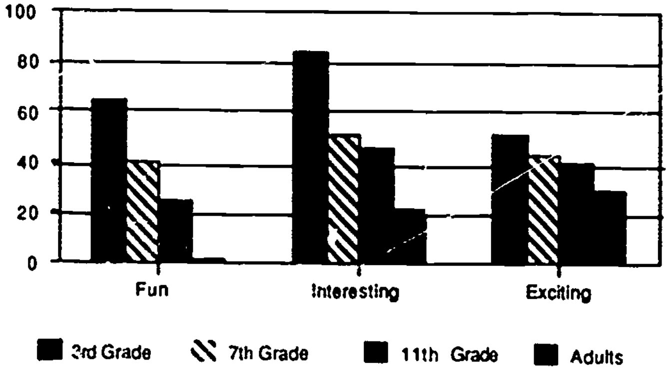
Fig. 2: ENGINEERING Ph.D.s, 1986

- 3,375 total engineering doctorates in 1986
- 1,661 doctorates awarded to US citizens
  - Δ 139 women
  - Δ 25 Hispanics
  - Δ 14 Blacks
  - Δ 6 American Indians

Changing America

Fig. 3: AMERICAN ATTITUDES TOWARDS SCIENCE

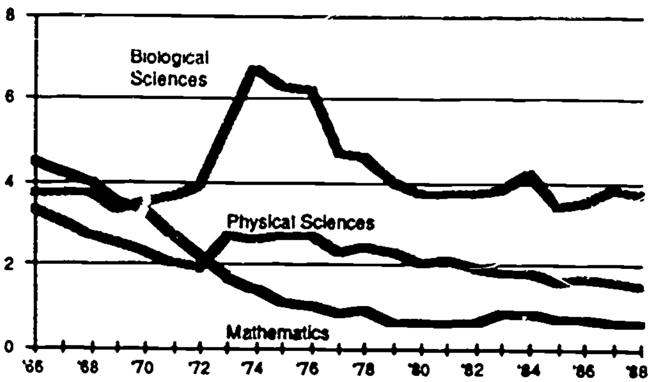
(percentages)



Yager & Penick, 1986

Fig. 4: FRESHMAN INTEREST IN SCIENCE MAJORS

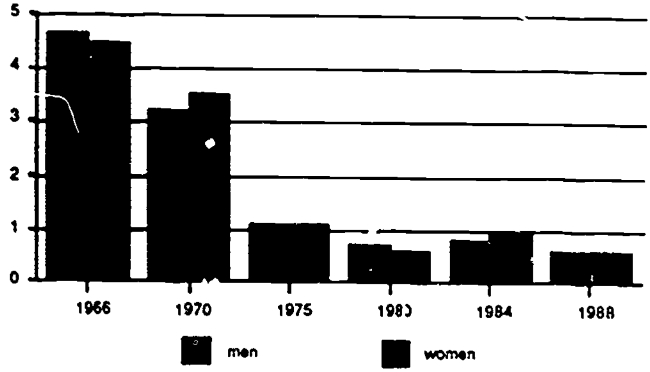
(percentages for first-time, full-time college freshmen, 1966-1988)



Higher Education Research Institute, UCLA

Fig. 5: FRESHMAN INTEREST IN MATHEMATICS MAJORS

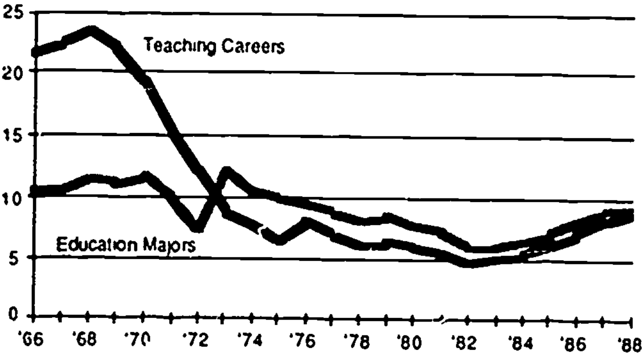
(percentages for first-time, full-time college freshmen 1966-1988)



Higher Education Research Institute, UCLA

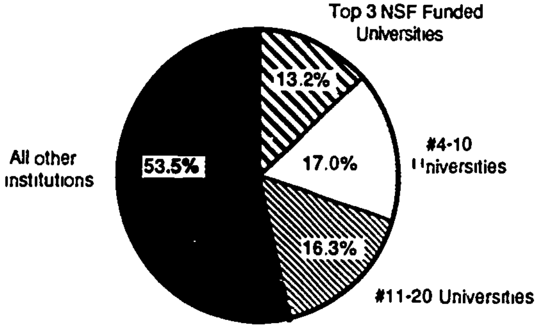
Fig. 6: SHIFTS IN FRESHMAN INTEREST IN TEACHING CAREERS AND EDUCATION MAJORS

(percentages for first-time, full-time college freshmen, 1966-1988)



Higher Education Research Institute, UCLA

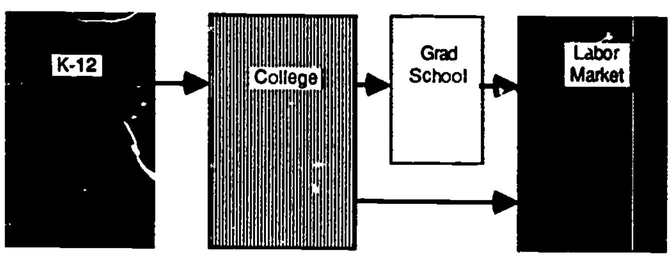
Fig. 7: NSF R & D OBLIGATIONS, F/Y 1983



Total 1983 R & D Funding = $759 million

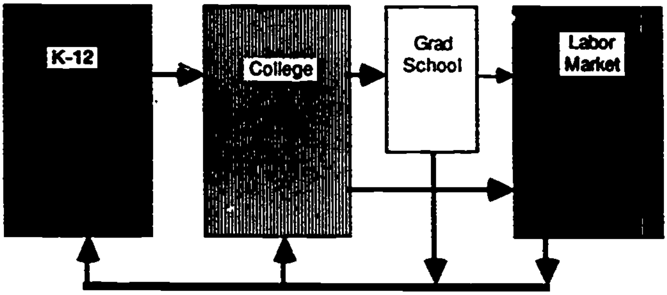
National Science Foundation

Fig. 8: THE "OLD" SCIENCE PIPELINE



Traditional View Focuses on Labor Market Needs

Fig. 9: THE NEW SCIENCE PIPELINE



New Perspective Recognizes Urgent Need to Reinvest in K-12 Education

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A PROFILE OF UNDERGRADUATES IN THE SCIENCES

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Background Materials Prepared for Field Hearings on

Math, Science, Engineering, and Education: The National Need

Subcommittee on Postsecondary Education

United States House of Representatives

May 1, 1989

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A PROFILE OF UNDERGRADUATES IN THE SCIENCES[1]

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The health and vitality of the "pipeline" of students planning undergraduate work in the sciences is an important indicator of the human resource component of the nation's science resources. For more than two decades early indicators of undergraduate interest in the sciences have been tracked by the annual American Council on Education — UCLA Cooperative Institutional Research Program (CIRP) survey of entering college freshmen. Begun in 1966, the CIRP is now the nation's largest and oldest empirical study of higher education. The annual CIRP freshman and follow-up surveys are a rich resource for data about the students who pursue higher education in the United States. In recent years more than 300,000 students attending some 600 two- and four-year colleges and universities across the country have participated in the annual CIRP survey of college freshmen.

The CIRP Freshman Survey data can be used to develop normative profiles of students by ethnicity, by ability level, and by intended college major. Drawing on cross-sectional and longitudinal data, the CIRP offers a unique resource for studying the undergraduate pipeline in the sciences.

This paper focuses on the population of freshmen who enter college planning to major in science and engineering (S/E) fields. It offers a comparative profile of S/E-oriented students against students planning other majors; it also compares the profile of science students within various science fields. This research draws on data from 1988 CIRP Freshman Survey, from previous CIRP surveys of entering students, and from a 1986 follow-up study of 1982 and 1984 college freshmen.[2]

SOME INITIAL FINDINGS — AND CONCLUSIONS

Let me begin with a simple and direct statement. *We must recognize that the infrastructure of the American educational pipeline in the sciences and resulting human resource capacity in the sciences and technology has suffered serious erosion over the past two decades.* The evidence from the CIRP surveys is very persuasive:

- Freshman interest in key undergraduate science majors has dropped dramatically — by almost half — over the past 23 years.
- Freshman interest in technology careers has experienced a dramatic decline in just the past six years. Between 1982 and 1988, the proportion of freshmen planning to pursue engineering careers fell by almost one-fourth; the proportion of freshman planning to pursue careers as computer professionals has plummeted, falling by nearly three-fourths in just six years.

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[1]Keynote presentation, meeting of the Sigma Xi National Advisory Group on Undergraduate Education in Science, Mathematics, and Engineering at the Wingspread Conference Center, Racine, WI, on January 23, 1989. This work was supported in part by funds from Sigma Xi and from a grant to Sigma Xi from the National Science Foundation. The views expressed in this paper are solely those of the author and do not necessarily reflect the official position of the sponsoring groups.

[2]Most of the science-oriented data presented here focus on first-time, full-time students enrolled in four-year institutions. Although the CIRP does include community college students in the survey population, full-time students now comprise a less than half of the "undergraduate" enrollment in two-year institutions. Consequently, any CIRP-based portrait of the science interests of students in two-year colleges and pipeline capacity of community colleges would not provide a complete picture two-year college students

- Every fall tens of thousands of academically-able students enter college planning to pursue science majors. Yet more than half these students change their intended major for other, non-science fields. Moreover, the high "defection" rates for aspiring science majors are not offset by recruits from other (non-science) fields.
- The disciplinary-training of secondary school science teachers has declined dramatically over the past two decades. Today very few aspiring science and mathematics majors plan to pursue careers as high school teachers.
- Finally, if undergraduate science departments were run like for-profit businesses — that is, without substantial institutional subsidy — most programs might be bankrupt, largely because of their capacity (some might say basic inclination) to "alienate" potential clients.

There is, of course, some risk in simply echoing the increasingly common refrain of a series of recent national reports bemoaning the declining science interest and scientific performance of American students (see, for example, Mullis and Jenkins, 1988; Yager and Penik, 1986). However, the declines in science capacity reflected in the CIRP data point to serious problems for the science-based infrastructure of the nation's labor market and the nation's capacity to respond to the scientific, technological, and economic challenges of the 1990s and the 21st century.

GENERAL TRENDS IN FRESHMAN INTEREST IN THE SCIENCES

Between 1966 and 1988, the proportion of college freshmen[3] planning to major in the biological sciences, the physical sciences, and mathematics fell by half, from 11.5 to 5.8 percent (Figure 1). The largest portion of this decline occurred in mathematics: over the past 23 years,the proportion of aspiring mathematics majors dropped from 4.6 to 0.6 percent, a decline of more than four-fifths. In the physical sciences (i.e., chemistry, physics, and related fields), freshman interest has fallen by more than half, from 3.3 percent in 1966 to 1.5 percent in 1988. Only the biological sciences have maintained a stable "market share" of freshman interest: in Fall 1988, 3.7 percent of the entering freshmen planned to pursue majors in biological science fields, about the same as the recorded in the late 1960s, but well below the peak numbers recorded in the mid-1970s (when more than 6 percent of the entering freshmen expressed interest in bioscience majors).[4] However, the seemingly stable interest in the life sciences reflects student interest in premedical studies rather than any intrinsic interest in biological science majors. Moreover, of the aspiring bioscience majors who really harbor aspirations for medical school will ultimately change their majors and career preferences when they confront organic chemistry, a traditional "point of departure" for many aspiring pre-med students.

The trends by sex for science majors paint an interesting — and in many ways a surprising — portrait of the past two decades. The conventional wisdom might suggest that interest in basic science majors among freshman women should have increased over the past twenty years, as women presumably received more encouragement to pursue "non-traditional" majors and careers. However, the CIRP data reveal that interest in science majors among freshman women dropped by more than two-fifths during this period (from 8.8 percent in 1966 to 5.1 percent in 1988). Admittedly, this decline among women is far less than the nearly one-half decline in these same

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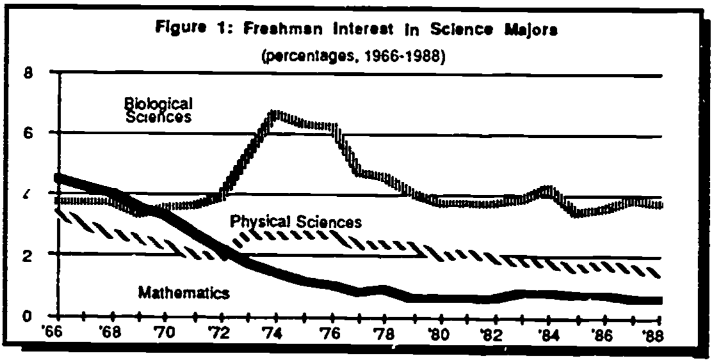
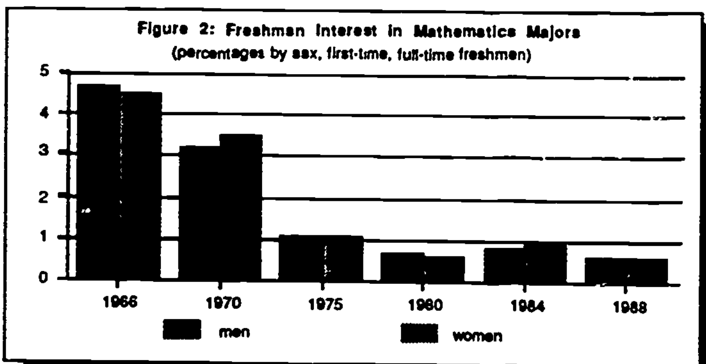
[3]References to the freshman population refer to *first-time, full-time* students, i.e., "modal" or traditional students. The CIRP data base automatically excludes those freshmen who are not enrolled as full-time students, and/or those students who have had some prior degree credit experience. See Astin *et. al*, 1988, Appendix A, for details about the CIRP survey methodology.

[4]The CIRP data do predict future trends in the number of earned undergraduate science degrees. Unpublished studies conducted by CIRP staff point to very high correlations (r^2 values) between the proportion of freshmen planning to major in scientific fields and the number of earned undergraduate science degrees four years later (i.e., a four-year cohort approach). These r^2 values range from .88 for the biological sciences to .93 for engineering to .98 for computer science.

fields posted among men (from 13.8 percent to 7.0 percent during the same period). However it does run against the conventional wisdom and should be particularly distressing given the range of government, institutional, corporate, and philanthropic efforts to encourage young women to pursue training and careers in the sciences.[5]



The high losses in freshman interest in mathematics majors seem to play a strategic role in the larger issue of overall science capacity. I mentioned earlier that freshman interest in mathematics majors has dropped by more than four-fifths over the past 23 years. This decline occurs among both men and women (Figure 2). It should concern us for several reasons. First, there is the career path of math majors. Two decades ago the women who earned undergraduate math degrees often took teaching jobs in secondary schools. These women played a pivotal role in secondary



school mathematics education. First, they represented a large (if all-too-often transient) part of the teaching pool in science and mathematics. Second, they served as important role models.

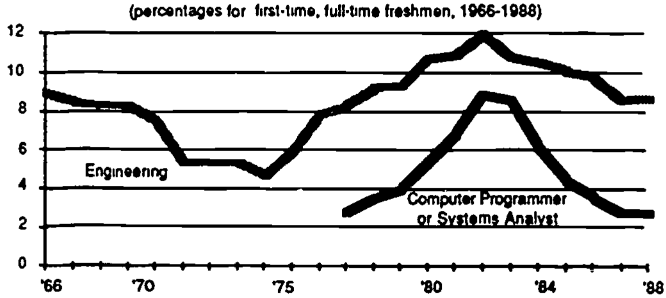
[5]An alternative hypothesis, of course, is that the investment in encouraging women to pursue science majors helped stem what might have been much larger declines in the proportion of freshman women planning to pursue science majors.

However, as women's career aspirations increased and options expanded beginning in the late 1960s, we began to see that their interests moved away from mathematics and out of teaching. The loss of this pool of potential math teachers has been an important factor in the deterioration of the science-oriented education infrastructure: one significant if often undiscussed consequence has been the impact on secondary math and science instruction and the science pipeline coming out of our secondary schools and into college.

TECHNOLOGY MAJORS AND CAREERS

The CIRP data also reflect student perceptions about the job opportunities for engineers and computer specialists (Figure 3). Freshman interest in engineering careers and majors fell precipitously during the early 1970s. This was the period just after the first Apollo moon landing *and* the termination of funding for the SST project and other large government contracts. Potential engineering students received ample doses of the televised images of unemployed engineers in Seattle, Long Beach, and St. Louis. Consequently, these science-oriented students opted for other majors. The rising interest in engineering careers that began after 1975 reflected both the return of men as well as the rising proportion (if still small numbers) of women coming into engineering. Freshman interest in engineering was further stimulated by the upheavals elsewhere in the economy: science/technology fields were the only "hot spots" in an otherwise down economy between 1977 and 1982 Over the past six years however, we have seen a surprising decline in freshman interest in engineering careers, from 12.0 percent in 1982 to 8.6 percent in 1988.

Fig. 3: Freshmen Interest in Technology Careers
(percentages for first-time, full-time freshmen, 1966-1988)



We have witnessed similar yet more significant declines in the proportion of freshmen planning to pursue majors and careers in computing (i.e., as programmers or systems analysts). After posting almost exponential gains between 1977 and 1982, from 2.8 to 8.8 percent, freshman interest in computing careers has plummeted, falling back to 2.7 percent in 1988. This decline reflects the fastest and perhaps most significant drop in a career choice documented over the 23 years of the CIRP data.

Like the concurrent decline in engineering, the decline in computing runs against the conventional wisdom about the job market and the job prospects for students with technical training. Why? Part of the explanation rests with events in the labor market over the past decade. The only bright spot in the economy during the last recession and even during the high inflation that preceded it seemed to be technology areas. The late 1970s and early 1980s were also the period when Apple Computer came out of the garage and went onto the Fortune 500 and schools introduced a "bits bytes and BASIC" approach to computer instruction. Clearly the nation is in the midst of a major transition in the structure of the economy; it is a transition that marks the movement away from manufacturing to service industries, to technology, and towards information systems. College students are sensitive to these changes in the structure of the labor market.

Why then the declining interest in technology careers? Our analyses suggest that the drop is largely due to the "outmigration" or "defection" of the "B" students to non-science fields, rather than an absolute loss of the academically-able (i.e., "A") students who are intrinsically interested in science. In other words, the dire state of the economy in the early part of the decade prompted many science-capable "B" students to consider technical careers. As employment options improved in other sectors, many of the "B" students who could handle the science and mathematics requirements of the engineering and computer science curriculum moved into other fields.

I should add, however, that the recent decline in computer science also seems to be a consequence of increasing familiarity with the technology. As the computer literacy movement grew in the 1980s, more students had contact with desktop computers. Moreover, the focus of activity shifted from programming to applications (e.g., word processing, spreadsheets, graphics). [The CIRP surveys indicate that over one-fourth (27.4 percent) of the 1988 freshmen "frequently used a personal computer" the year prior to entering college and nearly three in five (58.1 percent) had at least a half-year of computer instruction while in high school.] Consequently, as more students have exposure to computers, they (like many adults) now come to view the technology as a means to an end, rather than an end in and of itself.

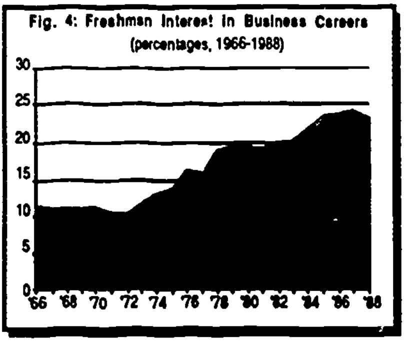
In sum, the decline in freshman interest in science and technology fields has been both severe and significant. The CIRP data, which correlate highly with the trends in earned undergraduate degrees in these fields, point to a troubling deterioration in the science-oriented portion of our education and human-resource pipeline.

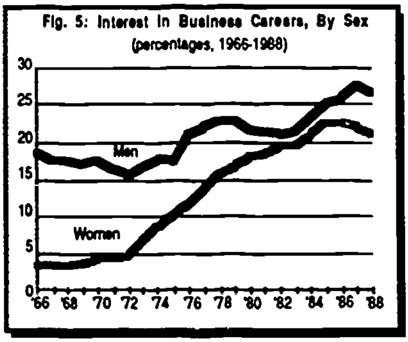
TRENDS IN OTHER MAJORS AND CAREERS

Where have the students gone if they are no longer interested in the sciences? Clearly it has been a bull market in business, particularly when we look at the shifts in career preferences by sex. Between 1972 and 1988, the proportion of freshmen planning to pursue business careers more than doubled, from 10.5 to 23.6 percent (Figure 4). And although business has declined slightly in recent years (from a peak of 24.6 percent in 1987), it is still the most popular career preference (and intended major) of today's freshmen, accounting for about one-fourth of total freshman preferences for majors and about the same proportion of undergraduate degree awards (National Center for Education Statistics, 1987, p. 105.).

Yet the overall shift towards business masks the particularly dramatic changes that have occurred among women in the past two decades (Figure 5). Between 1966 and 1988, the proportion of freshman women planning to pursue business careers exploded, rising by a factor of more than 6 (from 3.3 percent in 1966 to 21.3 percent in 1988). Indeed, in some business specializations women now outnumber men: for example, more freshman women than men now plan to pursue accounting majors and careers.

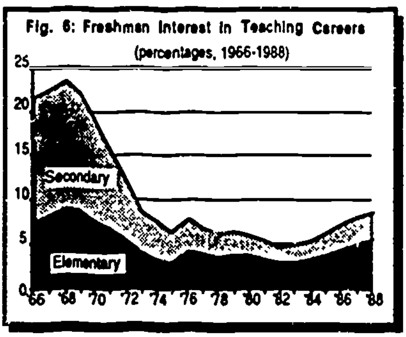
The rising popularity of business seems to reflect students' efforts to prepare themselves for the job market they envision in the 1990s and on into the 21st century. Freshman interest in business remains high, despite the rising chorus of corporate leaders who say they want their organizations to hire well-read, well-trained people prepared in the liberal arts. That students *do not* accept this message seems to be their way of saying they know CEO's do not work the campus recruitment circuit. The irony here is that students do not recognize the role of science as a resource for business careers. For example, undergraduate business majors will not be effective representatives for pharmaceutical companies; rather, to work in pharmaceutical sales and marketing students will need a strong background in the biological sciences and chemistry, along with strong writing, presentation, and interpersonal skills.

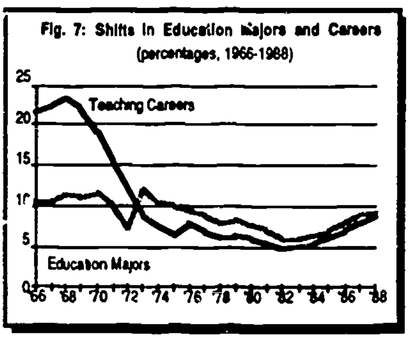




The pipeline in elementary and secondary school careers has also changed significantly since the 1960s. There is little question that these changes have had dire consequences for the sciences. Freshman interest in teaching careers fell from a peak of 23.5 percent in 1968 to a low of 4.7 percent in 1982 (Figure 6). Freshman interest in teaching has been rising recently, almost doubling to 8.8 percent in six years. However, the current levels are still far below those recorded in the mid- and late-1960s, and well below the levels need to meet future needs (see, for example, Carnegie Forum, 1986; National Commission on Excellence in Teacher Education, 1985). Moreover, even with the recent gains in student interest in teaching careers, the CIRP data reflect comparatively little interest in secondary school assignments. This should be particularly distressing for science educators as junior high school and secondary school science and mathematics courses stimulate student interest in these fields and provide the academic foundation for subsequent undergraduate work in these areas.

Also distressing is the loss of the population of "discipline-trained" teachers. Twenty years ago more than half the aspiring teachers planned to major in liberal arts fields, including the sciences. At present however, the CIRP data suggest that virtually all the freshmen planning to pursue teaching careers now plan to major in education rather than in other, more "academic" disciplines (Figure 7). The concern here, of course, is that future teachers — in English and literature, in the sciences and social sciences — may not have an adequate disciplinary base for the demands of the secondary school curriculum. The teaching profession is now wresting with var-





ious proposals to enhance the disciplinary requirements for teaching certification (e.g., enhancing minimum certification requirements so that all credentialed teachers have more than just a bachelor's degree). However, pending a quick resolution of this debate — one that involves unions, local school boards, state boards, and other parties such as the Colleges of Education — the sort-term consequences suggest that future secondary school science teachers may have more upper-division college credits in pedagogy than in physics.

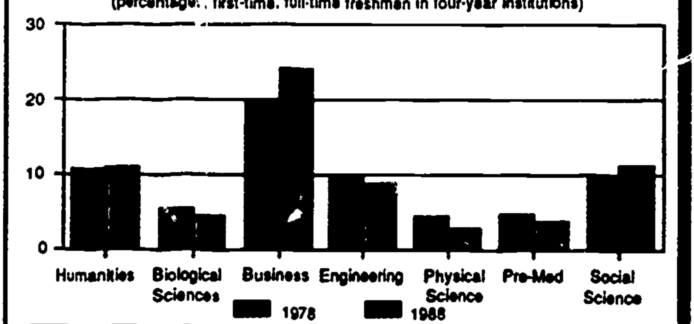
Teaching represents a situation where the loss of the "captive population" of women has had dire consequences for the sciences. Two decades ago the young women who completed undergraduate science degrees often entered high school classrooms; today, young women with science degrees now pursue careers in corporations or advanced training in medical programs and business schools. As women's aspirations and opportunities have increased over the past two decades we have lost a key resource in the pool of potential science instructors, as well as a key group of role models for women who might be interested in both the sciences and in secondary school teaching careers.

S/E STUDENTS IN FOUR-YEAR INSTITUTIONS

The data cited above reflect trends among *all freshmen in all institutions* (i.e., two-year colleges, four-year colleges, and universities). Let's now turn to CIRP data that profiles the population of first-time, full-time freshmen in four-year colleges and universities.[6]

Ten year trends point to a significant downturn in the the sciences among freshmen in four-year colleges and universities. These downturns for the science majors come as freshman interest in business and social sciences have increased by a one-fifth or more, and humanities and social sciences have also posted modest if steady gains (up by a tenth since 1978; Figure 8). In other words, even as some liberal arts majors show increases in student interest over the past decade, these gains in "market share" come at the expense of freshman interest in science majors.

Fig. 8: Changes in the "Market Share" of Undergraduate Majors (percentages, first-time, full-time freshmen in four-year institutions)

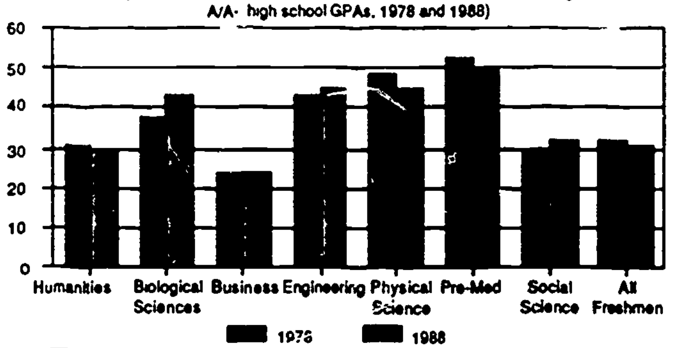


Although these declines in "market share" are troubling, the sciences continue to attract a disproportionate pool of academically able students. In 1988, 45.3 percent of the aspiring science/engineering (S/E) majors in four-year colleges and universities reported high school grades of "A" or "A-," compared to 26.3 percent for students planning non/S/E majors. And in contrast

[6] Full-time freshmen represent less than half the enrollment of entering students in the nation's two-year colleges; consequently two-year college students are not included in the disciplinary profiles presented in the following sections

to the consistent declines in "market share" for the sciences, we do see some gains in the "talent share" of freshmen planning S/E majors (Figure 9). In engineering, the change in talent share (i.e., proportion of "A/A-" students planning engineering majors) between 1978 and 1988 increased by nearly one-quarter, 14.1 to 17.4 percent. Social science majors also reflect some gains modest gains in talent share (up about a tenth, from 8.8 percent in 1978 to 9.8 percent in 1988). There s no change in "talent share" among the life sciences during this period (at 7.9 percent in both 1978 and 1988). Unfortunately, physical sciences and pre-medical majors posted declines over the past decade, falling 18.2 percent and 10.5 percent, respectively. However encouraging, these proportional changes may, in part, overstate the real significance of these gains or declines. For example, the roughly one-tenth gain in "talent share" in the social sciences represents an absolute again of only 1.0 percent over ten years, from 8.8 to 9.8 percent.

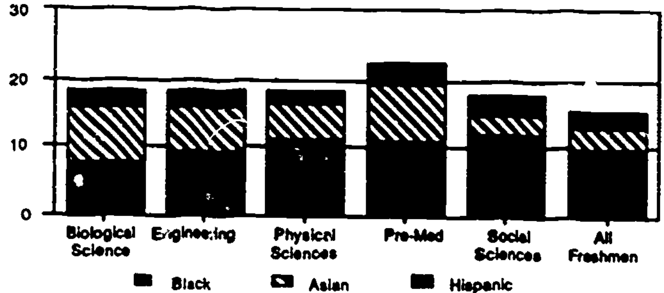
Fig. 9: Changes in the "Talent Share" of Undergraduate Majors
(percentages for first-time, full-time freshmen students reporting A/A- high school GPAs, 1978 and 1988)



MINORITY STUDENTS

The CIRP data on minority interest in the sciences suggest that there has been some improvement at the front-end of the pipeline over the past decade. Interest in engineering, physical science, and life science majors among Black and Hispanic freshmen all posted gains between 1978 and 1988. Moreover, in some cases these increases push minority students past many of the commonly-used measures of parity often employed to assess representation and progress (Figure 10). For example, Blacks represent 9.8 percent of the first-time, full-time freshmen enrolled in the nation's four-year colleges and universities in Fall 1978; however, Blacks also account for 11.5 percent of the freshmen planning to pursue physical science majors (e.g., chemistry, physics, mathematics) in Fall 1988. Similarly, Hispanic students represent 1.8 percent of the first-time, full-time freshman population this past fall and 2.1 percent of the aspiring freshman engineering students. In short, these data suggest that the long-term, institutional, governmental, philanthropic and corporate investment in expanding the traditional underrepresentation of Black and Hispanic students in the sciences is beginning to yield some real rewards. Of course these data reflect only shifts at the front end of the undergraduate pipeline and do not tell us about the persistence rates and ultimate majors of science-oriented minority freshmen. And this will be an issue of growing importance given both the demographic declines and shifts of the 1990s as well as the small likelihood of any real gain in freshman interest in science majors in the next five years.[7]

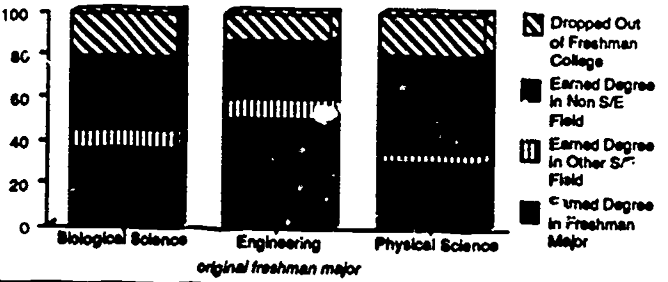
Fig. 10: Ethnic and Minority Student Interest in the Sciences, Fall 1988
(percentages, freshmen in 4-year institutions, Fall 1988)



PERSISTENCE AND DEGREE COMPLETION RATES FOR SCIENCE-ORIENTED FRESHMEN

Our longitudinal studies of freshman preferences indicate that a tremendous number of aspiring science majors ultimately "defect" or migrate to other non-science fields (Figure 11). Indeed, the sciences have the highest defection rates and lowest "recruitment" rates of any undergraduate fields. In short, science departments lose a huge proportion of their potential "clients" or customers — academically-able and intellectually motivated students who enter college with a genuine interest in studying science. Given the high defection-rates — the loss of potential "clients" — we could probably say most undergraduate science programs would probably be bankrupt if they were run as small businesses.

Fig 11. Retention and Degree Completion Rates for Aspiring Science Majors
(percentages, 1982 freshmen in four-year colleges and universities)



[7]Between 1980 and 1994, the size of the college age cohort declines by 25 percent. Concurrently, the minority representation in this age cohort will increase by almost one-fifth. (See Baldridge, Kemerer & Green, 1981)

This "small business" analogy will probably be offensive to most science faculty. Yet some science departments seem to take great pride in the number of students who "flunk out" of key courses in the lower-division sequence or who ultimately change majors. On many campuses there often seems to be an informal competition to see which (science) classes have the lowest grades or which programs have the lowest mean GPAs. Certainly organic chemistry has been a traumatic experience for hundreds of thousands of aspiring pre-med students over the years; many academically-able students never recover from the experience and ultimately change majors because of their experience in organic chemistry. However, any organization or enterprise that loses half or more of its potential clients may be in trouble. And these data should be especially troubling given that the sciences attract a disproportionate proportion of academically-able freshmen.

Where do they go? Most science aspirants leave for non-science fields, rather than dropping out of college completely. The path from engineering to business has been well-documented over the years on many campuses. Not surprisingly, the "defectors" usually do very well in their new departments

THE PROFILE OF FRESHMEN ACROSS SCIENCE MAJORS

Thus far most of the discussion has focused on students within the sciences, as opposed to comparisons of students across the various science majors. However, the CIRP data reveal some very interesting differences *across* the populations of aspiring life science, social science, engineering, and physical science majors.

Degree Aspirations

The degree aspirations of all American freshmen have been increasing in recent years. Between 1980 and 1988, the proportion of all freshmen (in all institutions, across all majors) planning to pursue some type of graduate degree rose by more than one-fifth, from 49.3 percent in 1980 to 59.0 percent in in 1988. During this period, freshman interest in the master's degree rose by one-fifth (from 29.7 to 36.3 percent), while the doctorate gained by almost half (from 7.9 percent in 1980 to 11.7 percent in 1988).

Although these gains are notable, they mask the even more dramatic rise in degree aspirations among women over the past two decades. Between 1970 and 1988, the proportion of freshman women planning to pursue a doctoral degree increased by two-thirds (from 6.5 to 11.4 percent). This compares to an ebb-and-flow pattern among men, beginning at 12.3 percent in 1970, falling to 8.5 percent in 1980, and then rising again to 12.1 percent in 1988 (Figure 12).

The rise in degree aspirations suggest that a growing proportion of students feel that the bachelor's degree will not provide adequate training or credentials for the demands of the job market of the next decade and on into the 21st century.

S/E students, in general, have higher degree aspirations than their peers in other majors. Moreover, there are interesting and important differences in the degree aspirations across undergraduate majors. Not surprisingly, a large proportion of aspiring life science majors (about one-third) ultimately hope to pursue medical training (i.e., as physicians, veterinarians, or dentists; see Figure 13). Also not surprisingly is that a far smaller proportion of aspiring engineering and the physical science majors indicate interest in medical careers.

Interest in the doctorate among science students in four-year institutions has been rising over the past ten years. However, gains have been less than the overall increase in doctoral aspirations posted for all freshmen in four-year colleges and universities. Between 1978 and 1988, the proportion of aspiring engineers planning to pursue the doctorate grew by almost one-fourth (from 15.8 to 19.5 percent). Among biological science students the gain in doctoral degree aspirations was almost two-fifths (from 17.5 to 24.3 percent). The social sciences registered a gain of almost one-third (from 20.9 to 27.5 percent) over the past decade. The smallest gains occur in the physical sciences and mathematics: these fields, which have been steadily dropping in freshman popularity over the past two decades, posted a gain in freshman interest in the doctorate of about an eighth (from 11.3 to 14.5 percent) during this period.

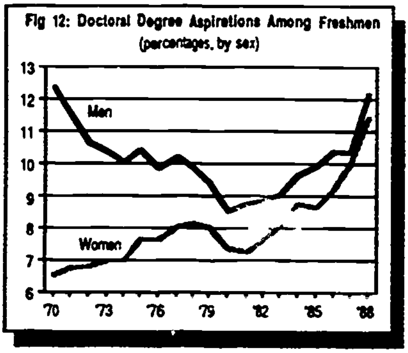


Fig 12: Doctoral Degree Aspirations Among Freshmen (percentages, by sex)

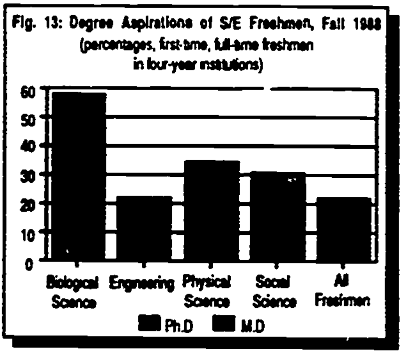


Fig. 13: Degree Aspirations of S/E Freshmen, Fall 1988 (percentages, first-time, full-time freshmen in four-year institutions)

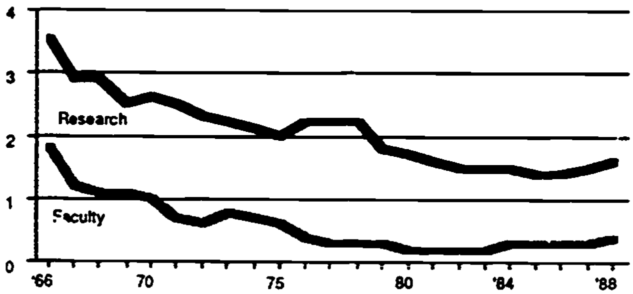
Although the increase in doctoral aspirations among aspiring science majors is below the levels for all areas, these recent gains mark the beginning of the renewed interest (and possibility of subsequent enrollment) of U.S. citizens into *graduate* science and technology programs. Admittedly, we are dealing with freshman data which has many limitations. It is a long time and distance from undergraduate registration to graduate school matriculation. A large number of these students will change major, career choice, and degree plans during their undergraduate years. Many academically-able and very motivated science students will encounter various hurdles that will redirect their interest in and academic commitment to the study of science. The *defectors* — students who leave the undergraduate study of science for other majors and careers — reflect a serious loss for the science pipeline. Additionally, the arduous path through graduate school and the increasingly common post-doc will channel many science and engineering graduates into the well-paying jobs increasing available to technical graduates upon completion of the baccalaureate.

Career Aspirations

The CIRP data also document a dramatic decline the proportion of entering freshman interested in faculty or research careers since 1966 (Figure 14.) Freshman interest in faculty careers has dropped by more than three-fourths over the past 23 years, from 1.8 percent in 1966 to 0.4 percent in 1988. And interest in scientific research careers among entering students has fallen by half, from 3.5 to 1.6 percent during the same period. These declines come at a time when many observers predict future shortages in the pipeline of prospective college faculty and scientific researchers in the United States.

The CIRP data profiling science-oriented freshmen in four-year institutions point to a slight decline in student interest in research careers over the past decade, coupled with very slight increases in faculty careers. Of course these are difficult distinctions in the sciences, as many faculty are engaged in research. Were we to aggregate the faculty and research career preferences over the past decade, we find virtually no change in the proportion of science-oriented freshmen who plan to pursue faculty/research careers. However, the seemingly "steady state" of career aspirations among science students is not entirely good news. The market share of science students has dropped along with the overall decline in the size of the freshman age-cohort. Taken together, the decline in two key values affecting the denominator in the science pipeline equation offsets any stability or gain in the numerator. In other words, a steady "market share" in a declining market still means fewer people in the pipeline.

Fig. 14: Freshman Interest in Faculty and Research Careers
(percentages, first-time, full-time freshmen in all institutions)



STUDENT VALUES

It is an increasingly common pastime in the academic community to lament the seemingly "better times" of earlier eras. Faculty who began their careers just before or shortly after the Second World War often speak fondly about the dedicated, GI-Bill students who populated the nation's colleges in the late 1940s and early 1950s. More recently, those of us who were on college campuses as undergraduates, graduate students, or faculty during the tumultuous period of the late 1960s and early 1970s engage in our own version of this game. We frequently compare today's students against the "60s generation." In general, the tendency is to find today's students guilty of a number of sins of omission and commission.

Let's be candid about the particular complaints commonly leveled against today's students. Without attempting to rank their alleged sins by the seriousness of the potential offense, we often hear that today's students are:

- *greedy and materialistic*, preoccupied with making money, and making it fast;
- *intellectually docile*, demonstrating little interest in challenging intellectual issues and their primary concern for making good grades; and
- *ambivalent if not outright apathetic about pressing social issues and commonweal concerns*, devoting more time to make life better for themselves and doing little or nothing that might benefit others.

Certainly some of widely publicized data from the CIRP surveys support this perspective. More than three-fourths of today's freshmen identify "being very well-off financially" as an "essential" or "very-important" life goal, up from less than two-fifths in 1970. And a record 72.6 percent of the 1988 freshmen indicated that "making more money" was a "very important" factor in their decision to attend college (Figure 15).

Are science students very different from their peers on these issues? Although the aspiring business students are the most likely to endorse the relationship between money and college, engineering majors rank second among seven student subgroups in endorsing the "money factor" as a key issue in the decision to attend college (Figure 16). Moreover, aspiring engineering students — like their peers in business — are less interested in the "general education" aspects of a college education than students in other science (and non-science) majors. In other words, aspiring engineers (like aspiring business students) seem more likely to view their college experience as a period of "technical training" and "portfolio" development — for building the foundations of a career— than as a time for broad learning and personal development. Freshmen planning other science majors seem to be less concerned about money than aspiring engineers and somewhat more interested traditional notions of "liberal education."

Fig. 15: Reasons for Attending College (percentage of entering freshmen indicating "very important")

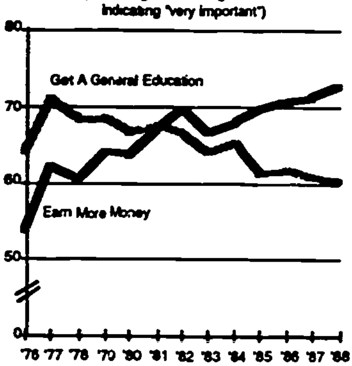
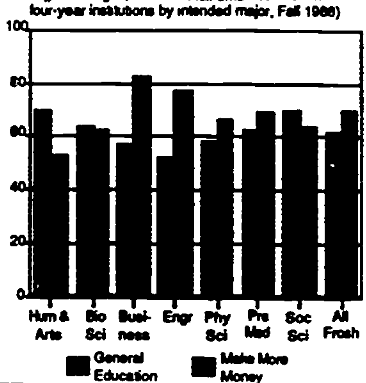


Fig. 16: Reasons for Attending College, by Major (percentages, first-time, full-time freshmen in four-year institutions by intended major, Fall 1988)



Yet despite the CIRP data and other indicators, it may be premature to dismiss today's students as "greedy materialists." Their behaviors and values demonstrate, in part, a readjustment of personal priorities and a reflection of their perceptions of the world. *Today's students are the children of an economic upheaval.* They came of age — into adolescence and early adulthood — during a period marked by the high inflation of the late 1970s, the severe recession of the early 1980s, and the current restructuring of the American economy. Their economic experience has been marked by upheaval and inconsistency rather than growth and stability. Their understanding of aspirations in the context of the American postwar experience — of equalizing if not surpassing their parents' economic accomplishments — is under attack. The key symbols of family economic aspirations — owning a home and sending your children to college — increasingly seem to be the perogative of the rich, or at least to require what today's students' perceive to be as "real wealth." And today's students know that their own families will require the determined efforts of two working adults to provide the financial comforts and security that they may have experienced in a family supported by only one working parent.

We may be offended students's talk about making "lots of money" and being well-off financially. However, we must recognize that the basis of their economic perspective is very different than the one that marked the 1950s and 1960s. The world view of today's students is more like that of their grandparents who experienced the Depression of the 1930s than that of their parents who grew-up during the economically prosperous 1950s and 1960s. The CIRP data document behaviors and attitudes — the shift to business majors, the concern about being well-off, etc. — that reflect a fundamental insecurity about the economic future.

The irony in this behavior, of course, is that demographic forces bode well for these students. These are also the children of the "baby bust." Demographic forces alone suggest that they will experience the best job market the nation has seen in the past 30 years. We already see indicators of this in the "help wanted" signs in many shops, restaurants, and department stores. Yet their outlook and behavior seems unaffected by the rational presentation of demographic and economic data. In short, today's students are scared, risk-aversive, and insecure.

NEW CHALLENGES FOR UNDERGRADUATE SCIENCE EDUCATION

Undergraduate science education confronts major challenges in the coming decade. The CIRP data suggest several. I would like to discuss four issues I see as critical to any effort to rebuild the talent pipeline and talent pool in science and technology fields.

Talent Development

The talent pipeline and science talent development is a critical issue for science these days. Each year tens of thousands academically-able and well-motivated students enter college planning to pursue S/E majors. Yet roughly half will ultimately migrate to other, non-S/E majors during their undergraduate years. This is a tremendous talent loss that institutions and programs need not incur — and that the nation probably can no longer afford. Admittedly this is not now a new problem: the sciences have long experienced high defection rates. However, the decline in both the numerator and denominator variables in the science pipeline suggest we can no longer afford this talent loss. The solution, of course, does not mean pandering to students by reducing expectations about academic performance. B t we should recognize that departments and programs need to develop an environment that enc urages students to pursue the sciences: undergraduates, and especially non-science majors, must perceive the environment — and faculty — as engaging rather than hostile.

The increasing external pressures on institutions to conduct various outcomes analyses may be helpful in this context. As part of institutional efforts to gain control over the growing assessment debate, campuses will have to identify various outcome measures as part of accreditation and program review activities. Data collection that provides information back to departments will be particularly helpful. The key data about program quality and student outcomes *are not* limited to post-test measures on cognitive examinations or department grading curves. Deans, faculty, and program chairs should be asking hard questions about recruitment, defection, and persistence rates among aspiring S/E students. These data contribute as much (if perhaps not more) than traditional testing approaches to an understanding of program quality and outcomes.

Opportunities for Non-Science Students

Second, we need to provide more opportunities and encouragement for non-S/E students in the sciences. Science is a key resource for people in a variety of different sectors. Pharmaceutical companies need people who understand biochemistry *and* market demographics. We also need to forge strong links between science education and public policy programs.

There are a number of different options campuses and departments could pursue. Some may not require the traditional science major. For example, twenty years ago most campuses offered a recognized minor, a separate and important upper-division concentration in an academic discipline other than the student's major. This is but one possibility; certainly there are others. Most important, however, is that these new (or revived) options involve more than students working their way through (or around) a curriculum model based on lower-division distribution requirements. And part of the responsibility for expan 'ing these opportunities rests with science departments and science faculty: they must be genuinely willing to encourage non-science majors to pursue science courses.

Student-Faculty Interaction

Third, we need to know more about the relationship between undergraduate science students and undergraduate science faculty. The discussion prompted by the Oberlin reports (Carrier and Davis-Van Atta, 1985 and 1987) about the "science productivity" of small teaching colleges highlights the key role of faculty in the talent development process. Unfortunately, most of the research about talent development usually ignores the interactive affects in student outcomes: pipeline studies traditionally focus almost exclusively on students and rarely on the key role of faculty behavior and attitudes in defining a learning and mentoring environment. Consequently, we know very little about the interaction between faculty and students in *individual disciplines*.

There are some fairly conclusive data about the interaction affects at the "macro" or institutional level: we know that contact with faculty is a very important factor in the context of career choice, satisfaction with college, persistence, and academic performance (see Astin, 1977). But we know comparatively little about how the faculty factor plays itself out in the individual disciplines. And this is very important information for the people concerned about the talent pipeline in the sciences.

Science in Secondary Schools

Finally, we must acknowledge the pressing need to bring science — and science students — back into secondary school classrooms. We need to explore various program alternatives, degree structures, curricular options, certification procedures, and financial incentives to encourage undergraduate science majors to pursue careers as junior high and high school science and mathematics teachers. We desperately need this talent back in our secondary school classrooms if we are to rebuild the infrastructure which will support the science talent pipeline that has contributed to the nation's research capacity and economic development during the postwar era.

The sciences play an important role in the life and progress of the nation. Science and technology are the engine that will drive the American economy in the 21st Century. There is much we must to do to maintain that engine. Certainly one key factor is recognizing the pipeline issues in the sciences. The CIRP data presented here provide important information that can help faculty, institutional officials, and government policymakers address some of the critical issues affecting the science pipeline in the next decade and the next century.

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Mr. WILLIAMS. Thank you very much.

Dr. Sheridan is Graduate Dean, University of Missouri-Columbia at Columbia. It is nice to see you, and please proceed.

STATEMENT OF DR. JUDSON SHERIDAN, GRADUATE DEAN, UNIVERSITY OF MISSOURI-COLUMBIA, COLUMBIA, MISSOURI

Dr. SHERIDAN. It is nice to be here to have an opportunity to talk about this very important topic—very important, not only for the nation, as you have eloquently presented and as the rest of the people talked about, but absolutely critical for our research universities and for our whole higher education, as well the entire education establishment.

I thought I'd begin by a personal note which occurred to me while I was listening to this last panel. I also happen to be a scientist, and it occurred to me that the reason I'm in science is because of my fourth and fifth grade teacher—the same teacher for two years—maybe it took two years for me to become really committed to science. So, on the basis of that experience, I certainly can appreciate the vital importance of early intervention, early identification of interest, and stimulation of interest. I have to say that my interest in science continued because of very critical interaction with a college professor.

But I happen to be a graduate dean, and so I'm seeing things now from a slightly different perspective in addition to those, and that is the importance of graduate education, and in particular, Ph.D education, as it relates to the full set of problems and issues that we've been talking about. It is our Ph.D's in science and engineering who provide the continual replenishment, the revitalization, not only of the needs of the industry and other private sectors, and the Government, but also, very critically, for the universities themselves. It is a part of an important feedback system and if the feedback loop is broken, the system will not be maintained.

I have too much in my written testimony to do anything other than summarize, and I will emphasize that last point, the point about breaking the feedback loop and how do we insure that that feedback loop is maintained.

A number of us are very concerned about some recent statistics that were put together by Dr. Richard Atkinson, who is Chancellor at the University of California-San Diego. His predictions—based on a very detailed and rather complicated analysis of both the supply, the potential supply, and demand expected by the end of this century—indicate that we could be as much as 7,500 Ph.D's per year in science and engineering below what we need to maintain the demand of the non-academic sector, but very critically to maintain this feedback loop that we need for the universities.

I don't have time to go into some of the facts. I know that a number of those were presented by Dr. Drew in his presentation, and I've got some of them here summarized from Dr. Atkinson's. I thought that what would be useful, perhaps, would be to first just reiterate a few of the things that I think need to be involved in any of the strategies that we would adopt to try to answer this mismatch of supply and demand. The emphasis, of course, has to be on the supply, because we are not likely to be in the business of trying to decrease the demand of industry or the demand of the universities.

You've heard most of these strategies. One of the most important ones is that the action we take has to begin immediately. If we are talking about producing Ph.D's for a greater demand at the end of this century, we have to be getting those students into the graduate schools at this time, or very shortly.

So, as important as the pipeline is, for the longer term we have to be doing things now to begin the process, even at the graduate level itself.

We have to act simultaneously, however, at all different levels, and that is because the pipeline is leaking, it is permeable, as somebody else mentioned. It also doesn't have enough tributaries, so that we have to have ways of getting more stimulation early on and preventing the leakage that occurs.

We do have to address this critical issue of, how do we accommodate the demand of industry and the private sector, and the demand of the universities? That occurs not only with the Ph.D's that leave, but it also occurs earlier in the process. Industry has a great tendency to take bachelor's degree candidates and divert them, not only from what they could do in elementary and secondary education, but divert them from the possibility of going on for Ph.D's. We have to struggle with this. I have no answer, but it has to be a cooperative effort, because we will both lose out in the long run.

The strategies obviously have to include attention to minorities, the issue of under-representation. That is a two-fold issue. It is a moral issue because of the fact that we have whole segment of the population that is not involved in a very important part of what we're all about. It is also an opportunity. It is an opportunity because it is a part of the population expanding more rapidly than any other. It is one part of the pool that has not been tapped, and therefore, with the right attention and with the right strategies, we might be able to really have a big change in the pipeline.

I think it is very important to recognize that a great deal of the resources needed for taking care of these various strategies are going to have to come from the Federal Government. Education institutions are currently committed and working very hard to put their resources into graduate education and into other forms of preparing teachers.

Industry is interested, as we heard from Dr. Montague about Monsanto and other industries, are interested in this problem and are putting resources in as well. For industry, it is difficult, because they are all geared to a much shorter-term solution. Although they may be able see off in the distance a long-term problem, individual industries are unable to factor this in in the way that it can be done on a national scale. It is a national problem and needs a national solution.

What I'd like to finish up with are a few examples of what could be done a bit more locally, because I think it is important to recognize that, although it is a national solution, it is a cooperation among a lot of units in the nation. It is not just a matter of the government doing it all by itself.

We have several programs that address certain of these various strategies or issues that are similar to ones around in other universities, but I think it would be useful to mention at least a couple of them, and I've listed several.

Probably a common theme amongst all of these things is to try to get our graduate students involved in ways other than simply getting their Ph.D's and then leaving. In other words, simply doing their research and leaving. One very important area is to convince at least an appropriate fraction of Ph.D students, that teaching is an extremely important part of what they are all about and what they will be all about as they leave to hopefully enter into the professoriate.

We have not done the kind of job, I believe, that we could do in emphasizing the importance of the teaching role of graduate students. Rather, what we have done is tended to talk about graduate students as somehow second-class teachers, and have forgotten the fact that their teaching experiences not only can be very vital and stimulating for the undergraduates they teach, but also are an important training ground for them as future professors.

We have developed a teacher training program. It began with this emphasis on international students. We, like most other research universities are find larger and larger numbers of international students in the sciences and engineering. What we have found is that those students respond very well to a carefully, ordered, mentored program for teaching skills and attitudes and motivation in teaching. We are having that program expanded to included others of our graduate students. We are not doing enough, yet, but I think it is the right direction to go.

In trying to address the minority student problem, we are fully aware of the fact that it is probably more than any of the others, a pipeline problem. Nevertheless, we need to act as much as we can at our level. We have instituted a fellowship program. It is a four-year fellowship program which provides support, and it has been effective in recruiting students, many of which actually are interested in the sciences and engineering.

But that is not the only place that we have been focusing our attention. That is, not only on our institution, on our own graduate students, but trying to see how the university can work further down the line. I'll pick just a couple of examples.

One, our graduate professional students, on their initiative, have developed a program for going out to visit high schools. What they do is to go as individuals or as groups out to the high school to tell the students about what is possibly ahead of them at college and more so, even down the line, in graduate school. The students showing the greatest interest, that is, the graduates that are showing the greatest interest have been those in the sciences and engineering. I think because they sense the importance of the crisis that is facing us.

Another way of getting involved earlier in the pipeline, this time at the college level, is to have research universities trying to develop cooperative arrangements with other universities close by, other colleges. We've had a long-time relationship/interaction with Stephens College, which is a predominately women's college in Columbia. That particular interaction has focused on our research reactor facility. It is the enthusiasm of one faculty member. The dedication and involvement and interest of a group of students and the full support of the institution through the research reactor have all combined to really be an effective experience for those undergraduates. I might add, that a very important part of the experience is their interaction with graduate students. They are doing research on the research reactor.

These various programs that we have, many more of them around the country and probably of considerably greater diversity, I think are extremely important for providing the right kind of complementary and cooperative sorts of effects and programs that can work with the support by the Federal Government.

These together will, we hope, have the possibility of preventing this costly shortfall of Ph.D's and the steep price that will be paid by all of us: by government, industry, universities, and the population as a whole.

Our future in science and technology is being determined today. We must act with vision and with determination.

Thank you.

[The prepared statement of Dr. Judson D. Sheridan follows:]

Sta⌞ement by

JUDSON D. SHERIDAN

Vice Provost for Research and
Dean of the Graduate School

University of Missouri-Columbia

Before the

Subcommittee on Postsecondary Education

Committee on Education and Labor

U. S. House of Representatives

May 1, 1989

INTRODUCTION

Mr. Chairman and members of the committee:

I appreciate the opportunity to participate in this hearing on math and science education and to comment on the particular problems facing doctoral education in these areas of critical national need.

I am Vice Provost for Research and Dean of the Graduate School at the University of Missouri-Columbia, one of the more comprehensive research universities in the country. My responsibilities include the promotion and facilitation of research and scholarship in twelve different colleges and in seven multicollegiate research centers and programs, and the encouragement, central management, and coordination of sixty distinct PhD and 122 other graduate programs, more than half of which are in the sciences. I am also a cell biologist and my concerns about the impending crisis in graduate education in science and math arise from my perspective both as an administrator and as a scientist.

THE PROBLEM

The preeminence of the United States in the world scientific community depends heavily on the unique merger of research and PhD education that characterizes our "research universities." PhD students not only contribute directly to the advancement of scientific knowledge as they pursue their degrees. They are the source of new researchers and scholars for replenishing and continually revitalizing the research enterprise in the academic, industrial, and governmental sectors. Consequently, maintaining our scientific and technological stature requires the continued flow of qualified undergraduates into PhD programs and of new PhDs out of the universities.

We can be proud of many aspects of doctoral education presently being delivered across the country. Yet alarms are being raised in many quarters about the prospects of a severe shortage of PhDs, a critical mismatch of supply and demand, that we can expect by the mid-to-late 1990's if we do not establish effective countermeasures.[1]

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[1] Sovern, Michael I., Higher Education - The Real Crisis, The New York Times Magazine, January 22, 1989.

Based on a particularly thorough analysis, Dr. Richard Atkinson, Chancellor of the University of California at San Diego and President of AAAS, recently presented a bleak picture to the California Board of Regents.[2] He discussed several factors contributing to the "growing imbalance between supply and demand -- an incre sing demand for PhDs that will not be met by the supply."

According to Atkinson's analysis the demand for new PhDs arises from non-academic and academic sources:

o Demand in the non-academic sectors, principally industry and government, should continue to increase "at least as rapidly as total employment, and probably more rapidly," reaching a projected annual need of 9,500 new PhDs in natural sciences and engineering by the year 2004.

o Demand in the universities is expected to change more precipitously over the latter part of the 1990s, a result of the acceleration of faculty retirements combining with a projected increase in college enrollments. The many faculty members hired in the immediate post-Sputnik era will begin to reach retirement age, increasing the need for replacement faculty from 2,000 in 1988 to 4,500 in 2004. An additional need for about 4,000 new PhDs responding to an enrollment increase will bring the academic demand to 8,500 new PhDs per year by 2004.

o Demand in total will be 18,000 by 2004.

Atkinson indicates that the supply, coming only from universities, presents an even more complex picture:

o Supply projections must take into account the rates of entry of prospective PhD candidates into the baccalaureate pool, the proportion expected to choose science and engineering, the proportion expected to enter PhD programs, the time it takes for the PhD to be earned, and the subsequent career goals of the PhDs.

o With a decreasing college-age population over the next decade, there must be a combination of a higher

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[2] Atkinson, Richard C. Supply and Demand for Science and Engineering Ph.D.s: A National Crisis in the Making. Remarks to the Regents of the University of California, February 16, 1989.

proportion of individuals entering college and choosing science and engineering with at least a constant pr ortion of baccalaureate recipients choosing PhD programs in these areas.

o Industry has been accused of "eating its own seed corn," however, by attracting many of the best science and engineering graduates out of the prospective PhD pool.

o The production of science and engineering PhDs has increased over the recent years, but heavily affected by greater numbers of international PhD candidates. While as high as 70% of these international PhDs currently remain in the U.S., this figure is likely to decrease as foreign governments build their science and technology capacity and increase the pressure for their citizens to return home after graduation.

o All factors combined suggest that the rate of science and engineering PhD production will decrease over the next decade, reaching a level of about 12,000 per year in 2006, down from about 14,500 currently. With the return of 30% of the international PhDs to their home countries, the net available to meet the demand will be 10,500.

Therefore, Atkinson's analysis leads to the startling projection of a 7,500 per year short-fall in science and engineering PhDs by 2006. If the academic and non-academic sectors share the short-fall equally, each will be severely affected. If the academic sector fairs less well in the competition for new PhDs, the imact on future generations will be even greater because the PhDs are needed to produce future PhDs - a drastic negative spiral will be produced, one from which it will be difficult for the country to recover.

Before commenting on the strategies for addressing the situation, it bears note that in the academic sector, the conditions for PhDs in humanities and social sciences may be similarly devastating by the end of the century. It is important to recognize that the integrity of the university curriculum and educational mission, even for scientists and engineers, requires a healthy liberal arts core; the breadth of that mission is important for the education and the performance of scientists and engineers as well as faculty and students in other disciplines.

STRATEGIES

Our strategies should be based on the following principles:

o The focus must be on increasing the supply. While the projected demands, as Atkinson admits, could be overestimated, without appropriate action, a serious shortfall is inevitable and we cannot afford the risk of being wrong about its magnitude.

o We must begin immediately to take action. In order for the flow of new PhDs to increase to meet the projected demand of the late 1990's, PhD candidates should be now entering the nation's graduate schools. We cannot wait for the changes in the market to become apparent - that will be too late for a satisfactory response.

o We must act simultaneously at several different educational levels to ensure both short-term and long-term effectiveness. Augmented support and incentives for college graduates to enter PhD programs are needed to address the most immediate problem, but we must also plug the leaks in the pipeline and increase the flow rate from the lowest level on up. Students decide in junior high school whether or not they are interested in science, and the necessary academic foundation for making the choice and for pursuing science successfully must begin its construction even earlier.

o Any strategies must include attention to the serious problem of underrepresentation of minorities[3] and, in certain cases, women, in science and engineering PhD programs. For example, Blacks received less than 1% of the PhDs awarded to U.S. citizens in the physical sciences and engineering in 1987.[4] The proportion of Blacks and Hispanics in the population is increasing, whereas the proportion entering colleges is decreasing.[5] If we are successful in attracting more of these students into college

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3 Minorities on Campus: A Handbook for Enhancing Diversity, American Council on Education, Washington, D.C., 1989, pp. 56-57.

4 Survey of Earned Doctorates, National Research Council, 1987, p. 48.

5 Seventh Annual Status Report on Minorities in Higher Education, American Council on Education, 1989, p. 1.

and graduate work, we will expand the pool of qualified and interested PhD candidates, as well as address the representation issues.

o <u>We must ensure that an appropriate proportion of science and engineering PhDs choose academic careers if we are to continue the production of new PhDs and the generation of the basic research knowledge now provided by university faculties</u>. PhD candidates need to be attracted by the entire spectrum of faculty responsibilities - teaching, research, and service. Special effort is needed to illustrate the rewards of high quality teaching and to prepare PhD students for the teaching components of faculty appointments.

o <u>The Federal Government should play a major role in providing the financial support for PhD students</u>. Universities are already heavily committed to graduate student support through special fellowships and teaching assistantships. Although industries stand to suffer from a PhD shortfall, we cannot anticipate that they will significantly increase their support of graduate education. This would require a change in corporate policies, which now favor shorter-term investments, an unlikely occurrence since the return on long-term investment for individual companies is too difficult to predict. The problem is a national one and requires a national effort.

The Federal response to the Sputnik crisis of the late fifties - the NDEA Title IV graduate fellowship program and other major new federal initiatives - led to an almost three-fold increase of PhDs from 1960 to 1969. These PhDs rapidly became the core faculty of our higher education institutions and the foundation of our preeminent research community inside and outside of academia.

From the peak of 1969, when 80,000 federally funded stipends were awarded, there has been a marked decline in graduate training funds, only partially offset by an increased number of research assistantships. The current level of less than 50,000 federally-supported fellows and research assistants is about 60% of that at the peak. New programs, such as the National Needs Graduate Fellowship program, have begun to reverse this trend, but more is needed and fast. Dr. Wilson will address this issue and the effectiveness of the National Needs program in his comments.

o While the direct support of PhD students is the most immediate concern, enhanced Federal support for other aspects of the university research enterprise is critical if scientific research in a university context is to attract the necessary numbers of PhD candidates and new faculty members. The newest government trends are encouraging, especially those aimed at restoring the greatly eroded research infrastructure and facilities. Again, more is needed for a significant impact on the problem.

UNIVERSITY INITIATIVES

Federal programs will work best in the context of complementary and cooperative efforts by states and universities. Most states and universities have already begun to respond to the impending crisis. A few examples from my own institution are illustrative. They represent a wide range of attempts we are making to reach students earlier in the pipeline and to convince them to consider graduate education and careers in science and engineering, especially in academia.

o We have begun an extensive and intensive program for training graduate student teaching assistants, as an attempt to give teaching skills a greater emphasis in the graduate education process. Our broader premise is that T.A.s need to become better "communicators" in order to contribute optimally to the undergraduate educational experience and to prepare for entry into the professoriate, where teaching will be one of their major functions, or into other careers, where communication in some form will be an essential component of their professional responsibilities. The program began with an emphasis on international students and has broadened to include all our T.A.s. Workshops, video analysis, and detailed evaluation by expert teachers are used to enhance teaching skills and to increase motivation. Because many of our T.A.s are masters' degree candidates, we hope that some of the best of these will be encouraged to continue for a PhD when they recognize the rewards of teaching in combination with research.

o We have recently instituted a major fellowship program for minority graduate students. Our program has some distinct features. PhD candidates are guaranteed four-year support at a level of $12,000 plus all tuition and fees. Departments must contribute a one quarter-time teaching assistantship each year to each fellow, which ensures departmental involvement and an opportunity for the minority students to develop teaching skills and interest. This program, named for our first black graduate student, Dr. Gus T. Ridgel, has attracted considerable interest among highly qualified minority students. For next fall, we have made a third of our offers to students interested in the sciences or engineering. We have combined this fellowship program with an aggressive recruitment effort involving visitation of nearly 50 institutions and extensive mailing and telephone followup. Some of our more effective recruiting efforts involve our own black graduate students, a strategy we believe could be extended to our general recruiting activities.

o Our university has begun publishing a science magazine aimed at junior high school students and focusing on scientific research by our faculty. The most recent issue of the magazine highlights research in such areas as nuclear medicine, archeology, anthropology, veterinary medicine, and food science. This activity represents only one of our efforts to affect students at the time they begin making decisions about pursuing science or other areas of potential graduate study.

o Some of our graduate and professional students have recently begun visiting state high schools as part of a new program established by their student organization. Their aim is to describe graduate and professional education and to encourage the high school students to begin thinking about future academic and professional careers. Much of the focus is on research and scholarship, with a particular emphasis on science and engineering and associated mathematics.

o Our campus has been involved in another innovative program, funded by the state and targeted on gifted students ready to begin their junior year in high school. The Missouri Scholars Academy provides a three-week, residential program for 300 students coming from all over the state and chosen on the basis of academic and leadership potential. There is a strong emphasis on developing creativity in approach to ideas and problems. Although a wide range of academic subjects is available, many students emphasize science and mathematics.

o Two of our research centers have taken advantage of the NSF program, Research Experiences for Undergraduates (REU), joining well over 150 recipients of "Site" awards nationwide. This program provides an opportunity for universities to cooperate with the Federal government to encourage involvement of undergraduates in research and to expose them to graduate students. One of our "site" awards was made to the University of Missouri Research Reactor and will provide the undergraduate participants with a valuable opportunity to engage in a wide range of research projects from neutron scattering to radioisotope production and application. The students will interact with reactor staff, faculty, and graduate students. Thus they will experience an active research environment and learn first-hand about the research side of graduate education.

o Another way that research universities can affect the pipeline is by providing research opportunities for students in nearby four-year colleges. We have such a program involving our research reactor and students at Stephens College, a private college in Columbia. The fact that this is predominantly a women's college has special significance given the underrepresentation of women in physical sciences. The enthusiastic support and guidance of a dedicated faculty member at Stephens, the interest and motivation of students, and the encouragement and mentoring of professional staff at the reactor combine to make this an effective program. Over the years, the students in this program have won several local awards for research projects and papers. More important, their interest in scientific research careers has been fostered and their prospects for entering and completing PhD programs in science have been enhanced.

CONCLUSION

These various programs, and many others like them at research universities around the country, help address the PhD supply problem in sciences and engineering. If we can be assured of strong leadership and sufficient financial support from federal sources, together we can work toward preventing a costly Ph.D. shortfall and the steep price that will be paid by government, industry, and universities. Our future in science and technology is being determined today - we must act now with vision and determination.

Mr. WILLIAMS. Thank you.

Our final member of this panel is Dr. Ed Wilson, Dean of Graduate Studies at Washington University in St. Louis. Doctor, it is nice to have you with us.

STATEMENT OF DR. ED WILSON, DEAN OF GRADUATE STUDIES, WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI

Dr. WILSON. Thank you, Mr. Chairman, Mr. Coleman, for offering me the opportunity to participate in this hearing. As you mentioned, I serve as the Graduate Dean at Washington University. I am also a professor of mathematics, and that is not unrelated to the fact that a number of examples in my testimony will be drawn from mathematics.

I'm going to begin my testimony with just a few remarks supplementing comments of other speakers, and then spend the remainder of my time explaining how the new Federal program entitled, Graduate Fellowships in Areas of National Need, can be effective as a partial address to the problems under discussion today.

Every commentator and graduate educator—and I think nearly every member of the panel—now calls attention to the rising percentage of foreign students in the sciences. Among the conclusions customarily drawn is that college science teachers will, in the near future, be increasing foreign born. In fact, the study conducted two years ago by the Conference Board of the Mathematical Sciences shows that new junior faculty and post-doctoral fellows in leading mathematics departments across the country are already twice as apt to be foreign as a decade ago. The numbers are on page seven of my written testimony. I presume you'll find them rather startling, because the change has been very, very rapid.

Although I'm unaware of comparable hard data on hiring patterns in other disciplines, the example of anecdotal lessons, with a trend toward increasingly foreign faculty is already even more pronounced in engineering than in mathematics, and it certainly regulates the foreign born in physics.

I fully concur with Dean Sheridan that to adequatly address the general problem we're discussing today will necessitate a number of new cooperative programs and initiatives at every level of our educational system.

I might interject that I, too, as Dean Sheridan was commenting, was remembering my high school teachers. There were simply three mathematics teachers, all women, who were absolutely superb. I noted in Dr. Drew's testimony data indicating that high school teaching, especially mathematics, is no longer as appealing to women and is certainly has an awful lot to do with what we're now seeing at the college level.

I also was remembering an undergraduate mathematics instructor was just absolutely superb and dedicated to teaching—probably didn't get the recognition that he deserved. So, we are talking, as we know, about a pipeline that has plenty of leaks.

But I believe it is very important to dwell at length on the benefit the new National Need Program has already provided in its first year of operation.

National Need follows the pattern of the highly successful NDEA Title IV program in providing sizable block grants that act in the departments for the purpose of supporting institutionally designated American graduate studies. I was one of the nearly 46,000 students supported by NDEA over its 14 years of operation. In my case, the NDEA funds were the only practical means by which my department could support me through my final two years.

Under NDEA, Title IV, in the past, the National Need today targeted departments and institutions acquire the means to stabilize or enlarge their graduate programs, their flexibility to accommodate individual student needs, and the capacity to recruit students who might otherwise not attend graduate school.

At Washington University, both our mathematics and physics departments were fortunate to be among the 42 departments selected nationally to receive National Need grants in the first cycle. Our physics department enjoyed unprecedented success in recruitment this Spring of American students. Both the quality and quantity of applicants and acceptees was very much up. For the first time in many years, a Black student will be entering the department next year.

The department described to me a number of specific benefits from the grant that came in the areas of enhanced recruiting power and flexibility to fund students and the ability to admit more students.

The mathematics department, my home department, in most of the recent past years, have had at most two Americans who deserve conclusion on strict academic merits among the top 30 applicants. It is the top 30 from which we normally expect to draw our class. But this year we were able to offer admission to eight Americans, rather than the three or four we leaned over backwards to admit in prior years.

The problem that we're up against is that the average foreign student that we admit is roughly three years ahead of all the Americans that are both mathematically talented and well prepared.

With National Need funds, we can, in good conscience, admit these students, give them an extra year or two to strengthen their backgrounds, and develop special summer seminars to acquaint them with questions in mathematical research. I assert that it is in the national interest to make an attempt to develop this pool of adequate and trained talent and that National Need grants to other mathematics departments can tantalize the effort.

I spoke recently with Dr. Matt Riley, professor of chemical engineering at Lehigh University, concerning his department's experience with their National Need grant. He stated that the grant had revitalized their graduate program through adoption of a new look at recruitment strategies; introduction of optional academic and industrial internships; academic internships for the kind of pedagogy training that Dr. Sheridan was talking about; and in preliminary success, in encouraging all the companies to insure long-range perpetuation of the new departmental initiatives made possible by National Need.

I'm sorry that time does not permit me to poll the other departments around the country who are enjoying National Need grants.

It might be that each one could supply other fascinating illustrations of innovative and productive use of the grants.

I'm going to conclude my testimony by expressing the profound gratitude of the entire graduate community for the prodigious efforts by Representative Coleman to establish the National Need Fellowship Program. We followed with avid interest and admiration, as the issue of activities, from introduction of the initial legislation to the long authorization process and the many levels of House and Senate debate over appropriation, and oversight through his staff of program implementation and direction.

Representative Coleman, we salute you, for illustrating so vividly what a member of Congress can achieve through vision and tenacity.

Mr. Chairman, thank you again for inviting me to testify. I'll be happy to answer any questions.

[The prepared statement of Dr. Edward N. Wilson follows:]

Edward N. Wilson
Dean, Graduate School of Arts and Sciences
Washington University in St. Louis

Remarks at the Hearing in Kansas City, Missouri,
of the Subcommittee on Post-Secondary Education
House Committee on Education and Labor
Honorable Pat Williams, Chairman

May 1, 1989

Thank you, Mr. Chairman, for offering me the opportunity to participate in this hearing. I have served for the past six years as Dean of the Graduate School of Arts and Sciences at Washington University, administering my University's twenty-odd Ph.D. programs and forty-odd Master's programs. In addition, I continue to do a limited amount of undergraduate and graduate teaching in the Department of Mathematics where I have been a faculty member since 1973.

My testimony today will begin with a few comments supplementing the remarks of previous speakers on the dwindling participation by U.S. citizens in science and mathematics graduate programs. The remainder of my time will be devoted to explaining why I believe the new program entitled Graduate Fellowships in Areas of National Need can be very effective as a partial address to this problem.

Fewer American Graduate Students and More Foreign Faculty

Appendix 1 to this testimony cites depressing, albeit familiar, data from the National Research Council's Survey of Earned Doctorates on the steady decline in the percentage of new mathematics and science Ph.D.s who are U.S. citizens. These data have triggered a stream of reports and speeches forecasting dire consequences for both the research enterprise and the teaching of future undergraduate generations. Yet all of us can recall alarmist predictions in other contexts which subsequently proved to be exaggerated. For this reason, I regret that the study conducted two years ago by the Conference Board of the Mathematical Sciences has not received more national attention. This study, some tables from which are reproduced in Appendix 2, demonstrated that the anticipated dilemma of increasingly foreign-born mathematics faculties is already at hand. Thus the percentage of foreign junior faculty in leading Mathematics Departments rose from 26.9% in 1977 to 36.3% in 1985 and then jumped to 45.6% in 1986, the last year analyzed by the survey. Since junior faculty at research universities are increasingly drawn, in mathematics and the sciences, from the ranks of postdoctoral fellows, even more ominous is the fact that the percentage of mathematics foreign postdocs rose from 27.6% in 1977 to 39.7% in 1985 and then skyrocketed to 59.6% in 1986. Given the recent Ph.D. production figures, it seems safe to presume the current year percentages are even higher.

I don't in any way wish to imply that foreign-born faculty are inherently bad. One has only to recall the ample evidence that in mathematics and throughout much of the sciences, the post-World War II rise to world prominence of American research was largely fostered by an influx of highly skilled foreign nationals. Would-be mathematicians learn quickly to cope with foreign accents and to appreciate the international nature of their discipline. But undergraduates whose mathematical instincts are not as strong are understandably less well disposed toward calculus instructors with heavy accents and unconventional notions of pedagogy. Since calculus is fundamental for all prospective scientists, there is abundant reason to be alarmed at the above percentages while simultaneously acknowledging the large number of foreign-born mathematicians who teach superbly in our colleges and universities.

Although I am unaware of comparable hard data on hiring patterns in other disciplines, there is ample anecdotal evidence that the trend toward increasingly foreign faculty is even more pronounced in engineering than in mathematics and has become readily observable in physics.

Graduate Fellowships in Areas of National Need: A Trigger for Innovative Partial Solutions

I fully concur with Dean Sheridan that adequate address to the general problem we are discussing today will necessitate a number of new cooperative programs and initiatives at every level of our educational system and with sponsorship from many sources. Nonetheless I believe it important to dwell at length on the benefit the new National Need program has already provided in its one year of operation and the high importance I place on maintenance of this program for the future.

National Need follows the pattern of the highly successful NDEA Title IV program in providing sizable block grants to academic departments for the purpose of supporting institutionally designated American graduate students. Nearly 46,000 students were supported by NDEA during its fourteen years of operation from 1959 to 1973. I was one of these. In my case, the NDEA funds were the only mechanism under which my department could support me during the two years I spent writing my dissertation out of residence under the close-at-hand mentorship of a mathematician who had taken a faculty position at another institution. One of my fellow graduate deans has informed me that in his case as well successful completion of graduate study would likely not have been possible without an NDEA Fellowship. Appended to my testimony are results of a survey favorably comparing the subsequent scholarly accomplishments of NDEA Title IV beneficiaries with scholars whose graduate study was supported by other mechanisms.

Under NDEA Title IV in the past and National Need today, targeted departments and institutions acquire not only the means to stabilize or enlarge their graduate programs, but the flexibility to accommodate individual students' needs and to recruit students who might otherwise not attend graduate school. At Washington University, both our Mathematics and Physics Departments were among the forty-two departments nationally who were awarded National Need grants in the program's first cycle. Dramatic consequences have resulted in both departments. The Physics Department has enjoyed unprecedented success in recruitment of American students this spring. Both the quality and quantity of applicants and acceptees were up dramatically. For the first time in many years, a black student will enter the department next year. In response to my query on the specific benefit Physics has realized from their National Need grant, the Departmental Graduate Coordinator responded as follows.

** capacity to guarantee long-term funding for students irrespective of the future success of faculty in securing external grant support for their laboratories; flexibility to continue current students without interruption when an advisor's grant dries up;

** lifting of the necessity to tightly regulate graduate admissions in accord with available teaching assistantships;

** enhanced recruiting power derived from elevated departmental image and perception by students of federal commitment to the discipline.

In mathematics, our National Need grant has provided both the impetus and capability for us to fully implement a two-tiered graduate program. This year, as in past years, at most two Americans deserved inclusion on strict academic merits among the top thirty applicants out of a total pool of approximately 120. But this year we were able to offer admission to eight Americans rather than the three or four we leaned over backward to admit in previous years. Startling as it may sound, the average foreign student we admit is roughly three years ahead of all but the very best American applicants, i.e., the students who are not only mathematically talented but had the good fortune to attend an undergraduate institution able to offer them a demanding and rigorous mathematics curriculum. The Americans we were forced to reject in previous years included straight A, best in the class students from small colleges unable to provide more than a very rudimentary foundation for mathematical research. With National Need funds, we can in good conscience admit these students, give them an extra year or so to strengthen their backgrounds and, most importantly, introduce them to modes of mathematical thought and open research questions through carefully designed summer seminars and directed studies. Neither we nor anyone else can guarantee a 100% rate of success with such remediation efforts. I am, however, convinced that it is imperative to make the attempt to develop this national pool of inadequately trained talent. For the numerous reasons under discussion today, we must anticipate the passage of many years before there will be an adequate national supply of Americans able to compete in mathematics on an equal basis with foreign chronological peers admissible into our nation's graduate programs. The National Need program can play a vital role in permitting other mathematics departments to adopt the kind of approach I've described above.

I spoke recently with Dr. Matt Reilly, Professor of Chemical Engineering and Director of Research Development at Lehigh University, concerning Lehigh's experience with their National Need grant in Chemical Engineering. Dr. Reilly stated that the grant had revitalized their graduate program by encouraging and enticing the entire department to take a comprehensive fresh look at its graduate program. Among the specific initiatives catalyzed by the grant are the following:

** new look at recruitment strategies, especially for minority and women students, enlisting selected University personnel who have general expertise in recruitment as resource people in a Recruitment Advisory Council;

** integration into the graduate program of optional academic and industrial internships, the academic internships to entail individualized pedagogy training under the supervision of a senior faculty member: guest lecturing appearances in regular courses with subsequent constructive critique, design of new courses, etc ;

** extension of existing substantial interactions with local industries, including use of the National Need funds as challenge grants to industry in order to ensure long-range perpetuation of the activities made possible during the three-year duration of the National Need grant; thus far, there has been delight over the positive reception to this campaign with reports received that several companies are working toward future budget commitments to the department;

** acceleration of efforts to establish an exchange agreement with the University of Puerto Rico under which Lehigh would provide graduate training to selected Puerto Rican students with the expectation that a number would thereafter assume faculty positions at the University of Puerto Rico.

I regret that time did not permit me to poll more departments around the country who have received National Need grants. My guess is that each would supply other fascinating illustrations of innovative and productive use

I shall conclude by expressing the profound gratitude of the entire graduate education community for the prodigious efforts by Representative Coleman to establish the National Need Fellowship program. We have followed with avid interest and admiration his leadership activities from introduction of the initial legislation through the lengthy authorization process, the many levels of House and Senate debate and compromise resulting in appropriation, and oversight through his staff of program direction and implementation. Representative Coleman, we salute you for illustrating so vividly what a member of Congress can achieve through vision and tenacity.

Mr. Chairman, thank you again for inviting me to testify. I shall be happy to answer any questions prompted by my remarks.

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Appendix 1.

Decreasing Number of U.S. Ph.D.s in Science and Mathematics

	Biosciences		Engineering		Mathematics		Physical Sciences	
Year	Total Ph.D.s	% U.S. Citizens	Total Ph.D.s	% U.S. Citizens	Total Ph.D.s	% U.S. Citizens	Total Ph.D.s	% U.S. Citizens
1982	3502	84.9	2644	44.1	720	63.6	3348	75.0
1983	3732	[illegible]	2780	41.8	701	58.6	3438	74.0
1984	3872	84.7	2915	42.5	699	58.2	3459	73.6
1985	3766	83.0	3165	40.4	689	54.6	3531	70.3
1986	3791	82.3	3376	40.8	730	50.3	3679	66.1
1987	3824	77.7	3716	41.8	740	46.6	3637	65.1

Source: Annual Summary Reports on Doctorate Recipients from United States Universities, produced by the National Research Council.

Appendix 2.

Report of the Committee on American Graduate Mathematics Enrollments

*Conference Board on Mathematical Science**

The following is a summary of a report by the Conference Board of the Mathematical Sciences (CBMS). Alarmed by anecdotal reports about the decreasing fraction of mathematics graduate students who are U.S. citizens, the CBMS appointed a committee on American Graduate Mathematics Enrollment in May 1986. The committee consists of Joe Kohn, Princeton University; Betty Lichtenberg, University of South Florida; Willard Miller, University of Minnesota; and Barry Simon, Committee Chairman, California Institute of Technology.

The charge to the committee includes the following:

- to determine if there is a problem by examining available statistics, and if necessary to collect additional statistics
- to examine the effects of the problem, if one exists.
- to make recommendations about how to cope with any possible problems

The committee obtained some of the data for the study from the National Science Foundation which provided information for the years 1977 to 1984. The rest of the data was solicited from the top thirty-nine institutions in mathematics as listed in the last AMS survey; all but one of the institutions responded. However, for some of the years the report says some institutions did not supply any data.

Table I. NSF Data on Graduate Enrollments

	1977	1980	1984
U.S. Citizens			
All S/E Disciplines	197 716	198 429	199 693
Mathematics	7,910	6 618	6 710
Physical Sciences	17 509	17 174	18 187
Foreign			
All S/E Disciplines	38 448	50 120	64 452
Mathematics	2 455	3 254	4 513
Physical Sciences	4 696	5 744	7 479
% Foreign			
All S/E Disciplines	16 3%	20 4%	24 4%
Mathematics	23 7%	32 9%	40 2%
Physical Sciences	20 9%	25 1%	29 1%

Table I shows NSF data for three selected years in three categories: all areas of science and engineering (S/E), mathematics (including statistics), and physical sciences (not including mathematics). Table 2 breaks down the 1984 data by field.

Table II. NSF Data on 1984 Graduate Enrollments by Field

	Total	Foreign	% Foreign
Engineering	56 862	23,946	42 1%
Physics	9 911	3,765	38 0%
Chemistry	14 996	3,567	23 8%
Mathematics	11,223	4,513	40 2%
Computer Science	11 448	4 507	39 4%
Biological Science	37 554	5,896	15 7%
Economics	8 976	3,522	39 2%

The report notes a "clear and quite dramatic" trend toward a consistently higher percentage of foreign students in mathematics than in the physical sciences or than in science and engineering overall. However, Table 2 shows that the situation is just as bleak in several other areas. The report pointed out that the drop in the number of mathematics graduate students with U.S. citizenship was accompanied by a slight rise in the total number of graduate students.

Tables 3 and 4 contain data collected by the committee from the top thirty-nine institutions.

Table III. Foreign Graduate Enrollments in Mathematics

Year	% of First Year Students	% of All Students
1977	22 4%	19 6%
1978	24 9%	18 2%
1979	25 7%	22 6%
1980	32 1%	27 1%
1981	39 4%	27 7%
1982	32 1%	32 5%
1983	36 8%	39 2%
1984	38 2%	41 1%
1985	46 7%	44 6%
1986	46 2%	45 8%

Referring to Table 3, the report noted that the problem is worsening. In addition, of the thirty five schools that provided information about first year students in 1986, half indicated that 50% or more of their first year students were foreign. The report observed, not surprisingly, that the steady increase in the fraction of foreign graduate students is mirrored in the steady increase of foreign postdoctoral fellows and untenured faculty

Table IV. Foreign Nontenured Personnel in Mathematics

Year	% of Nontenured Faculty	% of Postdoctoral Fellows
1977	26.9%	27.6%
1978	32.5%	26.3%
1979	[illegible]2.6%	38.9%
1980	28.4%	43.9%
1981	32.8%	25.0%
1982	34.9%	2[illegible]%
1983	36.1%	29.2%
1984	37.3%	35.1%
1985	36.3%	39.7%
1986	45.6%	59.6%

Analysis

New talent The report notes that mathematics has influenced many aspects of our modern technological civilization, from the security of bank transactions, to elementary particle physics, to the development of computer algorithms In the post-World War II period, the emergence of the United States as the premier power in mathematical research produced an explosive growth in the field. The report goes on to say that, because those who entered the field in the 1950s will be retiring in the next fifteen years, mathematics will be facing severe manpower shortages All predictions suggest that the average age of tenured faculty in mathematics will increase. This trend, the report says is "not healthy in a field in which research accomplishments are dominated by the young" Warning that continued American leadership in the mathematical sciences is central to the long term prosperity of the nation, the report points out that the current prognosis for the vitality of the field is bleak.

Teaching For foreign graduate students postdoctoral fellows, and faculty, language barriers can present teaching problems In mathematics the report says, teaching assistantships have traditionally been a major source of support for graduate students, and the bulk of postdoctoral positions involve teaching Even when the teachers have excellent written and oral skills in English, the report maintains their accents can make them very difficult for students to understand. There have even been cases in which undergraduates brought suit against their schools because their instructors had inadequate English skills and in several states legislative action is being considered

The report urges that adequate instruction in English be made available to foreign students Fluency examinations as a precondition of acceptance to graduate school are rejected in the report on the grounds that administering them abroad is too complicated and that the results are difficult to quantify

Why has it happened? The report says that the mathematics community has [illegible]ed to attract many of the very best potential mathematicians and conjectures three reasons for this failure

- Salaries in academia are lower than in competing areas such as law, medicine, and business
- Society as a whole has become more materialistic
- Students introduced early to computers are often likely to study programming rather than mathematics

Recommendations

The report urged a more detailed follow-up study, under the auspices of the National Research Council, to examine the full spectrum of manpower problems in the mathematical sciences including the lack of women and minority mathematics students Some specific suggestions are

- studying the educational and career paths of those who do well on the various national high school examinations, such as the Putnam examination;
- studying the distribution of foreign mathematics graduate students by country of origin, and investigating how many have permanent residence status,
- studying the extent to which the increase in the percentage of foreign students is due to a decrease in the number of American students or due to an overall growth in the number of students,
- studying the extent of the problem in statistics The committee received anecdotal evidence that the situation is worse in statistics than in the mathematical sciences as a whole.
- adding more schools to the top thirty-nine used by the committee in this study

The report also gave recommendations to rectify the language barriers that cause teaching problems

- First year foreign students should be given positions that only involve grading until they demonstrate spoken fluency
- Mathematics departments need to convince the administrations at their institutions to offer formal instruction in English for incoming graduate students Receiving such instruction may mean delaying slightly the schedule for meeting other requirements that may be more academically significant
- Mathematics departments must insist that their instructors be fluent in spoken English Too often postdoctoral fellows are hired on the basis of their mathematical potential without regard to language difficulties that might affect their teaching

Early on in the study, the committee noted a dearth of mathematics programs for bright high school students While a few programs do exist the report says that they are not an adequate solution to a national problem The chairman of the committee visited the NSF to try to convince some key people of the importance of a program for high school students

Subsequently, the report says the education directorate at the NSF proposed such a program, which is included in the budget proposed to the Congress by the Office of Management and Budget Entitled the "Junior Scholars Program" and budgeted at $3 9 million it would allow about 1 500 students to attend summer institutes in the summer of 1988 The report applauded this initiative but noted that because the program addresses all sciences the funding is inadequate and needs to be increased in the future

Source: Notices of the American Mathematical Society (August 1987), pp. 748-50.

Appendix 3. Highlights of 1975 Followup Study of NDEA Fellows.

Title IV of the National Defense Education Act of 1958 supported 45,829 graduate Fellows for varying amounts of time up to 3 years, over the period 1959-1973. Title IV was intended to alleviate the then existing and projected shortage of [illegible]lege teachers, and to achieve a wider geographic spre[illegible] of strong graduate programs.

- Approximately half of the male NDEA Fellows and one fourth of the female Fellows (49.2% and 23.5%) of 1959-1972 [illegible] attained doctorates by 197[illegible], the cut-off date for follow-up in the present study.
- Approximatel[illegible] one fourth of the male Fellows and one eighth of the female Fellows (26 [illegible]% and 13.6%) could be identified as faculty members in U.S. colleges and universities in 1975. Because of problems of identification, these are probably underestimates.
- About 2.6% of the male Fellows and [illegible]% of the female Fellows had by 197[illegible] become dissertation advisers of PhD's who had graduated up to that time.
- The baccalaureate-to-doctorate time lapse for male NDEA Fellows averaged about 7.0 years; for the female Fellows 8.[illegible] years. These figures vary substantially by field and graduation cohort, but are generally lower than the average for all P[illegible]D's by about 20%, where comparable data are available.
- Of the NDEA Fellows attaining doctorate degrees, the proportions planning to take postdoctoral training were generally comparable to those of all PhD's of the same fields and same graduation cohorts
- Of NDEA Fellows who were supported in science fields in 1963-1966, [illegible]% won s[illegible]pport through research grants from NSF or NIH by 1972 in a competition judged by their scientific peers.
- Although 90% of NDEA Fellows who attained doctorates did so in departments within the Roose-Andersen (R-A) rating system, only about 15% of Fellows with doctorates could be identified as faculty members in R-A rated departments in 1975, while 28% were in unrated departments. Although both of these percentages are lower-bound figures, they document a massive--and inevitable--movement toward the unrated departments, many of them in non-PhD-granting institutions.
- Of NDEA Fellows who took doctorates in science and engi[illegible]ring fields, only 1.3% were found in follow-up in 1973 and 1975 to be unemployed; another 1.3[illegible]% were found to be part-time employed. Of those employed, [illegible]% were in educational institutions in 1973. In 1975 the academic proportion dropped to [illegible]%

- The second most frequent employer category for the science/engineering PhD's among NDEA Fellows is business and industry, roughly comparable to that of the general population of PhD's in science and engineering fields.

- The primary work activity of science and engineering PhD's who had been NDEA Fellows was teaching for 47% in 1973 and 43% in 1975, reflecting the shift from academic to nonacademic employment noted above. Other work activity categories show a corresponding shift toward industrial/commercial types of activity.

- Over half (56.8%) of science and engineering NDEA Fellows who took doctorates in the early 1960's had published in the scientific literature by 1972, for a group ...age of 4.9 papers each. For those who graduated in the late 1960's, 45.2% had published, with a group average of 2.2 papers. Those graduating in the 1970's had little time to publish by 1972, but 29.6% did so; t[illegible] average was 1.1 papers each for this group. Even 11.1% of those without doctorates published; the average for this group was 0.4 papers each.

- Inter-regional migration of NDEA Fellows shows net shifts parallel to, but stronger than those of PhD's in general. The overall pattern was migration from the northeast toward the south, with the South Atlantic states as the largest net gainer at each successive career stage from baccalaureate to doctorate to post-PhD employment.

Provided by the Association of American Universities from Documents on file in that office.

Mr. WILLIAMS. Thank you, and the chair wants to associate himself with your commendable remarks about Tom's leadership in what has been a very vital need in America.

Mr. Coleman.

Mr. COLEMAN. Thank you, Pat. And Dr. Wilson, thank you for those comments.

I only was able to do that because of the type of support and data which many people, including yourself, pro ided me with to go and convince my colleagues and the Appropriations Committee. Tomorrow I will go back to re-convince them to try to fund the third year of that very important graduate program. I'm going to pull some of the testimony that I've heard here today, throw it at the Appropriations Committee tomorrow, and hopefully will be persuasive enough to keep at constant level funding, those fellowships and stipends that we've already been able to fund and someday, perhaps, increase it.

As you know, we were only able to fund, that is the Department of Education was only able to fund, of the appropriations that we have obtained, about 10 percent of all the grants that could have been funded at a very high, expert level that the applications were.

Let me say to the three of you. Dr. Drew, these computer print outs are fantastic for somebody to look at these things all at once and see the attitudes of Americans toward science. It starts high at third grade. By the time you're an adult, it is almost off the map here. Freshmen interest in science majors has dwindled considerably since the 70's, trickling down to the bottom. It just re-emphasizes everything we have heard today from other people in the field.

Judson Sheridan, you have impressed me again about the immediacy. That is why, I think, the Graduate Program in Areas of National Need is so important, because you can see the payoff. If we don't do this now, as you indicated, regardless of pipeline questions, we are not going to be able to make an impact 10 years down the road because we won't have Americans teaching these subjects. Other Americans by then, hopefully, will be in the classroom eventually ..., that is why it is so important.

And to replenish the supply, that is what you're saying, replenish the supply at the Ph.D. level. They in turn provide various teaching assignments. They are the ones that will be teaching the Yocum's and others that come on for the teaching profession. So, that is why it is so darn important.

Ed Wilson, again I thank you for your fine comments. I don't really have any questions. These people have, in the past, supplied great information to me, and I thank them for that.

I appreciate it very much, Pat.

Mr. WILLIAMS. Thank you.

I believe that the majority of the members of our subcommittee, perhaps, and Tom, would sense that this is true, also—are supportive of the foreign students who attend American higher educatio That is not our concern, nor, I think, has it been the concern anyone who has expressed the issue today. Rather, our concerr that the r o of foreign students to American students is alarming.

We join with you on our committee in having great pride in higher education in the United States and significant pride in our ability to attract foreign students, who know where to go to get the best education in the world. Come to America.

In my judgment, we Americans do nothing better than what we do in higher education. That is the business of America, higher education.

Another point that needs to be made, lest it be misunderstood, and speaking for myself now, I think that productive, well-educated immigrants to the United States are critical to our future. It is interesting that at a time when we need well-educated immigrants, many Americans seem resistant to allowing them to enter the United States. But we desperately need them, economically, and we continue to need them socially and culturally, as well as we always have throughout our history.

Gentlemen, we're very appreciative of the time you've taken to come before us and share your thoughts with us. Thank you very much.

Mr. Coleman, any closing remarks?

Mr. COLEMAN. No. But I do want to associate myself with your remarks that the thrust of what we're trying to do is to encourage Americans to be in those classrooms, to be able to compete with whoever else is in those classrooms, and recognize that by education we can convey our sense of democracy and culture to others, and we're very, very happy to see them in our classrooms. The question is, why aren't there Americans seated in those classrooms. and that is what we're trying to address. I think that was very good that you said that, lest others may misinterpret you.

Again, I want to thank you and the staff for coming here to Kansas City for our hearing. I want to thank all of the panelists. I thought it was a very good hearing, and members of the press who have found time and interest to come to cover a very important subject for this nation.

Again, thank you, Mr. Chairman.

Mr. WILLIAMS. Thank you. The hearing is adjourned.

[Whereupon, at 11:18 a.m., the subcommittee was adjourned.]

[Additional material submitted for the record follows.]

CORPORATION FOR PUBLIC BROADCASTING

Donald E Ledwig
President and
Chief Executive Officer

May 10, 1989

The Honorable Pat Williams
Chairman
Subcommittee on Postsecondary Education
Committee on Education and Labor
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

It has come to my attention that the Subcommittee on Postsecondary Education conducted a hearing focusing on math, science, and engineering education from kindergarten through graduate school on May 1, 1989. I would like to offer for inclusion in the record of your hearing an overview of the efforts by the Corporation for Public Broadcasting (CPB) to bolster primary through postsecondary education in America.

CPB is a private, nonprofit, nongovernmental corporation authorized by the Public Broadcasting Act of 1967 to facilitate the development and distribution of high-quality public service programs for all Americans. The Corporation has long recognized that it is in the public interest to direct sufficient resources toward the development of educational and instructional series and their ancillary materials for use in the home, the classroom, and in the library.

Recent studies indicate that as much as a quarter of the American labor force lacks the basic reading, writing, and math skills necessary to perform in today's increasingly complex job market. One out of every four teenagers drops out of high school and, of those who graduate, one of every four has the equivalent of an eighth-grade education. Employers are facing a proficiency gap in the workforce so great that it threatens the well-being of hundreds of U.S. companies which are now forced to pour millions into educational and training programs in order to meet basic levels of competency.

Public broadcasting in the United States is a multifaceted and diverse endeavor, consisting of many elements, including more than 600 independent local public radio and television stations. In this context, the principal task of the Corporation is to find, initiate,

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20 Years of Quality Programming

The Honorable Pat Williams
Page two
May 10, 1989

and finance the production of high-quality educational, informational, instructional and cultural programs of greater than local interest which are not available from other sources. The programs are produced by a variety of entities, including public broadcasting stations, minority-based production companies, independent producers and educational institutions. Through their educational content, innovative qualities and diversity, these programs are intended to enhance the knowledge and imagination of all Americans.

Since its inception, CPB has always strongly encouraged the use of public television as a supplement to textbook education. Currently, approximately 65 percent of the public broadcasting schedule is devoted to delivering educational programming during the school day. In conjunction with this, CPB-funded programming delivers a wide range of programming and services addressing educational problems both at home and in the classroom, including:

- 3-2-1 Contact, a science and technology series for eight- to 12-year-olds that encourages youngsters, particularly minorities and girls, to view science and technology as a vital part of everyday living;

- Square One TV, a series designed to encourage children's interest in, and enthusiasm for, math and is aimed at eight- to 12-year-olds;

- Reading Rainbow, a series designed to motivate young people, kindergarten through third grade, to read on their own; and

- Spacewatch, a new series on space science and exploration targeted to youngsters in grades 3 to 7, responding to the need to improve science instruction in the schools.

A major part of the Corporation's commitment to educational programming is instructional programming for use in the classroom. One excellent example is the Annenberg/CPB Project. For the past nine years, CPB has helped fund the creation of college courses and the demonstration of advanced technologies for use in education through this endeavor. These efforts have allowed students and faculty to collaborate at great distances and provided access to resources by otherwise unreachable students. Forty-four complete college courses are now either available or in production. Computers, laser discs, communication networks, and interactive video are some of the new tools available to teachers.

The Honorable Pat Williams
Page three
May 10, 1989

Since 1980, the Annenberg/CPB Project courses have been adopted by more than 1,000 colleges and universities. Since 1984, the Project's efforts have garnered more than 50 awards and critical acclaim from broadcasters and educators for programs such as The Brain, The Constitution: That Delicate Balance, and Planet Earth.

Basic education skills are vital to the general well-being of our society, as well as to America's economic stability. As one response to the critical need for new and innovative methods of teaching tools, CPB in 1988 provided critical funding to the Satellite Education Resource Consortium (SERC). As part of the Star Schools program, CPB's funding allowed the planning and start-up semester of this project. SERC is an educational initiative designed to boost America's competitiveness in a global marketplace and is a partnership between CPB, state educational television networks or associations and state departments of education in eighteen states, serving 59 schools.

SERC currently offers courses such as Probability and Statistics, Introduction to Japanese, a teaching course for teachers in AP Calculus, a series of eight science seminars for students, and a series of eight forums and workshops for teachers. Next fall, SERC will offer five high school courses, two graduate courses, and an array of teacher in-service programs.

Not only has CPB funded programming as part of our commitment to education, but the Corporation has taken a leading role in developing other initiatives designed to strengthen the relationships between instructional programming, textbook materials, and other ancillary materials. As a cornerstone to these relationships, CPB has worked to strengthen the involvement of teachers, parents, and students in providing the best educational tools available.

To encourage teachers to make the most of available programming by linking material in textbooks to instructional programs that cover the same topics, CPB published textbook correlations for series such as Up Close and Natural or Community of Living Things to science textbooks. Other guides funded by CPB are a part of each major children's series. They help build lesson plans and provide follow-up activities for teachers to use in integrating Square One TV or 3-2-1 Contact into their classes. CPB also funded study guides for students to use with special series such as The American Experience and specials such as Pyramid.

Other educational initiatives funded by CPB include EDISON -- Educational Information Services Online -- an advanced nationwide computer network that connects teachers with a number of education

The Honorable Pat Williams
Page four
May 10, 1989

information databases. This allows teachers to research educational materials, review new material, or see which of the hundreds of ITV series currently available can be incorporated into their lesson plans. Another project is Learning Link. Developed by WNET/New York, Learning Link provides public TV program descriptions, long-range schedules, and an avenue for exchanging teaching tips.

Finally, CPB is currently developing a brochure that is designed to promote partnerships in education. Included in this brochure will be information on classroom program production and distribution, print materials for classroom use of regular public television programming, SERC, electronic information services, pilot demonstration projects, community outreach activities and national awareness efforts. This brochure is being developed for school boards, superintendents, legislators, education advisors, foundations and national and local public television funders.

The brochure is intended to motivate potential partners between CPB, PBS and regional networks; with other broadcasters; with program producers and distributors; with textbook publishers; with state and regional departments of education; and with community groups, PTA's and teachers.

These and other programs and services offered by CPB and the public broadcasting community represent just a few of the valuable contributions public broadcasting has made, and can continue to make, to education. The job of educating our youth is too big for anyone to do alone. The commitment and vast pool of talent, imagination, and expertise of CPB and public broadcasting are limited only by the resources necessary to put them to work toward enhancing both conventional and innovative teaching methods. As always, CPB stands ready to provide whatever assistance it can to bring the best in educational programming and materials to all Americans.

CPB applauds the Subcommittee's attempt to focus greater attention on the importance of issues affecting education today. As always, we are pleased to offer our views and pledge the Corporation's commitment to assist in any way possible.

Sincerely,

Donald E. Ledwig
President and
Chief Executive Officer

St. Louis Science Center

5050 Oakland Avenue
St Louis Missouri 63110
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MAY 22 1989

May 8, 1989

The Honorable Pat Williams, Chairman
House Subcommittee on
Postsecondary Education
Committee on Education and Labor
U.S. House of Representatives
616 House Office Building Annex #1
Washington, D.C. 20515

Dear Congressman Williams:

I am writing to express my appreciation for the opportunity to testify before the Subcommittee on Postsecondary Education. The hearings provided important information on the issues confronting our Nation and suggestions for the improvement of science education in the elementary and secondary schools.

Science centers can perform an important role as the translators of science between the scientist and students and the general public. Through the use of interactive hands-on exhibits and informal education programs, science centers can instill the excitement and motivation needed for students to continue pursuing careers in science.

If I can provide further information or be of assistance, please do not hesitate to contact me.

Sincerely,

Dennis M. Wint

Dennis M. Wint
President

DMW/shh