DOCUMENT RESUME

ED 330 398 JC 910 184

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TITLE The Status of Science, Engineering, and Mathematics Education in Community, Technical, and Junior Colleges.
INSTITUTION American Association of Community and Junior Colleges, Washington, D.C.
SPONS AGENCY National Science Foundation, Washington, D.C.
REPORT NO ISBN-0-87117-231-3
PUB DATE 91
NOTE 72p.
AVAILABLE FROM American Association of Community and Junior Colleges, One Dupont Circle, N.W., Suite 410, Washington, DC 20036 ($18.00; $15.00 for AACJC members).
PUB TYPE Reports - Descriptive (141) -- Viewpoints (Opinion/Position Papers, Essays, etc.) (120) -- Reports - Research/Technical (143)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS College Bound Students; College Faculty; *Community Colleges; Curriculum Development; Educational Improvement; Educational Objectives; *Engineering Education; Futures (of Society); *Mathematics Education; National Surveys; Public Colleges; Public Education; *Science Education; Science Programs; Student Educational Objectives; *Technical Education; Technical Institutes; Two Year Colleges; *Two Year College Students; Vocational Education.
IDENTIFIERS *American Association of Community and Junior Colls

ABSTRACT

An overview is provided of the status and future of science, engineering, and mathematics education in public two-year colleges. In addition, results of several national-level studies are reviewed, and 15 recommendations developed by the National Task Force for the Improvement of Science, Engineering, and Mathematics Education in Community, Technical, and Junior Colleges are presented. Parts I through III of this report provide background to the study; examine the role of the American Association of Community and Junior Colleges in advancing science, math, and engineering education; review study methodology; and provide an overview of the report. Part IV discusses the important role of two-year college faculty in the success of student pursuing careers in science and technology. Part V profiles students enrolled in such programs and discusses influences on their success. This section also discusses pre-college students, examining Scholastic Aptitude Test scores and noting the factors which may influence students to pursue science and mathematics in higher education. Part VI stresses the need for a curricular reform that emphasizes science literacy in two-year colleges. Part VII summarizes relevant data generated by several national studies, and data acquired from a review of state documents. This section examines student enrollments, program financing, and state support, and presents the results of a survey of two-year college coordinating offices. Parts VIII and IX present recommendations dealing with state and local college boards, local colleges, faculty and staff, and national concerns. A 26-item bibliography, and a list of task force members are included. (JMC)

THE STATUS OF SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION IN COMMUNITY, TECHNICAL, AND JUNIOR COLLEGES

By

Leslie Koltai & Michael Wilding

American Association of Community and Junior Colleges

A Report Funded By
The National Science Foundation

THE STATUS OF SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION IN COMMUNITY, TECHNICAL, AND JUNIOR COLLEGES

AMERICAN ASSOCIATION OF COMMUNITY AND JUNIOR COLLEGES

A REPORT FUNDED BY
THE NATIONAL SCIENCE FOUNDATION

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Published by the American Association of Community and Junior Colleges
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Phone: (202) 728-0200

ISBN 0-87117-231-3

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PART ONE:

A MESSAGE FROM THE PRINCIPAL INVESTIGATOR

The National Task Force for the Improvement of Science, Engineering, and Mathematics Education in Community, Technical, and Junior Colleges was established as a result of the recommendations made by the NSF Workshop on Science, Engineering, and Mathematics Education in Two-Year Colleges. The workshop took place in the fall of 1988. In their report, the workshop participants made a variety of recommendations. In particular the "Partnership Recommendations" suggested that:

* *NSF and the two-year colleges develop an ongoing partnership that enhances participation of two-year college representatives in NSF activities.*

* *NSF establish programs to encourage formation of additional partnerships involving the two-year colleges with business and industry, universities, public schools, and other institutions.*

* *The American Association of Community and Junior Colleges (AACJC) and appropriate discipline-based professional associations establish a National Task Force for the Improvement of Science, Mathematics and Engineering Education in Community, Junior, and Technical Colleges.*

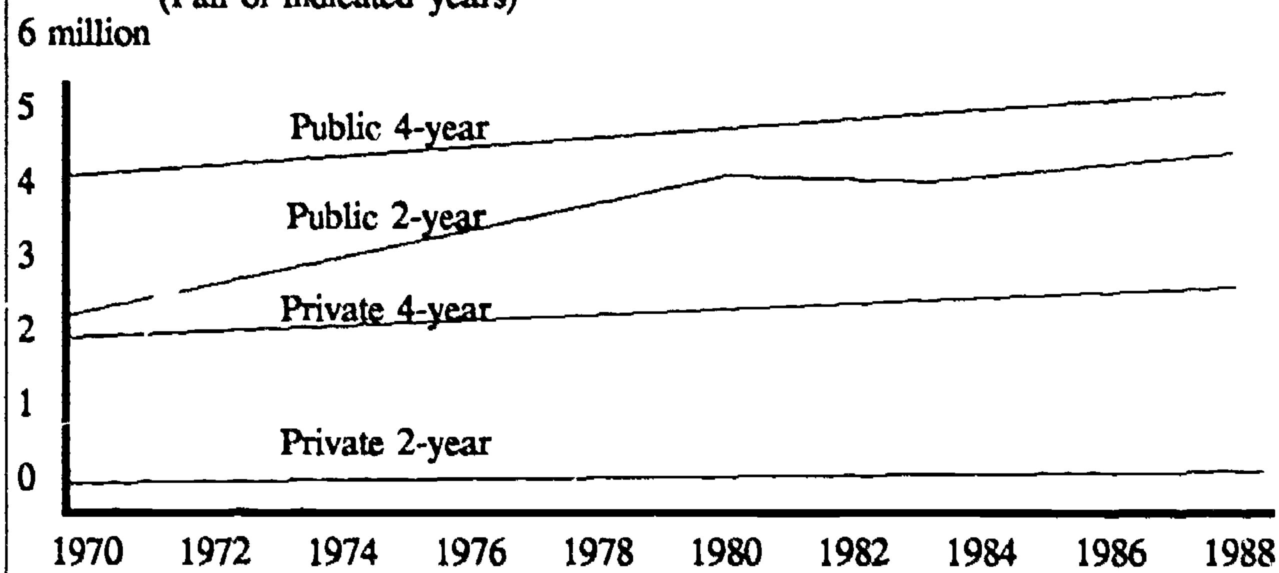
It is this last recommendation that gave rise to this study. The Task Force is funded by the National Science Foundation and is being administered by the American Association of Community and Junior Colleges (AACJC). The partnership between these two organizations is indeed a positive step toward the improvement of sciences and technology in the nation's two-year colleges.

Each member of the Task Force has brought to the organization invaluable expertise. Without their input, this report would not have been possible. I found that our meetings were extremely productive affairs, with each member exhibiting why they are a national leader in two-year science, engineering, and mathematics education. My gratitude is extended to each and every project participant. In particular I would like to thank Robert F. Watson from the National Science Foundation and Dale Parnell from the American Association of Community and Junior Colleges for their support throughout the project.

This project is far from over. The vast variety of programs and unique solutions to common problems found at the two-year level allows us continued investigation, as well as continued reporting on the evolving nature of two-year science, engineering, and mathematics education. In this light we have included recommendations for further study. We found that the scope of science, engineering, and mathematics in the nation's two-year colleges is extremely complex and impossible to fully examine in a document of this size. What follows then is a series of recommendations based upon a review of recent studies and the results of several meetings with national leaders.

This report focuses primarily upon the public community, junior, and technical college. We recognize that a variety of other institutions exist which offer less than four-year degrees. However, the enrollment in these institutions is small compared to the public institutions. Analysis of the findings from the High School and Beyond study indicate that proprietary, not-for-profit private, and public less-than-two-year schools attracted approximately one in 20 high school students. In contrast, the public two-year institutions attracted nearly one in five students continuing beyond high school. Thus, to address the majority of two-year college students we have focused our efforts upon the public two-year community, technical, and junior college. It is important to note, however, that many of our findings are also applicable to other (non-public) less-than-four-year colleges.

Table 1. Trends in college and university enrollment by type and control
(Fall of indicated years)



Source: National Center for Education Statistics, 1988a

The Task Force recognizes that two-year colleges are concerned with many aspects of higher education. If transfer of their students to the senior institutions was their primary concern they would be essentially general education, undergraduate programs, and their problems would be the same as the four-year undergraduate programs. In contrast, the two-year college is also concerned with vocational training, technical training, industrial partnerships, job upgrading, and pre-college education.

We recognize that the two-year college enrolls the highest proportion of minorities, and a wide variety of students with alternative goals unrecognized by traditional curricular offerings. The administrative challenges offered by the two-year college are only balanced by the potential rewards. Considering the impact of this system should not create a burden. Instead, imagine the possibilities, focus on what is positive, and on the positive changes to come.

Students, in their earliest years, must be instilled with a desire to reach their highest potential.

The American system of higher education, particularly in the sciences and technical fields, fosters change, exploration, and discovery. Our higher education system is recognized as the finest system in the world; no other country provides comparable access to higher education at a comparable cost to the student. Indeed, with over 6 million students enrolled in the 4-year colleges, and close to 5 million enrolled in two-year colleges, we can proudly say that our system is open to all people who are able to benefit from instruction.

Now, more than ever, is the time to look upon the system as a ladder. We as educators must lead our students to the base of this ladder and provide the opportunity for success. For students to continue the climb to the highest levels and ultimately take positions of leadership, they must be provided with a solid foundation. It is precisely here that the two-year college plays a significant role. Without a quality two-year system, potential leaders are lost, and too many of our most promising students will not be able to find the first important steps.

Just as the two-year college provides a foundation for the higher levels of education, the elementary and secondary schools provide the building blocks for higher education. Students, in their earliest years, must be instilled with a desire to reach their highest potential. While the primary focus of this document is science, engineering, and mathematics education at the two-year college, we recognize that the two-year college does not operate tary and secondary level has as much to do with successful students as any factor considered at the two-year college level. Therefore, we have included, in this report, a recognition of this fact and an exploration of scientific, technological, and mathematics education at these levels.

Other highlights of this report include a review of past research concerning two-year and undergraduate science, engineering, and mathematics. Specifically, we focus upon the role of faculty, students, and curriculum. In addition, we include an analysis of survey data related to the status of science, engineering, and mathematics education in two-year colleges throughout the nation.

This study focuses attention upon the importance of scientific and technological knowledge and literacy for the general population. Literacy in these areas is no less a requirement for productive citizenship than literacy in the spoken and written word. As the world becomes increasingly technical we must respond by ensuring all citizens an opportunity to acquire a quality mathematics, science, and technical education. In addition, we focus upon the role of the two-year college teacher. The collective talent of the nation's two-year faculty, administration, and staff has been under-recognized for far too long. This report is a step along the road that must be traveled if we hope to maintain America's standing as the leader in science, mathematics, and engineering education.

Finally, in a section discussing students, this report has recognized that the associate degree is the highest level of education many will elect to pursue. We must not abandon this portion of our population. No matter how far they choose to go up the ladder, each step should be one of quality.

Leslie Koltai

PART TWO:

STATEMENT FROM THE AMERICAN ASSOCIATION OF COMMUNITY AND JUNIOR COLLEGES (AACJC)

The American community, technical, and junior college has been recognized as a vital segment in our system of higher education. The American Association of Community and Junior Colleges, the National Science Foundation, and many other government and professional associations have recognized this fact and are aggressively pursuing avenues of improvement. In its recent report, *Undergraduate Science, Mathematics, and Engineering Education*, the National Science Board's Task Committee on Undergraduate Science and Engineering stated:

Although many of its students are enrolled in college transfer programs, the two-year college provides the majority with their last opportunity to study science in a formal educational setting. A typical community college student is more likely to pursue an occupational or technical curriculum than a liberal arts program. Many move directly from the two-year college to employment. Those that do transfer to four-year institutions often have satisfied any science requirements before transfer and do not elect additional science.

The quality of engineering, science, and mathematics taught at two-year colleges is thus of prime importance. It provides the *underpinning on which technical skills of occupational students are built, and is the culminating science education experience for a substantial portion of citizens* (National Science Board, 1986, p. 33).

We will be highlighting science, engineering, and mathematics in 1991 as well as at future conventions.

We at AACJC understand the importance of maintaining a quality system of education for all student interests. The mission of AACJC is to serve the public by providing access to quality higher education for millions of individuals. A primary function of AACJC is to help identify the broad public interest and assist colleges in responding to this challenge. Through our contacts with member colleges we recognize the increasing importance, both nationally and locally, of science, mathematics, and engineering education at the two-year college level.

Our 1990 AACJC Public Policy Agenda includes a Minority Education Initiative designed to improve the participation and success of ethnic minorities in higher education. As part of this effort we will highlight science, engineering, and mathematics in 1991 as well as at future Conventions.

With over 1,300 colleges, over 6 million students in credit courses, and nearly 5 million enrollees in non-credit courses, the system of community, junior, and technical colleges is the largest segment in American higher education. For the most part these colleges are "community-based," in partnerships with the surrounding community, and under the control of local boards. They include a broad spectrum of programs designed to fit the diverse needs of their students. The two-year college enrolls a substantial portion of all college students and the majority of all minorities engaged in higher education. Not surprisingly, the cost of enrolling in a community college is significantly less than the cost of enrolling in four-year institutions.

For many students, community, junior, and technical colleges serve as a bridge between the secondary school and four-year institutions. Success in their later undergraduate years, as well as in other educational pursuits, is, in many ways, dependent upon their experiences in a two-year institution. This bridge function cannot be underestimated in its importance, and should be the subject of continuous review and enhancement.

With the current demographic changes in the American labor force, the importance of the two-year college is becoming more evident as we enter the 21st century. Over 50 percent of all college students will receive their first exposure to collegiate-level science and mathematics at the two-year college. More importantly, the two-year college is where a significant portion of college students will receive their last exposure to science, engineering, and mathematics.

With these thoughts in mind, it is imperative that there be an improvement in the quality of science, engineering, and mathematics education at community, technical, and junior colleges. This document does not offer "band-aid" treatments to the problems confronting two-year science, and technology education. Rather, we are seeking to be proactive. The scope of our recommendations is extensive and will require years of effort and significant financial support. But we must begin now.

James F. Gollatscheck, Executive Vice President
American Association of Community and Junior Colleges
National Task Force Member

PART THREE:

METHODOLOGY AND HIGHLIGHTS OF THE STUDY

The Task Force, whose members are listed at the beginning of this document, met for the first time in December of 1989. Acting upon their guidance, the investigative team presented to them a status report in April of 1990. At this time the Task Force presented preliminary data to the 1990 AACJC Convention. These efforts were then followed by continued interviews, data collection, and research. In January of 1991 the Task Force presented its report to the National Roundtable for the Improvement of Science, Engineering and Mathematics in Community, Junior, and Technical Colleges. This distinguished body, whose members are also listed at the beginning of this document, provided additional suggestions, modified the Task Force recommendations, and extended its approval to the contents of the report.

The National Roundtable included several members from the National Science Foundation who fully recognize the significant role two-year colleges play in the science pipeline. The NSF is committed to providing strong and continued leadership in addressing the issues brought forth in this document. In his address to the National Roundtable, Luther Williams, director of the National Science Foundation Directorate for Education and

Human Resources, outlined four objectives of the NSF:

The improvement of pre-college mathematics, science, and technology education, including the two-year college courses formally designated as remedial education.

The enhancement of undergraduate science, mathematics, and engineering education. In this area the NSF has greatly expanded its funding commitment to programs enhancing science education. Increases from years past amount to 102 million dollars, or 46 percent over last year's commitment.

The maintenance of the science and engineering personnel essential to the nation's education function. This year NSF is initiating an Undergraduate Faculty Enhancement Program designed to meet this objective.

The broadening of participation by underrepresented groups in educational institutions. Here Williams fully recognized the percentage of minorities enrolled in two-year colleges and the role these institutions must play, with proper support, in their increasing participation in science, engineering, and mathematics.

The broad range of programs sponsored by the NSF to accomplish the above goals are available to two-year college participation. That two-year colleges generally apply for these funds at lower rates than four-year institutions is a fact lamented by the National Roundtable. For its part, the NSF has encouraged increased levels of participation by sponsoring participant workshops, increasing the numbers of two-year college reviewers, and opening more programs to undergraduate institutions.

This document is, in many ways, a reflection of the neglect given to pre-college and undergraduate science instruction. In Part One, Leslie Koltai, the project's principal investigator, noted the increasing enrollment in two-year colleges, leading to their current impact upon the American education scene. In addition, he calls for a recognition that all segments of education are interrelated and interdependent upon one another for success. Students, he notes, must be the highest priority.

In Part Two, James F. Gollattscheck, executive vice president of the American Association of Community and Junior Colleges, addresses the role of the AACJC in meeting this challenge. The public policy agenda of the association includes a commitment to underrepresented students, as well as a recognition of the leadership required to carry out these objectives. AACJC will be highlighting science, mathematics, and engineering education in their future conventions.

Part Four recognizes the significant role faculty play in the success of students pursuing careers in science and technology. The report notes that a large percentage of two-year college science faculty are in the last third of their careers. Increasing retirements coupled with difficulties in faculty recruitment will lead to a crisis situation in coming years. The increased professional status of faculty, improvements in working conditions, and opportunities for professional development are all factors which can alleviate predicted problems.

Part Five discusses the factors effecting the students who pursue science, engineering, and mathematics across the spectrum of education in our nation. The report includes a section on pre-college students, noting the forces at work which may encourage them to pursue science and mathematics in higher education. Two-year college students, the report notes, are unlike their counterparts in four-year institutions. A greater percentage are part-time students, on average they are older, and they are more likely to be from a minority group. These are the individuals that are going to make up the majority of the future work force. In fact, many of these students are attending primarily for vocational degrees. Of greatest concern is that these students are increasingly electing to pursue courses of study not related to science, engineering, or mathematics.

Part Six addresses curriculum issues in the sciences. The report recognizes the unique vertical nature of quantitative education and stresses the need to develop curricular reform around this concept. Science literacy, a goal of the National Science Foundation, is addressed by asking why general requirements in these areas are being diminished while the world is becoming progressively more technical.

Part Seven details the results of several national level studies of science, engineering, and mathematics education in the nation's two-year colleges. The survey completed by the Task Force notes that while two-year colleges are becoming more centralized in their control, this trend is not being accompanied by increases in central data collection. Thus, trying to determine the status of science and technical eduction is hampered by a data collection method in need of improvement. In conjunction with this fact, Part Eight calls for improvements in data collection as well as the maintenance of a resource base where educators can seek information regarding innovation in the sciences.

The recommendations found throughout the report and in Part Nine are intended as plausible objectives that, when implemented, will result in significant improvements in the two-year science, engineering, and mathematics pipeline of quality students.

PART FOUR:

THE TWO-YEAR COLLEGE SCIENCE, ENGINEERING, AND MATHEMATICS FACULTY

The faculty is truly the heart of the two-year institution. Their impact upon students cannot be underestimated. They develop new and exciting programs, engage in curricular innovation, and are frequently on the cutting edge of new pedagogy. With nearly 300,000 members, the two-year college faculty has a significant impact upon American higher education.

Table 2. Faculty in Community, Technical and Junior Colleges

FACULTY STATUS	QUANTITY
Full-Time Faculty	110,909
Part-Time Faculty	164,080
Total Faculty	274,989

Source: El-Khawas, Carter, and Ottinger, 1988

Yet, according to some surveys, faculty feel "out of touch" with the leaders in their disciplines and experience difficulty in remaining current (National Science Foundation, 1989b, p. 3). To remedy this situation the Task Force encourages that our education establishment endow the two-year college faculty with the same status given to any professional who has completed postgraduate education. We note that D. Allan Bromley, assistant to President Bush for science and technology, has sought to increasingly professionalize the teaching environment. He states, in his message to the NSF Advisory Committee on Math and Science Education (1989), that year-round rather than nine-month employment, would help the faculty maintain its professional status as well as provide time for professional development. In addition, year-round programs would enable a more efficient use of the physical facilities. The current idle time experienced by most college classrooms and laboratories could be put to use in a variety of ways improving the status of science education.

RECOMMENDATION 1: Professional associations need to recognize the role of the two-year faculty in the area of science, engineering, and mathematics, and seek to enhance their participation as active and valued members. Moreover, the colleges themselves must encourage participation in these organizations.

The time required for preparation and "staying current" should be a recognized aspect of any teaching position. As with other professionals, interaction with colleagues, planning, continuing education, and research leading to enhanced performance are necessary aspects of quality job performance. To expect faculty to remain effective instructors throughout their careers without developmental support is an unreasonable assumption. To stay current and teach five classes, or 15 weekly hours a term, is more than most faculty can accomplish in the average school calendar. In a survey of faculty attending the 1990 AACJC convention the Task Force found that nearly 50 percent of the respondents felt that preparation time was an essential element to providing quality education.

The heavy teaching load (defined as large numbers of students, lab hours, and instructional hours) found in most two-year institutions may have a far greater impact upon the quality of education than previously recognized. Faculty burnout, dissatisfaction, and attrition are some of the symptoms which directly effect classroom performance. By default these problems directly effect the quality and quantity of students pursuing careers in science, engineering, and mathematics. Students who encounter methods of instruction inhibiting their success are likely to pursue other courses of study or simply drop out of college. Facilities and renovation are not the only answers. Bromley has stated:

I would like to point out that the U.S. already spends as much on education as our major competitors and a goodly amount more than many countries that--judged from the comparative educational assessments--are doing a better job than we are. And that is true whether on compared educational expenditures as a percentage of GNP or as a percentage of overall government spending. More money will be needed to improve and reform our educational system ... but money is not--on the face of it--the main cause of our problems. Nor is it likely to be the main source of our solutions (Bromley, 1989, p. 3).

In the two-year institutions faculty development must be one of the most important aspects of any effort to improve the status of science, engineering, and mathematics education. The goals of such efforts must be directed at student and faculty retention, curricular reform, and the recruitment of underrepresented groups, both faculty and students, into the quantitative areas of study.

The major aspects of faculty enhancement should include developing joint efforts with senior institutions as well as recognizing and rewarding outstanding individual efforts. Moreover, the recognition of the importance of mathematics and science education to our nation's future should be extended to individuals in administration, staff, and counseling positions. Through an integrated faculty and staff development effort we will begin to see real improvement in the mathematics, science, and engineering pipeline. An impressive model of staff development can be found at California's Glendale Community College. This college is committed to a development program which addresses a variety of needs among the staff. Their evaluation documentation states:

Appropriate activities are offered to promote positive and productive interaction among all staff members with the ultimate purpose of improving instructional delivery services and enhancing the educational experiences of all students (Purser and Scull, 1989, p. 4).

Glendale Community College is a small, one-college district, yet their commitment to supporting innovation, research, and publication is excellent.

About half of the current faculty members are in the last third of their careers.

RECOMMENDATION 2: The improvement of two-year science, engineering, and mathematics education is largely dependent upon a qualified, innovative, and motivated faculty and staff. Faculty and staff development for teachers of lower-division undergraduate science and mathematics should be increased nationwide in such a way that two-year college faculty are motivated to attend and have easy access. Special emphasis should be placed upon minority faculty and their relationships with minority students.

In-service development activities have been shown to be cost effective and varied in their effects upon the faculty. The infectious naure of motivated faculty upon their peers as well as students allows large effects from small investments. When faculty are given significant input into curricular development they tend to embrace changes more readily and are further infused with enthusiasm. The NSF can play a role in faculty development. We encourage that two-year colleges be given improved access to funds at NSF, as well as other funding agencies. Heavy teaching loads, combined with a general lack of institutional support, make it difficult for two-year faculty to compete for these funds. It has been shown that even small amounts of support, can greatly enhance faculty effectiveness. In colleges where innovation has occurred results indicate that peer and student interest is increased. Institutional reputation is enhanced leading to greater credibility of transferring students. As an institution's reputation grows it attracts more students, who, by their enthusiasm, further improve the quality of the institution. It is an upward spiral, ultimately benefiting science and technology on a national level (Purser and Scull, 1989, p. 26).

RECOMMENDATION 3: Sources of stipends must be developed that enable a greater number of two-year faculty to further their education in the area of science, engineering, and mathematics. National-level grants and scholarships should be made available to a large number of interested faculty. This concept, together with the sabbatical program, will greatly enhance the quality of instruction at the two-year level.

RECOMMENDATION 4: Faculty development is essential. Two-year college faculty in mathematics, engineering, and science should receive incentives for participation in structured, long-term staff and curriculum development whose outcomes can be measured.

Faculty in the two-year system can have a dramatic impact upon the future aspirations of young science students. Indeed, there is a strong correlation between a student's first experience in higher education science courses and his or her decision to continue with subsequent course work (Friedlander, 1981, p. 6). Thus we can see that teaching skills are essential to maintaining student persistence in the sciences. A series of measures should be initiated to improve teaching skills at the two-year level. We support the establishment of intern and mentor teachers, as well as increased evaluative efforts. In addition, a regular system of teacher training should be completed prior to taking a place at the head of a classroom. In this way, we can help to ensure quality teaching as well as safe laboratory practices.

Indications are that retirements are increasing within the ranks of the two-year college science, engineering, and mathematics faculty faster than the production of qualified replacements. About half of the current faculty members are in the last third of their careers. Shortages of qualified instructors are expected to reach their worst point between 1995 and 2010. There are several reasons for this state of affairs. One major reason is, of course, the diminishing numbers of students electing to pursue careers as science teachers. Another important reason is that it takes a motivated student approximately 9 years to earn a Ph.D. from the point of college entry. Thus, if intense action were taken now, shortages would still be apparent in the mid-1990s.

Table 3. Average Faculty Salary in Two-Year Colleges

Institutions with ranked faculty	$30,000
Institutions with unranked faculty	$31,240

Source: El-Khawas, Carter, and Ottinger, 1988

A second major reason is that science, engineering, and mathematics are some of the most difficult areas in which to recruit faculty. This is largely due to increased competition between education and industry for qualified people. In specific topic areas shortages are being noticed as well. For example, in a report of the Joint Subcommittee on Mathematics Curriculum at Two-Year Colleges, it was noted that the supply of available talent (to become teachers) is shrinking (Davis, 1989).

Our discussions with two-year college faculty and staff delineated another important factor with respect to recruiting talented teachers into the sciences. Many faculty members expressed dissatisfaction with the pay generally awarded to young faculty. Noting that salaries are much greater within industry, they found it difficult to recruit promising talent into the faculty ranks. Moreover, salaries at the two-year level tend to be less than at the four-year level, where they too are experiencing trouble filling open positions.

The majority of two-year college faculty are White men. This trend is even more pronounced in the science, engineering, and mathematics fields. We acknowledge that significant efforts will have to be made to recruit more minority and women instructors. Should the two-year colleges be successful in this endeavor, the impact upon minority and women student recruitment and retention will be quite positive.

However, these efforts will only be as effective as the quality of the instructors recruited into positions of leadership. Without continued professional developmental activities, high levels of recruitment will have little impact upon the science pipeline.

PART FIVE:

STUDENTS IN COMMUNITY, TECHNICAL, AND JUNIOR COLLEGES

Meanwhile, the march of technology moves forward at an ever more rapid pace, while the traditional approach to science education continues to focus primarily on the top 10 percent of our students--the ones who, in general, will make it anyway.

-- James D. Watkins, Secretary of Energy (1989).

Secretary Watkins goes on to point out that national effort must be focused upon the middle strata of students. These individuals, most commonly enrolled in two-year colleges, will make up 80 percent of our emerging work force. Science, engineering, and mathematic knowledge, he notes, enhances critical thinking and self-esteem, raises expectations, and promotes the understanding of nature. These are the qualities of an effective and productive citizenry (p. 3).

PRECOLLEGE STUDENTS

A discussion of the status of students enrolled in the nation's two-year college system must be preceded by a look at prior education. We frequently discuss universities, community colleges, high schools, and elementary schools as though they exist in separate environments. In fact, there is more that links than that separates these segments of education. One fundamental step we must take to improve our educational system is to recognize that education in this country is an interrelated, intersegmental entity. We must recognize that all levels of education are inherently woven together. Moreover, each segment must be sensitive to the needs and problems of other levels. This report recognizes the interconnected nature of our system, and for this reason we have included, as a part of this report, a section discussing the sciences and mathematics at the primary and secondary levels.

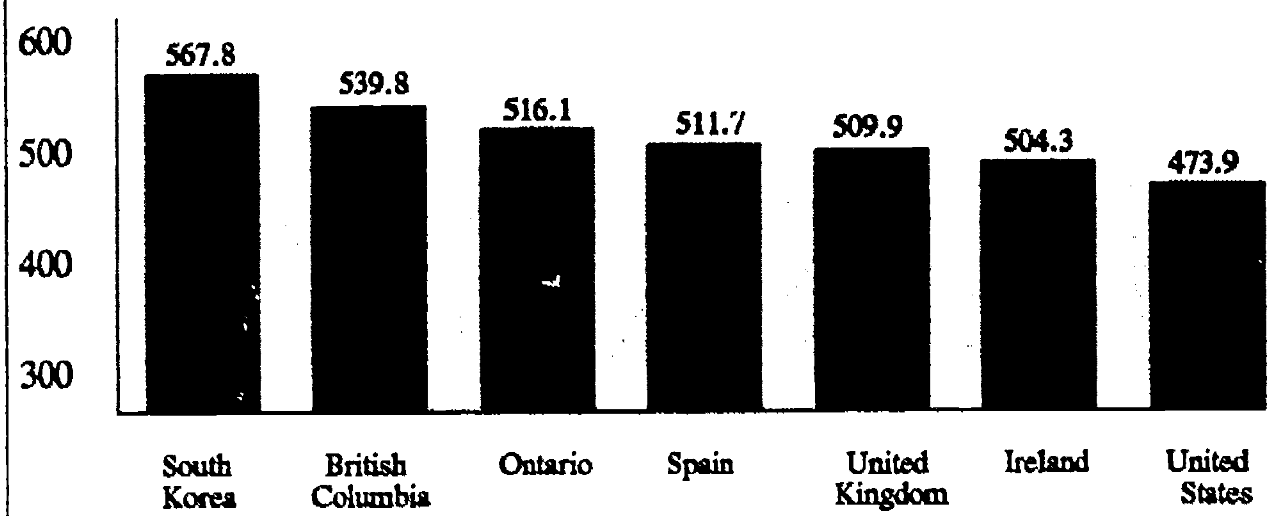
In the early 1980s the nation became acutely aware of the problems in our early education system. The publication of *A Nation At Risk* had an extraordinary effect upon how we viewed public education. As a nation we came to see the problems of dropouts, poor facilities, and out-of-date curricular materials as threats to our future well being. Just as they are today, these problems were of particular concern when applied to minority citizens.

In the immediate post-Sputnik era of the 1960s, when the call was for reform of our science and technology education, hundreds of school boards developed programs based upon "the fundamentals." Requirements were modified, texts were carefully evaluated, and basic skills were increasingly emphasized. Now, with the emergence of alarming reports with regard to our deteriorating prominence in subjects such as mathematics, biology, and science, we have once again begun to call for education reform.

The following tables illustrate an important trend with respect to our relative position in science, mathematics, and biology. This data, from the National Science Board, is even more alarming considering the ever increasing internationalization of the world economy. In a large-scale study sponsored by the NSB the

United States scored last among a selected list of countries and Canadian Provinces in the field of mathematics (National Science Board, 1989).

Table 4. Average scores in mathematics achievement tests for students age 13

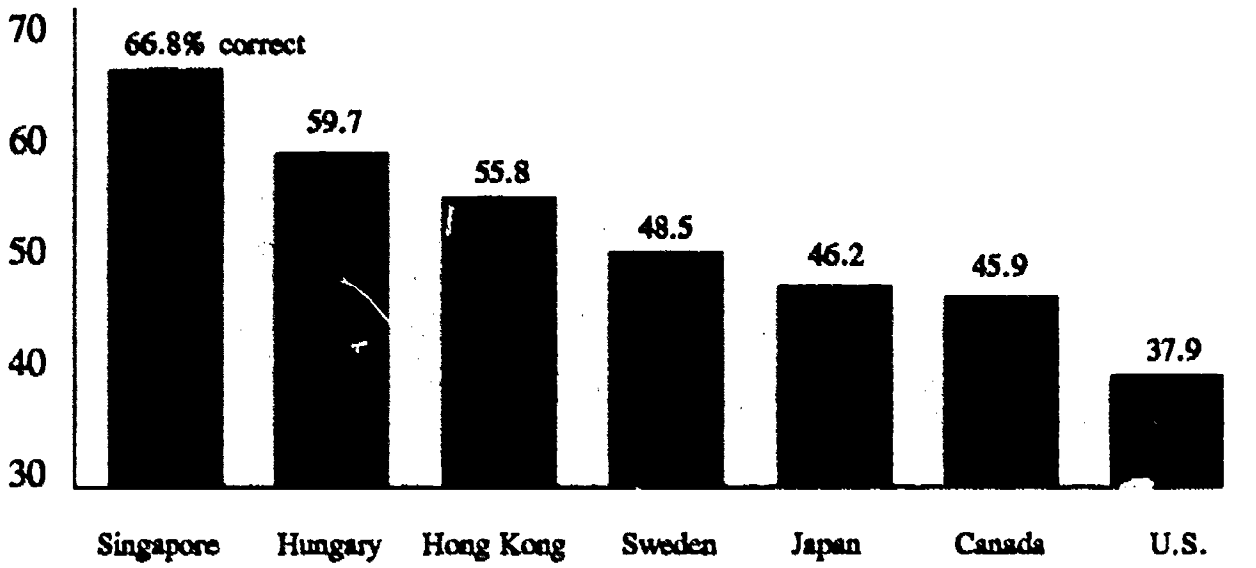


Source: National Science Board, 1989

Additional findings show that the U.S. is the among the lowest in science achievement. Furthermore, the data on science achievement point out an alarming trend for American higher education. U.S. 10-year-olds were among the middle performers in science (with Japan and South Korea at the highest levels). However, by age 14 the U.S. students were ranked third from last. By their last year in high school the U.S. students scored last among the countries tested.

While these results may, in part, be misleading in their comparisons between two very different educational situations, one fact that cannot be denied is that we are failing to maintain a strong interest in science education through the primary and secondary years into college. This point has been further

Table 5. Mean scores on biology test among students taking biology in their final year of high school



Source: National Science Board, 1989

amplified by the Bassam Shakhashiri, former assistant director of the National Science Foundation Directorate for Science and Engineering Education. He states:

Consider a study that started in 1977 and tracked that year's high school sophomore class prospectively through the educational pipeline. This cohort numbered about 4 million, of whom roughly 730,000 expressed an interest in the natural sciences and engineering. By the time they were seniors their number had dropped to 590,000, and at the time of entrance to college it had dwindled to 340,000. In 1984, 206,000 received a B.S. in the natural sciences, which means 40 percent of the science major candidates changed their minds during their undergraduate years (Shakhashiri, 1990, p. 18).

Table 6 graphically illustrates this trend.

Table 6. Persistence of Natural Science and Engineering (S/E) interest from high school through Ph.D.

Class/Year	Number interested in Science and Engineering and those who actually achieve degrees: from cohort of 4 million.
H.S. Sophmore 1977	750,000
H.S. Senior 1979	590,000
College Freshman 1980	340,000
B.A./B.S. in S/E 1984	206,000
Grad. Students in S/E	61,000
Masters in S/E 1986	46,000
Ph.D. in S/E 1992	9,700

Source: Shakhashiri, 1990

A slight positive trend has been observed by a long term study conducted by the Educational Testing Service. This study sought to track scientific achievement among nine-, 13- and 17-year-olds in this country. The results revealed initial declines in the 1970s followed by modest gains in the early 1980s. Of particular interest to the two-year college system are the results reported for minority students. (Recall that two-year colleges enroll the majority of the nation's minority student population). The findings reveal that the average achievement of Black and Hispanic 13- and 17-year-olds is at least 4 years behind their White peers. Girls in the nine-year-old range are generally on a par with their male counterparts; however, by age 17 they have fallen behind in both mathematics and scientific achievement. In general, the National Science Foundation noted:

While scores have increased slightly over the past few years, these gains have not off set the losses experienced in the early part of the study period (1990, p. 14).

The results reported for the mathematics assessment of nine-, 13- and 17-year-olds are similar to that of science achievement. Generally speaking, there has been little improvement during the 13 years of the study. Minorities improved, especially in the middle years, yet still remained behind the achievement level of White students.

Two of the most important predictors of interest and success in science, engineering, or mathematics is the SAT math score and prior high school experiences in the sciences. ETS has found that SAT verbal scores average 19 points higher for students planning to major in math, science, or engineering. SAT math scores average 38 points higher for students expressing interest in these areas. During the period between 1975 and 1986 the mean SAT Math score has risen from 403 to 417 for Black male students intending to major in either science, engineering, or mathematics; Black females interested in these fields averaged around 380. (Grandy, 1987).

Table 7 demonstrates how the SAT score correlates to the choice of science- and engineering-related fields. We caution, however, that this information not be used to discourage students with average scores to pursue science, engineering, or mathematics. Instead, use this information as a catalyst to change a system in which so many students are seemingly excluded from these fields based upon prior preparation. If we hope to achieve real change in scientific literacy as well as student recruitment and retention, we are going to have to attract and retain students who score below the top ten percent on these tests.

Table 7. Intended college major and SAT score

Intended Major	Mean SAT Verbal	Mean SAT Math	Combined Mean Score
Physics	558	641	1199
Economics	519	576	1095
Chemical Engineering	490	589	1079
Chemistry	500	572	1072
Math and Statistics	469	593	1062
Political Science	507	515	1022
Biological Sciences	480	524	1004
Civil Engineering	436	533	969
General Psychology	448	463	911
Child Psychology	415	428	343
Sociology	414	429	843
Agriculture	404	436	840

Source: Grandy, 1987

As a final note, we looked at a study, reported in the National Science Board's *Science and Engineering Indicators* (1989), that reported upon the quantity of time spent upon science and math instruction. A sample of the nation's elementary and middle schools reported relatively little change over the period between 1977 and 1986. The type of instruction in the sciences was reported as basically lecture and discussion, as opposed to hands-on and field-work activities. This is an interesting fact considering that most teachers reported believing that hands-on activities are a more effective means of education. The number one reported reason for this finding is that schools lack the appropriate facilities.

We now know that there are a variety of forces in a young person's life that can encourage him or her to pursue a career in science, engineering, or mathematics. Positive parental influence, particularly for girls who face a variety of cultural barriers in the pursuit of an education in the quantitative fields, is essential. Prior preparation in the form of science courses in junior and senior high school, a strong mathematics background, and the development of critical thinking skills are also positively correlated to pursuing science, engineering, or mathematics in college. Young students must be provided with positive role models and a chance to develop positive attitudes about science. Counseling must not perpetuate the belief that science, engineering, and mathematics are for the select few with high scores. Women, minorities, and other non-traditional students must be encouraged to pursue these avenues. Given proper encouragement, curricular innovation, and a strong desire, these students will begin to experience success in increasing numbers. These factors, more than any others, will increase student participation and persistence in science, engineering, and mathematics.

THE TWO-YEAR COLLEGE STUDENT

The two-year college is perhaps best characterized by its open-door policy. In effect, any individual who can benefit from the education offered by these institutions may attend. A reasonable fee structure further enables thousands of students to attend who otherwise might be declined access to higher education.

The impact of the open door has an effect upon the student demographics found in the two-year system. Most notable is the high proportion of minorities. Consider, for example, that while two-year colleges account for approximately 37 percent of the total higher education enrollment, they enroll 47 percent of all minority students. This figure represents an increase of 45 percent from 1976 statistics (National Center for Education Statistics, 1988b).

The U.S. Department of Education's National Center for Education Statistics has noted that:

The rise in total enrollment between 1976 and 1986 has resulted *in a 2 percent shift toward two-year institutions. Four-year institutions accounted for about 65 percent of total enrollment in 1976, while 2-year institutions had about 35 percent. The 1986 percentages were 63 and 37 percent, respectively* (1988b, p.9).

Table 8. Minority enrollment in two-year institutions

Hispanic	288,000
American Indian	45,000
Asian	165,000
Black	457,000

Source: El-Khawas, Carter, and Ottinger, 1988

Furthermore, according to the Department of Education, the recent growth of minority enrollments in the four-year sector of higher education was, by and large, steady but not spectacular. The two-year colleges, however, witnessed a dramatic rise in minority enrollments. Black enrollment in two-year institutions increased about 9 percent; Hispanic enrollment increased at about 64 percent, Asian or Pacific Islander increased at 135 percent, and American Indian increased at 24 percent. (National Center for Education Statistics, 1988b).

In general, two-year students have demonstrated different course enrollment patterns. Department of Education studies point out that most students in institutions of higher education attend school full time. However, as shown in Table 9, this attendance pattern varies somewhat by selected institutional and student characteristics. For instance, while 69 percent of the students in four-year institutions attended school full time in 1987, only 36

Table 9. Distribution and attendance status of students (in thousands)

Type of Institution	Total Attendance	Full-Time Attendance	Part-Time Attendance
4-year	7,992 - 100%	5,523 - 69.1%	2,469 - 30.9%
2-year	4,776 - 100%	1,709 - 35.8%	3,068 - 64.2%

Source: U.S. Department of Education, 1987

percent of the students in two-year institutions attended school full time during this period.

Women were more likely to attend part-time than men, 47 percent to 39 percent, respectively. Further, the two-year college student is much more likely to be working while attending school. In addition, they are more likely to be living away from their parents. Indeed, their average age is approximately 28.

Table 10. Distribution of two-year college students by age

Age Range	Percent of Enrollees
14 to 21 years	46.7%
22 to 34 years	38.6%
Over 35 years	14.7%

Source: El-Khawas, Carter, and Ottinger, 1988

Students at two-year colleges who elect to pursue courses in science, engineering, and mathematics differ from their peers who choose other courses of study. While most two-year college students attend part-time, a higher percentage of science majors are full-time students. Science students tend to have higher academic aspirations than their peers. And they are more likely to be interested in transferring to four-year institutions. (National Science Foundation, 1989b).

These are important factors when considering recent demographic trends among the college age population. Studies have demonstrated a steady decline in the 18- to 24-year-old population between 1980 and 1986. However, during that same period college enrollment increased 9 percent. Clearly an increase in the enrollment rates of people over the age of 25 was the major contributing factor. Moreover, colleges witnessed increasing numbers of non-traditional students, many of whom enrolled in a two-year college. In 1980, 2.9 percent of the population aged 25 or older was enrolled in higher education. Between 1980 and 1986, this age group increased their enrollment by 12.3 percent (National Center for Education Statistics, 1989).

What all of this means, of course, is that the two-year college is enrolling a significant proportion of the nation's current and future labor force. We know, for example, that in the coming years the percentage of minorities and women in the work force is going to increase sharply. Consequently, we must improve the scope and quality of science education in these institutions. Furthermore, given the demographics of the students who pursue science, engineering, and mathematics education, we must find a way to encourage more women and minorities to enroll and persist. It may not be an overly dramatic statement to say that our nation's future is dependent upon the success of this endeavor. Finally, considering that over 47 percent of the higher education minority population is enrolled in a two-year college, the need for undergraduate education reform in these subjects becomes imperative.

CHOICES OF THE COLLEGE STUDENT

It is a source of concern that few of the available students now entering college are choosing to study science, engineering, and

Table 11. Most frequent Associate Degree awards

Field of Study	Percent
Business	25.6%
Liberal/General Studies	23.4%
Health	15.1%
Engineering Technologies	13.2%
All Other Fields	21.7%

Source: El-Khawas, Carter, and Ottinger, 1988

mathematics. What is even more alarming is the decline in students who are choosing careers as teachers in these subjects. The most alarming trend, of course, is the lack of women and minorities interested in these fields. As discussed earlier, one of the major factors accounting for the low representation of women and minorities in science, engineering, and mathematics is their pre-college course selection patterns and subsequent placement test scores. Recall that the SAT average is 50 points lower for females than males in the mathematics portion of the exam. Among minorities (Blacks, Native Americans, and Hispanics) scores are between 50 and 100 points lower than the national average. Asians, on the other hand, average 40 points higher than the national average (National Science Foundation, 1990). Moreover, while the same proportions of men and women take introductory mathematics courses in high school, men are more likely to take advanced courses such as calculus and trigonometry (National Science Foundation, 1990). In addition, it is well known that White students are more likely to pursue academic courses, rather than vocational or general courses, while in high-school, than are Black students and other minorities.

In 1986 women were earning more than one-half of the associate degrees and about one-half of the bachelor's degrees. Between 1971 and 1986 their share of associate degrees grew from 43 to 56 percent on a generally upward path. Indeed, women now comprise the majority of students attending two-year colleges. In the two-year college women make up 56 percent of the students, while men enroll at a rate of 44 percent (El-Khawas, Carter, and Ottinger, 1988). Women were to be found in all areas of study. However in some fields, such as mathematics, increases in the proportions of women were due largely to a decrease in the numbers of men achieving degrees. In the fields of science and engineering, women have not reached a parity with men. They continue to earn a much smaller proportion of the degrees conferred at all levels in the physical and computer sciences, as well as engineering.

RECOMMENDATION 5: Each school should establish a process by which the administration, admission, advisement, and support staff offices of the college are sensitive and knowledgeable with regard to the science, mathematics, and engineering programs of the college.

Since the 1960s the American Council on Education and UCLA's Cooperative Institutional Research Program (CIRP) have been conducting studies of interests among college freshmen. These studies have grown into the largest and oldest longitudinal study of higher education in the United States. Analysis of its findings demonstrates how the interests and attitudes of our nation's college students have changed over the decades. For example, interest among freshmen in science majors has declined at a steady rate over the past 20 years. Interest in en-

Not only do the sciences have a high attrition rate; they are, by and large, unable to recruit majors from other fields.

gineering and technical fields has declined sharply in just the past 5 years. In addition, science and mathematics courses aimed at future secondary school teachers have also declined over the past two decades.

Further alarming trends are evident in the CIRP data. In the last twenty years the proportion of college students planning to major in the sciences fell by approximately half (from 11.5 percent to 5.8 percent). The largest decline was in the area of mathematics. (Astin, Green, and Korn, 1987). Not surprisingly, this same time period witnessed healthy gains in freshmen planning to major in business-related fields. The growth in this area was from 10.5 percent to 23.6 percent.

Perhaps the most alarming statistic emerging from the CIRP Twenty Year Study is that a large proportion of aspiring science majors eventually leave for other fields of study. Not only do the sciences have a high attrition rate; they are, by and large, unable to recruit majors from other fields. One study has speculated as to the cause of this phenomena by suggesting that the blame partially lies with the science departments themselves. They often take pride in difficult courses that weed out the less-than-academically superior. This informal competition to be more rigorous than other departments is, of course, a troubling trend given the facts emerging as to the status of science, engineering and mathematics (Green, 1989).

PART SIX:

CURRICULUM ISSUES IN TWO-YEAR SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION

It is our feeling that NSF should place its effort on helping the two-year colleges strengthen the foundations of their basic science, mathematics, and engineering programs. This will serve to benefit in the broadest and most fundamental way the colleges and their full population of students, not just those concentrated in technician training programs (Watson, 1989, p. 6).

The nature of science, engineering, and mathematics education requires laboratories, time-intensive instruction, and technology. These subjects are experimental and observational by nature. When most effective, they use hands-on education, where critical thinking is applied to observation and analysis. This form of pedagogy is known to be an effective means to achieving educational goals. However, this necessity is one of the main reasons for the decline in quality in science instruction. By and large, we have not maintained a commitment to up-dating facilities, laboratories, and instructional technology. In short, we have not maintained committed funding.

Science education, as well as mathematics and engineering, is a vertical endeavor. This is to say that one course builds upon another. In the humanities and social sciences, for instance, this is not necessarily the case. This necessity is fundamental to the problems of science education we are now facing.

A student cannot be expected to learn physics without calculus. Undergraduate science and mathematics education has to provide the building blocks for later, more advanced course work. If we expect more students to advance to the postgraduate level, we must recognize the vertical nature of the program and enhance all levels of study. This, we feel, is particularly true in the elementary and secondary schools as well as the undergraduate years. Here, the two-year college can and does play an important role in advancing science.

It is well known that the sciences attract the best pool of students. Fear of math, physics, and chemistry, or the difficult nature of the curriculum sometimes frightens interested students away from these courses. Consider for a moment the fear generated in the average student by the thought of organic chemistry or advanced calculus. It is no wonder that most students seek to avoid this challenge, opting for less rigorous paths to a degree.

The irony, of course, is that students majoring in the sciences are expected to perform well in general level courses offered in social science and humanities as well as courses offered in their own departments. They are, through the general education curriculum, exposed to at least a modest amount of courses outside the quantitative fields during their student careers. The logic behind these requirements is, of course, to make them well-rounded individuals. If this is the case, then why are so few science courses found in the general education curriculum? Why are we not exposing a proportional amount of science, engineering, and mathematics courses to students majoring in humanities and social science? Are we doing these students and the nation a disservice? Or are the individuals who design the curriculum responding to previously held notions that these courses are insurmountable hurdles for these students?

If one were to inquire today as to the most important issues about which a citizen must be informed, certainly the broad implications of nuclear physics would rank near the top of the list. One cannot look for guidance from the men and women educated in the humanities at elite American institutions; they probably will have been exposed to only one half-course in physical science, and know virtually nothing about nuclear physics. This may not prevent them from having opinions; it will only prevent them from having informed opinions. (Westhiemer, 1988, p. 34).

The elimination of math, science, and engineering requirements from the general education curriculum is a problem that extends beyond the achievement of national education goals. In most cases, individual departments are funded based upon enrollments, or in some cases, daily attendance. Since these courses are perceived as difficult and as they become increasingly avoidable by the general student population, two things occur:

* Interest wanes, causing a decline in students declaring science, engineering, and mathematics majors.

* Funding and facilities are cut due to lack of enrollments.

Departments are forced to increase class size, further exasperating an increasing teaching load. The results are a decline in the quality of both teaching and facilities in mathematics and science.

The nature of science education greatly hinders survey courses designed for non-science majors. Physics without mathematics is undoubtedly a great deal more difficult than a program of study with logical progression. The result of the efforts by colleges to require sciences without requiring "too much" science is a diluted curriculum lacking in its original intent. The sciences, in reality, have a core curriculum, a body of knowledge that must be understood to advance to upper division levels. The implications for the two-year college transfer function are profound. Undergraduate education in the sciences must provide the quality and quantity of education to enhance success in later education. Moreover, the two-year college must provide the appropriate building blocks for those students terminating their science education at the two-year institution.

In a 1986 report the National Science Board studied the problem of general education science courses. The Neal Report noted that:

Too often, it seems, these special course are watered-down non-mathematical versions of the standard introductory courses for science students; some have a strong "applied" or "environmental" orientation; and some focus narrowly on selected topics such as kitchen chemistry, physics for airline passengers, or biology for the home gardener. All of these attempts, in the views of their critics, fail what ought to be their central objective, to illustrate the nature of science and scientific thought; they overemphasize facts, under-emphasize process and methods, and avoid abstraction (National Science Board, 1986, p. 25).

RECOMMENDATION 6: To enhance its curriculum, community colleges should explore methods by which they can create environments that encourage success in science, engineering and mathematics. One successful method is to provide opportunities for students to do individual projects, research, or otherwise work closely with faculty members on science, engineering and mathematics problems. These activities, coupled with positive attitudes among faculty, will prove very effective.

RECOMMENDATION 7: **The curricular role of community colleges should include pre-service and in-service training in mathematics, science, and technology for current and future elementary and secondary school teachers. Funding for programs such as these has been set aside in the Teacher Enhancement Programs of the National Science Foundation.**

RECOMMENDATION 8: **While many of the nations two-year institutions are denoted community colleges, relatively few have developed a system of community service education in the sciences. This trend should be reversed by placing an emphasis upon cooperative programs with public schools. The results will be an enhanced curriculum at all levels of education continuum. These programs will serve to enlighten young students about the college environment, as well as further interest them in science and technology careers.**

RECOMMENDATION 9: **The precollege education or remediation function of the two-year college is not unique to these institutions. It is, however, a necessary part of the curriculum. As community-based institutions, priorities should be given to science literacy, community science programs, and programs aimed specifically at the parents of future science students. Faculty at community colleges should work with faculties at both elementary and secondary schools to develop comprehensive programs. Public and private funding must be set aside for proposals that seek to enhance these special programs.**

While the transfer function was long considered the "most important" aspect of the two-year institution, we know now that there are several other reasons behind student attendance, each requiring understanding, and in some cases, enhancement. A recent report by the American Mathematical Association of Two-Year Colleges (AMATYC) and the Mathematical Association of America (MAA) entitled "A Curriculum in Flux" noted that:

In some scientific areas, as well as mathematics and engineering, the transferability of the courses works against experimentation in curricular matters. Thus change is sometimes slow to come to areas where the need is the greatest. This point further establishes the importance of partnerships between segments with all parties working toward a common goal (Davis, 1989, p. 5).

The report goes on to provide recommendations to enhance the transfer function:

If the transfer of two-year college students to the four-year institution is to remain a viable function, then stronger efforts at inter-segmental cooperation must be initiated. Past efforts have yielded a myriad of policy statements but little in the way of aid to transfer-minded students. We recommend that science, engineering, and mathematics courses in all the segments of higher education be truly equal, and that transfer become a mere formality rather than a major obstacle to continued studies. Furthermore, transfer should be guaranteed to any qualified student completing a lower-division course of study at a two-year college. The cooperation between the segments will ultimately benefit both the two and four-year institutions. With the proper resource allocation, the quality of eduction should improve dramatically (p. 6).

The science pipeline is, of course, severely affected by the success, or lack of success, of transfer students. While the issue has many complexities, the fact remains that effective transfer is largely dependent upon clear, concise agreements between the various segments of education. As these understandings develop so too will successful transfer students.

Across the nation, in community, technical, and junior colleges only about one-third of all degree-seeking students are enrolled in programs leading to transfer to a four-year institution and ultimately to a bachelor's degree. Of the remaining majority, most are in programs that lead to careers requiring an associate degree. Many of these programs are highly technical with strong bases in mathematics, science, and engineering. Since there is considerable overlap in the curricula for these programs and for transfer programs, most of the recommendations in this report apply equally.

There is, however, a new curriculum issue attracting considerable attention among community, technical, and junior college educators, and it is one that offers great hope for decreasing the number of high school drop-outs and increasing the number of high school students who enter higher education to pursue careers in technical/scientific fields. The Tech Prep/Associate Degree (TPAD) program combines the final two years of postsecondary education (the associate degree part) into a coordinated four-year program leading to an associate degree in a technical field and a career as a technician.

The leading advocate for the TPAD program has been Dale Parnell, president of the American Association of Community and Junior Colleges. In a recent article in *The Balance Sheet* Parnell wrote:

Many academically talented secondary school students have been well served over the years by the college prep/baccalaureate degree curriculum--but, unfortunately, we have allowed this curricular area to become the one definition of excellence in the secondary school curriculum. We have attempted to insist that all students must wear one size of educa-

tional program shoes. But it is clear that one curriculum will not serve all students any more than one size of shoes will fit all sizes of feet. In particular, the two middle quartiles of the typical high school student body (the neglected majority) have not been particularly well served by the college prep/baccalaureate degree curriculum--nor have they been well served by the unfocused and watered-down general education curriculum. In addition, these students have not enrolled in large numbers in the vocational education courses because of the image problem. Thus, most of them have not been served at all by vocational education programs.

As a result, some 11 million students out of the 40 million now enrolled in elementary and secondary schools will not even graduate from high school--in part, because of the problem of an unfocused, smorgasbord type of curriculum.

What can be done? First, high schools would do well to eliminate the unfocused general education program and replace it with a Tech Prep/Associate Degree Applied Academics Program--to be implemented alongside the college prep/baccalaureate degree program and the high school diploma/vocational education program. This new program targets the two middle quartiles of the typical high school student body in terms of academic talents, learning styles, and interests. Emphasis is placed upon the middle range of occupations requiring some postsecondary education, but not necessarily a baccalaureate degree.

The current nationwide 27 percent high school dropout rate can be reduced if students understand the application of their learning as well as the acquisition of knowledge. To accomplish this goal, schools need to establish a substantive applied academic program--one that would break down the walls between vocational education and academic education. The highest percentage of high school dropouts quit school between grades 10 and 11. This number can be reduced if students see a focused alter-

native learning opportunity for grades 11-12-13-14 that connects the high school and college curriculums with real-life issues.

The four-year, tech prep/associate degree program is intended to run parallel with--not to replace--the current college prep/baccalaureate degree program. It combines a common core of learning with technical education, and rests upon a foundation of basic proficiency development in math, science, communication, technology--all in an applied setting. Beginning with the junior year of high school, students would select the tech prep program (even as they now select the college prep program of the high school diploma/vocational education program). and continue for four years in a structured and closely coordinated high school/community or technical college curriculum (Parnell, 1990, p. 13).

First written about by Parnell in his 1985 book, *The Neglected Majority*, the TP/AD program has gained a wide following among community colleges and associate secondary school systems in the intervening five years. In 1990 TP/AD was written into federal law with $63.4 million funded for program development in all fifty states for the 1991 fiscal year.

What this program can mean for the sciences and for the possibility of getting more secondary school students into the pipeline may be inferred from a recent statement by School Superintendent Doug James of Richmond, North Carolina, whose school system has entered into a TP/AD program with Richmond Community Colleges:

Previous to Tech Prep, 25 percent of our high school students were enrolled in our pre-college program and 75 percent in the general academic/vocational curriculum. Now, over 30 percent are enrolled in the pre-college curriculum and another 30 percent in our Tech Prep program, which involves a more rigorous academic and technological course of study (than the unfocused general education program). Enrollment in Algebra I has in-

creased 42 percent over our 1985-86 enrollment, with an associated increase in our average end-of-course test scores. Algebra II enrollment has increased 57 percent with a slight decrease in average end-of-course test scores. A significant increase has also been experienced in student enrollment in more advanced English, social studies, and science courses.... Since the beginning of our Tech Prep program, our average SAT score has increased 4.8 points, the dropout rate has declined from 7.2 percent annually to 4.8 percent, and the percentage of graduates choosing to attend a community college has increased from 24 percent to 46 percent.

RECOMMENDATION 10: Community, technical, and junior colleges should actively pursue TP/AD agreements with their feeder high schools to bring more potential high school dropouts into technical programs with strong bases in science, mathematics, and engineering education.

PART SEVEN:

A NATIONAL ANALYSIS OF TWO-YEAR SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION

The following section of the report discusses a variety of facts from NSF, AACJC, the National Center for Educational Statistics, several research papers, and data collected via a review of state documents describing the status of science, engineering, and mathematics in two-year institutions.

The total enrollment in all American colleges and universities increased by nearly four million between 1970 and 1983. However, between 1983 and 1988 the growth rate was only about 4 percent. During the period between 1970 and 1983, enrollment growth was greatest within two-year institutions, more than doubling in size from 2.2 million to almost 4.7 million students. It is reasonable to conclude that since four-year and two-year institutions offer somewhat different types of programs, there is a strong indication of changing needs and preferences among the college-going population.

Consider that between 1970 and 1983 the number of students at four-year institutions grew by 10 percent, while during the same period enrollments in two-year institutions grew by 22 percent. No doubt this reflects, in part, an increasing interest in higher education by the non-traditional, older, and part-time students, many of whom elect to attend two-year institutions (U.S. Department of Education, 1987, p. 5).

Given this growth in enrollment, and the critical role two-year colleges play in higher education, several organizations have investigated the status of science, engineering, and mathematics in the nation's two-year institutions. Notable among these studies is the report completed by Westat Corporation in 1988 and the report submitted to the NSF by the Center for the Study of Community Colleges in 1988.

These reports have found that nearly all (99 percent) of the public two-year colleges offer courses in subjects such as biology, computer science, and mathematics. In addition, 98 percent offer engineering or applied technologies, 94 percent offer chemistry, and 94 percent offer physics. Technology courses, particularly those of a vocational nature, far outweigh physical or life science courses. The Westat report notes that the mean number of courses offered per term by their sample of colleges was as follows:

8 chemistry, physics, and earth science
13 biology
17 math and computer science

This is in contrast to much higher averages for technology, health, and engineering courses:

42 allied health
83 engineering

In attempting to account for the variation found among course offerings, Westat found that institutional control (public vs. private), institutional size (small, medium, large), and location all had an impact upon course offerings. Colleges located within an urban environment have found that a large amount of their students come to them underprepared in the quantitative fields (Westat, 1988, p. 3-12). This fact, in turn, leads to resources being directed to courses designed to alleviate these problems. Upper-level courses, leading to transfer or further study, become more rare, further diluting the quantity and quality of students in science, engineering and mathematics (Hooe, 1990, p. 23-25).

FINANCE

Collectively, two-year colleges have an operating budget in excess of 14 billion dollars. The major sources of income are listed in the table below:

Table 12. Major sources of financial support among the nation's two-year colleges

Sources of Support:	Percentage of Budget:
Federal	7.4%
State	48.9%
Local	23.4%

Source: El-Khawas, Carter, and Ottinger, 1988

Total expenditures in the public institutions are in excess of 13 billion dollars, while the far fewer independent institutions exceed 900 million. Expenditures per full-time equivalent student are similar between the public and independent institutions--approximately $4,200 and $4,400 per student respectively.

Tuition and fees are by no means stable from state to state. Our survey indicated that California has the lowest average fees, approximately $100 per year, while Vermont averages the highest, approximately $1,600 per year. In comparison to four-year institutions, community colleges are extremely cost-effective. Not only are students responsible for half as much in tuition, states themselves contribute substantially less in institutional support. For example, California appropriates approximately 26 percent of its higher education budget to community colleges: Florida, approximately 31 percent; Illinois, 15 percent; and Oregon, 18percent.

Nearly half of the financial resources of the public two-year college are spent in support of instruction. These colleges are teaching-intensive institutions. The average student/faculty ratio for the past several years has been approximately 20 to 1. Moreover, as student enrollment has risen, so too has the number of faculty hires. Unhappily, however, there has been a disproportionate rise in the number of part-time faculty, leading some observers to question the continued high quality of instruction.

STATE SUPPORT

In addition to a review of existing studies the Task Force has completed a survey of each state. One aspect of our survey was the investigation of state-level support granted to the science and technological fields. As we have noted above, the greatest level of financial support to the two-year system comes from the states themselves. We, in turn, sought to determine the degree to which this support is directed to the study and advancement of science, engineering, and mathematics.

The Task Force survey took place in three phases. Phase One of the study included a written (with telephone follow-up) request to each state, seeking documentation of activities related to the advancement of science and technological education in their two-year institutions. This phase yielded a wide variety of documents which were reviewed and analyzed for inclusion in the final report. In addition, our research team became familiar with the wide variety of programs and interpretations of common problems which exist across the country. The documents received as the result of Phase Two have proved to be a valuable resource for further study in governance and administration with respect to science and technology education. Phase Two included interviews with individuals from each state who possess knowledge with regard to the status of state support of science, engineering, and mathematics. The final analysis of this data, Phase Three, demonstrated a need for increased data-gathering activities and centralized organizations whose main function would be the promotion of science, mathematics, and engineering in two-year colleges.

Our analysis demonstrated that only 16 states reported maintaining a central office or organization whose function is to track and report on the status of science, mathematics, and engineering (Table 13). Given this low number, we investigated whether or not data was tabulated with regard to the quality and maintenance of labs and other required facilities. In addition, we investigated the compilation of data with regard to students and faculty associated with science and technology in two-year institutions. The results here are more promising; 23 states report maintaining data on these subjects usually as a part of general data-gathering efforts. Frequently data is not broken down by discipline area, thus analysis of specific topic areas (life science for example) is generally impossible given the current level of data collection in most states. Moreover, to determine the level of data available we investigated the level of support for curricular and grant development found at the state level. As is indicated in Table 13, few states have developed a system by which local two-year colleges can receive support for curricular development in the quantitative fields. Similarly, only 10 states report providing support or guidance to local colleges interested in developing grants designed to improve the status of science, mathematics, and engineering in their institutions.

The final topic area of the study dealt with staff development and the creation and maintenance of partnerships with local industry concerned with the improvement of science, engineering, and mathematics. We found that 14 states have a central system devoted to staff development. Common functions include planning annual activities designed to foster faculty exchange of ideas and methods to improve science, engineering, and mathematics instruction. Twenty states reported the establishment of partnerships with local industry as a means to improve science, engineering, and mathematics. These states generally maintain a

Table 13. Survey of state two-year college coordinating offices

States reporting a central office or organization which maintains data on two-year science, engineering, and mathematics education.	16
States maintaing data in a non-discipline-specific manner.	23
State central offices reporting aid to local two-year colleges for curricular development in science, engineering, or mathematics.	13
State central offices reporting aid to local two-year colleges for grant development to improve science, engingeering, or mathematics education.	10
States reporting regional or state level staff development activities for the improvement of science, engineering, or mathematics instruction.	14
States reporting the development of partnerships between two-year colleges and industry for the improvement of science, engineering, or mathematics education.	20

centrally located organization which acts as a coordinating body between the business and education establishment.

These results are the outcome of surveys and interviews done at the state level. We are fully aware that nearly every individual college can provide specific data with regard to many aspects of science and technological education. However, this information is of little use if it never reaches the hands of local, state and national policy makers. For this reason we limited our research to state-level offices. In addition, the state legislature is where nearly 50 percent of the financial support is generated for two-year institutions. We found that states are beginning to centralize their systems of two-year colleges. The move away from local control to state control will have a significant impact upon policy with regard to science, engineering and mathematics.

RECOMMENDATION 11: In light of increased global economic competition, states, in conjunction with local communities and institutions, should accept responsibility for maintaining quality and continuity in two-year college science, mathematics, and engineering programs. State and local leaders need to become increasingly aware of the national and international implications of their educational decisions.

RECOMMENDATION 12: Each state should establish a research function to gather appropriate data and review the status, condition, needs, goals, and objectives of science, engineering, and mathematics education in the two-year college. This information should be provided to institutions of higher learning, as well as educational, industrial, and governmental leaders, with the objective of improving teaching methodologies and environments that encourage student success.

RECOMMENDATION 13: A series of information and resource centers should be established for the purpose of continued investigation of the status of science, engineering, and mathematics education. In addition, these centers should be a rich source of information for local colleges seeking to apply for grants, conduct research, and establish improvements. These centers should work closely with each other as well as NSF to disseminate information pertinent to colleges wishing to enhance the quality of science, engineering, and mathematics education. Faculty development should be emphasized. Programs should be developed which reach 25 percent of the faculty in the region. Summer institutes, and in-service and pre-service training should be coordinated with wide dissemination of results through conferences, workshops, and publications.

RECOMMENDATION 14: State and local partnerships for the enhancement of science, mathematics, and engineering education should be developed between industries and corporations concerned with science, engineering, and mathematics. Such partnerships should be a major focus of the human resource initiatives of the National Science Foundation.

PART EIGHT:

RECOMMENDATIONS FOR FURTHER STUDY

Throughout this report we have noticed specific areas where information is not readily available to individuals interested in initiating improvements in science, engineering, and mathematics. Perhaps the best source for examples of curricu.um innovation is the ERIC database. Our review of these documents turned up dozens of interesting innovations. However, if one were to inquire as to the status of physical facilities related to science, engineering, and mathematics, one would find little in the way of comprehensive data. States, for the most part, do not produce reports that discuss facilities specific to science, engineering, or mathematics. Each college individually would be able to provide information. However, with over 1,300 campuses, collecting the data might prove to be a difficult and time-consuming task. Nevertheless, this is an area which needs exploration. Facilities are related to the currency of the curriculum and the ability of the faculty to conduct the most interesting and understandable courses. Moreover, safety is an issue in some decaying laboratories. Knowledge related to the infrastructure can be used in a variety of positive ways. Funding can be redirected, partnerships can be developed among colleges and between colleges and industry, and faculty can stay abreast of the changing technology available for the classroom. We feel this is an impor-

States, for the most part, do not produce reports that discuss facilities specific to science, engineering, or mathematics.

tant area of study, one deserving the full attention of the agencies which support educational research.

RECOMMENDATION 15: A national registry of reform and innovation in the sciences, engineering, and mathematics should be developed and maintained. This data should be readily accessible to any individual or institution seeking improvement in these areas.

A second area deserving further attention is the development of a resource base highlighting innovative and successful programs related to the teaching of two-year science, engineering and mathematics. During the course of our study we repeatedly ran across exciting ideas that were not to be found in libraries or other maintained databases. Part of the problem is that many of the individuals involved in the administration of these innovative programs do not recognize the value of "spreading the word," or, if they do, they frequently do not know the procedure for doing so. The ERIC database is an excellent resource, however, we encourage the compilation of programs which are specific to areas of study in science, mathematics, and engineering. Furthermore, dissemination and data collection must be aggressive, with priority being given to model programs found throughout the nation. The result will be an acceleration in the exchange of new ideas and methods designed to raise the quality of two-year science, engineering, and mathematics.

Also in need of further study is the development of an agreed-upon general education curriculum that increases the minimum requirements for students in science and mathematics. Curricular review should lead to updated program cores reflecting the needs brought out in this study. In addition, the bonds between precollege course enrollment patterns and postsecondary requirements should be strengthened. If our hope is for U.S. students to achieve superiority in science, engineering, and mathematics, we must link all segments of education together.

The thread by which we can weave this fabric of superior education is a logical and straight forward curriculum, adopted by all the school boards, college boards, and trustees who wish to maintain quality education.

In sum, a national agenda is called for in which priorities are directed to this important area of study. State legislatures, in conjunction with local school boards, should become involved in articulation agreements. Such a system, as found in Florida, will enhance the movement of students through the science pipeline. With students experiencing so many barriers to success it would seem logical to remove those that are bureaucratic. Our hope is to become and remain the leader in science, engineering and mathematics education.

PART NINE:

REVIEW OF RECOMMENDATIONS

STATE AND LOCAL COLLEGE BOARDS:

RECOMMENDATION 2: The improvement of two-year science, engineering, and mathematics education is largely dependent upon a qualified, innovative, and motivated faculty and staff. Faculty and staff development for teachers of lower-division undergraduate science and mathematics should be increased nationwide in such a way that two-year college faculty are motivated to attend and have easy access. Special emphasis should be placed upon minority faculty and their relationships with minority students.

RECOMMENDATION 8: While many of the nations two-year institutions are denoted community colleges, relatively few have developed a system of community service education in the sciences. This trend should be reversed by placing an emphasis upon cooperative programs with public schools. The results will be an enhanced curriculum at all levels of education continuum. These programs will serve to enlighten young students about the college environment, as well as further interest them in science and technology careers.

RECOMMENDATION 11: In light of increased global economic competition, states, in conjunction with local communities and institutions, should accept responsibility for maintaining quality and continuity in two-year college science, mathematics, and engineering programs. State and local leaders need to become increasingly aware of the national and international implications of their educational decisions.

RECOMMENDATION 12: Each state should establish a research function to gather appropriate data and review the status, condition, needs, goals, and objectives of science, engineering, and mathematics education in the two-year college. This information should be provided to institutions of higher learning, as well as educational, industrial, and governmental leaders, with the objective of improving teaching methodologies and environments that encourage student success.

RECOMMENDATION 13: A series of information and resource centers should be established for the purpose of continued investigation of the status of science, engineering, and mathematics education. In addition, these centers should be a rich source of information for local colleges seeking to apply for grants, conduct research, and establish improvements. These centers should work closely with each other as well as NSF to disseminate information pertinent to colleges wishing to enhance the quality of science, engineering, and mathematics education. Faculty development should be emphasized in these programs. In addition, programs should be developed which reach 25 percent of the faculty in the region. Summer institutes, and in-service and pre-service training should be coordinated with wide dissemination of results through conferences, workshops, and publications.

RECOMMENDATION 14: State and local partnerships for the enhancement of science, mathematics, and engineering education should be developed between industries and corporations concerned with science, engineering, and mathematics. Such partnerships should be a major focus of the human resource initiatives of the National Science Foundation.

LOCAL COLLEGES:

RECOMMENDATION 4: Faculty development is essential. Two-year college faculty in mathematics, engineering, and science should receive incentives for participation in structured, long-term staff and curriculum development whose outcomes can be measured.

RECOMMENDATION 6: To enhance its curriculum, community colleges should explore methods by which they can create environments that encourage success in science, engineering and mathematics. One successful method is to provide opportunities for students to do individual projects, research, or otherwise work closely with faculty members on science, engineering and mathematics problems. These activities, coupled with positive attitudes among faculty, will prove very effective.

RECOMMENDATION 10: Community, technical, and junior colleges should actively pursue TP/AD agreements with their feeder high schools to bring more potential high school dropouts into technical programs with strong bases in science, mathematics, and engineering education.

FACULTY AND STAFF:

RECOMMENDATION 5: Each school should establish a process by which the administration, admission, advisement, and support staff offices of the college are sensitive and knowledgeable with regard to the science, mathematics, and engineering programs of the college.

NATIONAL LEVEL:

RECOMMENDATION 1: Professional associations need to recognize the role of the two-year faculty in the area of science, engineering, and mathematics, and seek to enhance their participation as active and valued members. Moreover, the colleges themselves must encourage participation in these organizations.

RECOMMENDATION 3: Sources of stipends must be developed that enable a greater number of two-year faculty to further their education in the area of science, engineering, and mathematics. National-level grants and scholarships should be made available to a large number of interested faculty. This concept, together with the sabbatical program, will greatly enhance the quality of instruction at the two-year level.

RECOMMENDATION 7: The curricular role of community colleges should include pre-service and in-service training in mathematics, science, and technology for current and future elementary and secondary school teachers. Funding for programs such as these has been set aside in the Teacher Enhancement Programs of the National Science Foundation.

RECOMMENDATION 9: The precollege education or remediation function of the two-year college is not unique to these institutions. It is, however, a necessary part of the curriculum. As community-based institutions, priorities should be given to science literacy, community science programs, and programs aimed specifically at the parents of future science students. Faculty at community colleges should work with faculties at both elementary and secondary schools to develop comprehensive programs. Public and private funding must be set aside for proposals that seek to enhance these special programs.

RECOMMENDATION 15: A national registry of reform and innovation in the sciences, engineering and mathematics should be developed and maintained. This data should be readily accessible to any individual or institution seeking improvement in these areas.

PART TEN:

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