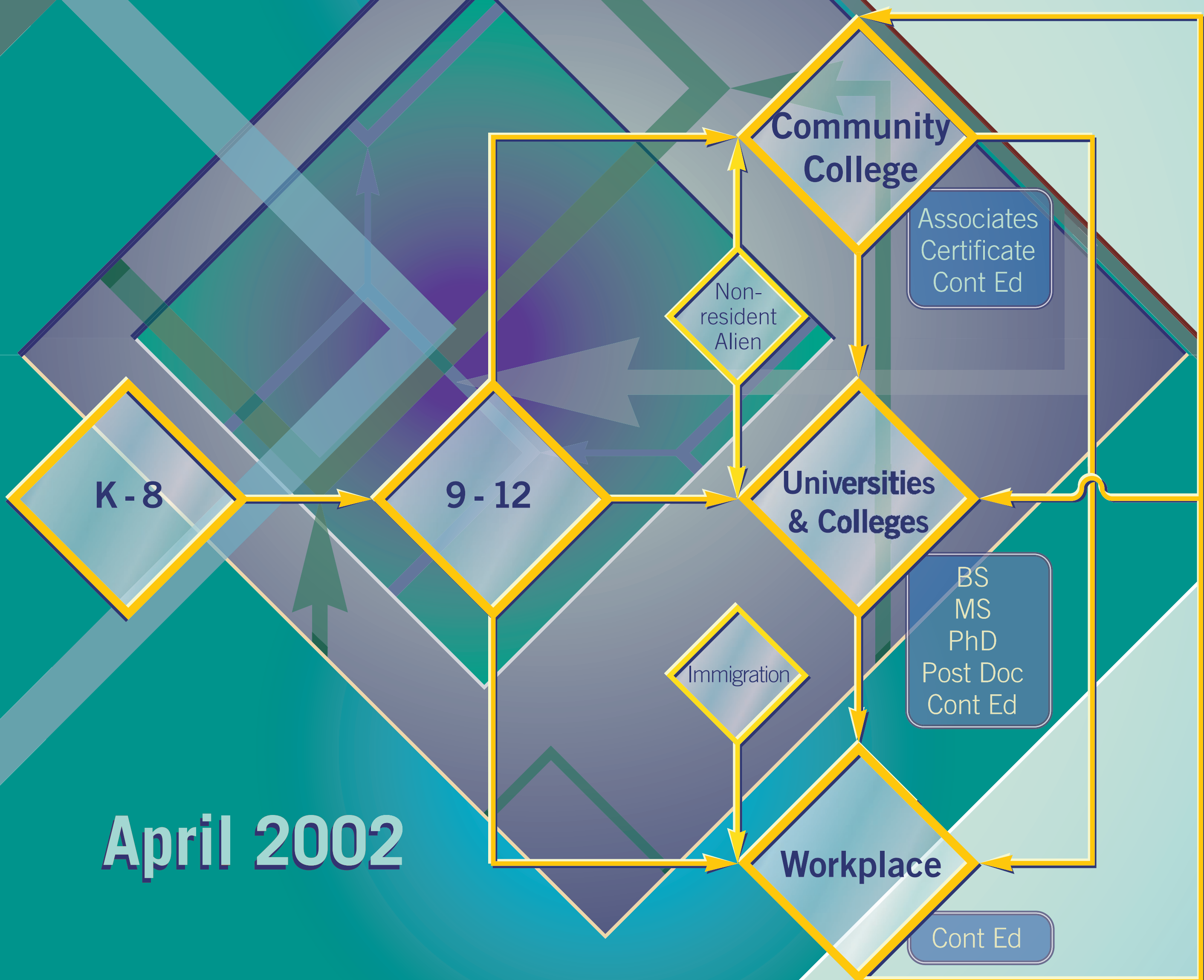
CRITICAL PATH ANALYSIS OF CALIFORNIA'S SCIENCE AND TECHNOLOGY EDUCATION SYSTEM



April 2002

CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY

LETTER FROM CCST MEMBERS

The preeminence of California's science and technology industries and the leading role our researchers play in technology innovation have helped create a state with tremendous economic diversity and strength. High-tech industries, ranging from aerospace to biotechnology to movie production, provide jobs, sustain a high standard of living, and offer innumerable other benefits to California residents. However, our own citizens are not being prepared in adequate numbers for the important, challenging – and well-paid – science and technology jobs, a fact that has not received adequate attention.

California's educational system is simply not producing the science and engineering graduates needed to meet industry's growing requirement for skilled workers. Furthermore, the participation by women and the state's fast growing ethnic groups in high-tech jobs is lagging behind. These factors are threatening California's leadership in science and technology and, given the state's leading role in the technology sector, will also jeopardize our national prosperity and security.

CCST has responded to this pressing concern by producing a Critical Path Analysis of California's Science and Technology Education System. This study, for the first time, analyzes the educational system as a whole, integrated, and inseparable system. It identifies how schools at all levels can better prepare future scientists, engineers, and skilled technical workers. No part of the system works in isolation and the solutions to the problems identified will require crossing boundaries between educational systems, the government, and industry.

This report has been prepared under the direction of the CCST Critical Path Analysis Committee, composed of Warren J. Baker, Charles F. Kennel, C. Judson King, Victoria P. Morrow, Roy D. Pea, Karl S. Pister, James M. Rosser, AnnaLee Saxenian, and George M. Scalise, with Lawrence T. Papay serving as committee chair. Each and every one of them has contributed substantially to the composition of the report and worked to maintain the inclusive perspective and integrated focus of the Critical Path Analysis.

Many individuals and groups have contributed to this report. Six studies were commissioned, focusing on individual segments of the educational pipeline (K-12, college, and continuing education), demand for workers in the science and technology sector, and the digital divide.

We would like to thank the William and Flora Hewlett Foundation, Hitachi, Ltd., and the University of California for their generous underwriting of this project and extend our sincere appreciation to the California State University, the California Institute of Technology, and the Semiconductor Industry Association for their support.

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Critical Path Analysis of California's Science and Technology Education System

A report prepared by the **California Council on Science and Technology**

April 2002

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The California Council on Science and Technology is a nonprofit organization established in 1988 at the request of the California State Government and sponsored by the major post secondary institutions of California, in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending policies and initiatives that will maintain California's technological leadership and a vigorous economy.

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California's Science & Engineering Education Shortfall

California is the nation's leading science and technology state. Science and technology have been at the core of California's leadership in agriculture, aerospace and defense, electronics, computers, software, movie production, multimedia entertainment, biotechnology, medical devices, environmental technologies, and telecommunications. This leadership provides jobs, sustains a high standard of living, and offers innumerable other benefits to California residents. Science and technology are vital to the state's future prosperity, and will help California transcend the economic slowdown of the last two years. As the nation and the state continue to recover from the recession and the aftermath of September 11, 2001, science and technology will help the state to continue to prosper.

High-tech industry is a crucial and growing component of the California economy and will be for the foreseeable future.

California is not producing sufficient skilled labor to meet demand.

To better understand how the state should respond to the changing technology environment, the California Council on Science and Technology (CCST) two years ago conducted a comprehensive evaluation of California's high-tech infrastructure. *The California Report on the Environment for Science and Technology* (CREST) analyzed the state's science and technology infrastructure to determine if California has the people, capital investment, and necessary state policies to maintain California's leadership in the face of increasing worldwide competition.

The labor shortage is especially acute regarding women and minorities.

We need to increase the number of graduates from public and private institutions.

A major finding of the CREST report was that the California labor market for science and engineering workers is increasingly tight and that California's educational system is not producing the science and engineering graduates needed to meet industry's growing requirement for skilled workers. There is a widening "gap" between the state's workforce needs and the educational system's ability to respond. While the science and engineering workforce gap is a national problem, it is a problem of critical significance for the state of California, as the CREST report demonstrated and as this report documents further.

In April 1983, the widely respected report, *A Nation at Risk,* began with these words:

> *"Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world…the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people…If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war."* [1]

Unfortunately, many of the observations and conclusions of that report apply to large segments of education in the state of California today, nearly two decades later, especially in the areas of mathematics and science education. The current educational problems in California are the result of many factors that have been decades in the making and will likely take decades to address. The educational system itself is an enormously complex system with no single controlling power and the state is not the sole driver of issues. Many of the recommendations in this report call for new forms of cooperation between institutions, industry, and federal and state government.

The aim of this report is to locate and define the weaknesses in California's science and technology educational system so that they may be more effectively addressed. This will hopefully position the state to sustain its history of high-technology business leadership, and ensure that California's citizens have a full and fair opportunity to participate in California's technology-dependent economy. Recommendations in this report have come from analyzing data on students moving through the educational system. The state government is aware of many of the problems and we would be remiss not to acknowledge its efforts initiated in the last few years. However, although the state's efforts are applauded and to be encouraged, it is too soon to assess the effectiveness of most of these programs and to determine appropriate changes or additions that may be indicated.

Given California's dependence on science and technology, its extraordinary and rapidly increasing diversity, and the existence of serious weaknesses in its educational system, California faces unique challenges if it is to sustain its position as a global leader in high-technology.

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1 *A Nation at Risk: The Imperative for Educational Reform, a Report to the Nation and the Secretary of Education*, United States Department of Education by the National Commission on Excellence in Education, April 1983.

Critical Path Analysis

A critical path analysis is often used for project planning and management processes. In this context, we define a critical path analysis as a comprehensive examination of each component of the California educational system, from kindergarten through graduate school, designed to assess the current status of the system, identify strengths and weaknesses, and find the bottlenecks in the educational pipeline that are preventing more young Californians from obtaining college degrees.

Over a period of a year, many education, industry and government groups and individual experts were consulted to conduct this project. The following research papers were also commissioned for this study:

- **Project 1: California's Demand for a Science and Technology Workforce**
  Cecilia A. Conrad, Associate Professor of Economics, Pomona College
- **Project 2: A Critical Path Analysis of California's K-12 Sector**
  Julian Betts, Professor of Economics, University of California, San Diego
- **Project 3: The Role of Universities and Colleges in California**
  Lynne Zucker, Professor of Sociology & Policy Studies, University of California, Los Angeles, and Michael Darby, Professor of Money and Financial Markets, University of California, Los Angeles
- **Project 4: Issues Impacting Baccalaureate Degrees in Science and Engineering**
  CCST with assistance from the University of California, the California State University system, and the Association of Independent California Colleges and Universities
- **Project 5: Alternative Paths to Competency: Continuing Education and Lifelong Learning**
  Mary Walshok, Associate Vice Chancellor for Public Programs, University of California, San Diego, and Carolyn Lee, Coordinator of Public Programs, Extended Studies and Public Programs, University of California, San Diego
- **Project 6: The Digital Divide**
  Edited by Roger G. Noll, Morris M. Doyle Professor of Public Policy, Department of Economics, Stanford University

Defining the Gap

California's share of total U.S. employment has hovered near 11% for the past 20 years while its share of U.S. science and technology (S&T) employment has ranged from 15-18% over the same period. High-tech jobs represent approximately 11.4%[2] of total employment in the state, making it the second largest California economic sector (after retail trade) and larger than the third and fourth sectors (wholesale trade and transportation) combined.

The rate of growth in technology-related occupations has consistently outpaced average occupational growth rates – and is projected to continue to do so. Most of the employment growth in California's science and technology sector will come from jobs that require a baccalaureate degree or higher in a science or engineering field. Although complaints of shortages of skilled labor have receded for the moment thanks to a slight decrease (about 2%) in some high-tech industries in 2001, these complaints are unlikely to disappear.

One estimate of the workforce gap in California indicates a current shortfall of over 14,000 workers with baccalaureate degrees in science and engineering (S&E).[3] In other words, 14,000 jobs requiring these degrees went unfilled. While this is an improvement over 1998 numbers, it remains extremely serious given the fact that fewer than 20,000 S&E graduates are produced each year. The number of S&E baccalaureates produced in California would need to increase by nearly 70% to make up for this shortfall.

Charting the Education System

To conduct our analysis, we divided the high-tech workforce production process into six sub segments. These include the K-12 schools; the California Community Colleges; Baccalaureate Degree Production at public and private institutions; Graduate Degree Production (master's of science, doctorate, or post doctorate) at public and private institutions; and Continuing Education. An examination of the Critical Path was conducted for each segment.

The K-12 System

The academic preparation K-12 students receive, especially in mathematics, science and reading, is critical to their ability to enter the S&T workforce or pursue further study in S&T fields. Although the K-12 system has received con-

[2] U.S. Bureau of Labor Statistics, March 2001.

[3] Cecilia A. Conrad, *California's Demand for a Science and Technology Workforce*, CCST, June 7, 2001, Figure 3.3.

siderable attention in recent years, evidence suggests that significant problems remain in the preparation students receive at this level.

In 2000, there were over 6 million students enrolled in the California K-12 system, an increase of over 22% since 1990. Latino students are now the single largest ethnic group in the system with 43% of high school enrollment and 50% of kindergarten enrollment.

Key findings of the Critical Path Analysis for the K-12 system:

- **The overall attrition rate in high school is too high (more than 30%). Of those who do graduate, too few have the a-g requirements[4] needed for college (approximately a third). The shortfall in academic preparation is particularly acute in science and mathematics.**

- **The college participation rate will likely get worse over time due to a change in demographics. Latinos, African Americans and Native Americans have become a majority in K-12. Their rates of college participation remain low. Currently only approximately 5% of Latino 9th graders complete high school fully ready for college. To improve college participation rates, significant intervention is needed.**

- **California is experiencing a growing shortage of qualified teachers, especially in science and mathematics, and many schools have exceptionally inadequate support systems and resources (e.g., counselors and librarians) compared to the rest of the country.**

- **Improving teacher quality, particularly at low performing schools, is an important key to improving student performance.**

- **Teacher salaries are not competitive with the labor market, and are particularly uncompetitive in science and mathematics.**

California's teachers are less highly educated than the national average and a significant number of teachers lack full and appropriate credentials. The percentage of California teachers holding master's degrees or higher (40%) trails behind other high-tech states such as Massachusetts (59%) and New York (75%). Within the state, there is considerable inequality in resource allocation among

[4] These are a specific series of classes considered a prerequisite for admission to the University of California and the California State University. They include history, English, mathematics, laboratory science, foreign language, and college preparatory electives. A similar set of courses is required for admission to many private institutions, especially those that are highly selective.

schools, including teacher education, experience, credentials, class size, and achievement, e.g., course completion in the “a-g” courses required for admission to the University of California and the California State University system or private universities, and completion of Advanced Placement exams that qualify students for college credit. Moreover, students begin to fall behind far before they reach high school. Acquiring literacy (basic reading and writing skills) by the 3rd grade and completing algebra in middle school are essential requirements for entering high school on a track leading to a science or engineering career. However, a strong science curriculum is also necessary. Partly because the standardized tests currently used by California don’t test it, science has been de-emphasized in many districts, particularly in elementary school.

It should be noted that there is an awareness and concern about these problems at the state level and steps have been initiated to begin to address them. For instance, as of 2001, California managed to raise per-pupil spending to just below the national average. In addition, legislation such as the Public School Accountability Act has the potential to alter fundamentally the dynamics of resource allocation and inequality in California student achievement. The external pressures created by the new accountability system may well induce school systems to find innovative new programs to boost student achievement. However, despite the promise these programs hold, there are no convincing measures of success yet and much work remains to be done. Per-pupil spending is near the national average today, but lagged the national average by 15-20% for nearly a decade; it will take years to recover from this legacy. In addition, the concentration of under-qualified teachers in low-performing schools, together with the numbers of students in these schools, presents a problem whose solution is yet to be found. Necessary reforms must include the active participation of local school districts and school teachers.

The Community College System

California’s community colleges serve multiple roles in providing alternative paths from high school to job related competency. Not only do they provide short-term courses of study leading to certification in technical areas, they also serve as a cost-effective means for students to take college level courses in preparation for transfer to UC, CSU, and private institutions.

Over 1.6 million students are currently enrolled in the California Community College system. Approximately 91,000 received an associate’s degree or certificate last year, yet fewer than 6,000 completed an S&E related program.

In the context of this report, community colleges are regarded as a crucial point of entry into higher education for many students because they provide programs for transfer to a four-year college, remedial or "catch-up" programs for students who lack a strong educational background, and continuing education for skills improvement. Consequently, the community college system offers the best chance to provide remediation for unprepared and underprepared students.

Key findings of the Critical Path Analysis for the community college system:

- **The number of S&E certificates and degrees granted is insufficient.**
- **The number of transfers to four-year institutions is too low.**
- **The community colleges have opportunities to expand their roles as bridges to work or further study; e.g., at-risk high school students benefit from programs which allow students to begin taking college courses and more aggressively prepare them for entrance to college.**
- **The community college S&E instructional capacity (lab, facility, teacher) is resource limited.**
- **The supply of counseling services is inadequate.**
- **There is no salary differential for faculty in S&E disciplines, despite the higher earning potential of S&E degree recipients in the labor market.**

Transfer students perform well in the state's universities. Various factors account for the low number of transfer students. Among the most serious impediments is the lack of an effective counseling system to provide information, advice, and support appropriate to students' particular needs. It should be noted that funds for UC to place "transfer counselors" in community colleges were cut from the state budget this year. The fact that most transfers occur only at or after four years is partly due to the fact that 80% of community college students are working, with 40% working full-time.

Several community college programs exist to encourage more high school students to attend college, including the First Year Experience and the Puente program. Both identify high school students interested or potentially interested in attending a community college and provide support and guidance to cohorts as they move through high school. Puente is designed to be particularly attractive to Latino students, as well as others. The Middle College High School is a promising program that allows students to begin taking college courses in their junior year of high school, but it is currently on a very small scale.

Transfer students from the California Community College system continue on to graduate school at lower rates than students who start university as freshmen, despite comparable academic performance. Possible factors that should be investigated are financial need and debt levels at graduation, degree of integration into the major department and the discipline, affiliation with faculty, participation in undergraduate research, family socioeconomic factors, and career objectives and aspirations.

Baccalaureate Schools

A baccalaureate degree is considered the minimum qualification necessary for nearly half of high-tech jobs. Many of the occupations projected to grow the fastest in California during the next decade require a baccalaureate degree. This is also the point at which students begin planning for graduate degrees.

There are over 575,000 students enrolled at the baccalaureate level in California, approximately half of whom are in the California State University system; the University of California and Independent institutions each have approximately 25%. However, the University of California is the dominant producer of S&E baccalaureates in the state, granting over 45% of total S&E degrees in 2000.

Baccalaureate degree-granting institutions in California are not producing a sufficient number of graduates in S&E fields, as noted on the following page. Various factors account for this:

- Low awareness of and interest in S&T fields and occupations among K-12 students.
- Inadequate preparation of students in K-12 and their consequent need for remediation.
- Inadequate K-12 teacher workforce in mathematics and science, particularly in low income and minority schools.
- Low transfer numbers from the community college system.
- Student difficulty in core baccalaureate S&E courses, experienced early on, causing them to become discouraged.
- Persistent lag in female and minority enrollment in S&E which may be a result of a lack of faculty mentors and role models of the same gender and/or ethnicity.[5]

[5] Lynne G. Zucker & Michael R. Darby, *Critical Path Analysis of California's S&T Education System: Universities and Colleges in California*, CCST, July 2001, p.6.

- Support services such as tutoring do not always reach the students who need them the most in a timely way and supply of these services often lags behind demand.
- Approximately one-third of California students who intend to pursue S&E degrees do not achieve this goal, which is higher than the 22% national attrition rate.
- The high attrition rate in S&E at CSU makes it difficult to maintain enrollment. The causes should be identified to implement strategies to improve retention.

Key findings of the Critical Path Analysis for baccalaureate schools:

- **California is not producing enough baccalaureates in S&E.**
- **There is a gap between degree production and workforce demand.**
- **California lags behind other states (NY, MA) in per capita production of S&E degrees and rate at which B.S. recipients pursue graduate degrees.**
- **The recent efforts to increase the number of S&E degrees are insufficient.**
- **Students are not often adequately prepared to pursue S&E baccalaureate degrees. They also have low interest in S&E. Both problems stem from inadequate exposure to S&E in K-12 and poorly qualified high school mathematics and science teachers, particularly in low-income and minority schools.**
- **The attrition rate in S&E at CSU is too high (close to two thirds).**
- **Unlike UC, CSU does not have a differential salary scale for S&E disciplines, despite the significant difference in earning potential in these disciplines.**
- **A rise in biology degrees in the past 10 years has masked declines or stagnation in engineering, computer science, mathematics, and physical science degrees.**

Maintaining and expanding high cost college and university science and engineering programs have been hindered by resource adequacy problems. For example, the methods by which CSU and community college S&E instructional programs are funded do not address the real cost of hiring additional faculty and supporting their instruction. Present inadequate funding has created decided disincentives for these campuses to invest in higher cost science and engineering instructional programs. The steady erosion of undergraduate enrollments and degrees in science and engineering disciplines (other than biology) over the past decade is in part at least a logical and inevitable consequence of this inadequate funding. Moreover, state funds are not presently provided to address the non-salary, research-related start-up costs (for laboratories, etc.) associated with the hiring of new and replacement science and engineering faculty.

To help reverse the decline in enrollments and degrees in CSU S&E programs and position them for future growth, and to strengthen the ability of public California colleges and universities to compete nationally – and internationally – for faculty, present funding must be reexamined.

Finally, there is insufficient explicit, targeted strategic planning for S&E programs by each of the higher education segments. As a result, most reform efforts have been piecemeal and the state's ability to counter the S&E decline severely hampered.

Graduate Schools—Master's Level

Over 42,000 master's degrees were granted in California in 2000, of which less than 15% were in S&E. Nearly half of all graduate students in California are enrolled in private institutions, which granted over 45% of all S&E master's degrees in 2000.

Key findings of the Critical Path Analysis for master's level graduate schools:

- **Master's degrees are in significant demand as shown by the numbers of H-1B workers who hold them.**
- **Growth in S&E master's degrees is largely driven by the increasing participation of women in the health and life sciences.**
- **A significant percentage (over 35%) of master's degrees are awarded to non-resident aliens. Many, perhaps most, of these students are not products of the California education system.**

The California Master Plan for Higher Education[6] designates different graduate school functions for the UC and CSU systems. The UC system is designated as the exclusive state school organization empowered to grant doctorates. CSU specializes in terminal master's degree programs; in some instances, CSU grants doctorates jointly with other institutions.

6 Liaison Committee of the Regents of the University of California and the California State Board of Education. *A master plan for higher education in California, 1960-1975*. Assembly of the State of California [1960]

Production of master's degrees has remained fairly constant throughout the 1990s despite a 9% rise in the number of non-resident alien degree recipients. This means fewer California baccalaureates are pursuing graduate degrees in S&E.

The value of the master's degree is too often overlooked. For many it is the primary educational goal, rather than a stepping-stone to a doctorate. Master's degree recipients in some disciplines, such as computer science and engineering, earn higher median salaries than doctoral recipients in life sciences and social sciences.

Fewer women and minority baccalaureate recipients go on to an M.S. or Ph.D. It is possible that gender and ethnic differences in continuation rate from baccalaureate to master's degrees (and beyond) are partly due to a lack of female and minority university faculty role models. White men dominate the ranks of full and associate professors in California as well as in New York and Massachusetts.

Graduate School—Doctoral Level

Completion of a doctorate is primarily required to enter the ranks of university faculty, or to conduct original R&D. In California, the Master Plan for Higher Education specifies that doctorates are to be awarded only by the UC system and Independent institutions. California institutions granted approximately 5,300 doctorates in 2000, of which close to 40% were in S&E. UC grants the most S&E

Key findings of the Critical Path Analysis for doctoral level graduate schools:

- **Ph.D.'s are very important to economic growth.**
- **A small number of top schools in California are responsible for the majority of innovation.**
- **Although California has many top research schools in the UC system and Independent sector, comparatively low levels of financial support for graduate students increase the difficulty of recruiting the best.**
- **Non-resident aliens earn over 30% of S&E doctorates.**
- **There is an increasing number of Ph.D.'s in relatively low paying postdoctoral positions in some disciplines (biology and physics), partially because their skills are directed more towards academe than industry.**

[7] *National Science Board, Science & Engineering Indicators – 2000*, Arlington, VA: National Science Foundation, 2000 (NSB-00-1) Figure 3-4.

doctorates, awarding 1,400 in 2000, while the Independent institutions graduate approximately 700 Ph.D. students. Although California has many top research schools in the UC system and Independent sector, comparatively low levels of financial support for graduate students increase the difficulty of recruiting the best.

Overall, the S&E unemployment rate for people with master's degrees and doctorates is approximately equivalent. However, Ph.D.'s have a higher unemployment rate in computer sciences, mathematics, and life sciences.[7]

Understanding the behavior of the market for Ph.D.'s is critical to the formulation of policy concerning the supply of scientists and engineers. The perceived "Ph.D. glut" fails to take into account disciplinary differences and the difference between people who prepare exclusively for employment in research universities and those who opt to work in research and development in the private sector and the K-12 or undergraduate sector. The issue here is that the Ph.D. in some academic science disciplines is too narrowly focused. This is not true for engineering, where there is no "Ph.D. glut".

Continuing Education

Non-credit post-secondary education and especially non-credit post baccalaureate education represent a critical and underreported element of California's science and technology workforce development capabilities. The data reveal large, annual enrollments in UC Extension, CSU Extended Studies and California Community Colleges courses. There are also an increasing number of private and for-profit educational institutions specializing in continuing education. A significant fraction of these students are taking courses or completing certificate programs that are directly relevant to science and technology fields and competencies.

Key findings of the Critical Path Analysis for continuing education:

- **Continuing education providers play a vital and often unrecognized role in qualifying generally educated students with industry specific skills.**
- **Typically these programs reflect local industry workforce needs but are not tracked sufficiently at the state level.**
- **State programs do not sufficiently support continuing education.**
- **There is a significant lack of regional demographic data on the effects of continuing education on the science and technology workforce.**

Enrollments in UC and CSU continuing education programs can dwarf regular full-time enrollments on the same campus. Unduplicated head counts for extension and continuing education programs are unavailable due to current reporting practices at the campus level. Nevertheless, the number of working adults participating in extension and continuing education training programs on an annual basis is enormous. In FY1999-2000, combined degree enrollments at UC and CSU exceeded 520,000 while their combined extension enrollments exceeded 700,000. More dramatically, UC Extension enrollments are four times larger than regular UC full-time enrollments.

Enrollments in non-degree oriented, post-secondary and post-baccalaureate education and training appear to reflect the regional character of industrial clusters, in particular science and technology clusters.

Workforce Immigration

One tangible indicator of the tightness in the science and technology sector is the increasing reliance of California employers on the H-1B visa program. The H-1B visa program allows a skilled foreign person to work for a maximum of six years in the United States. The H-1B visa holder must be in a "specialty occupation" – one that requires both the theoretical and practical application of a body of highly specialized knowledge and attainment of a baccalaureate's degree or higher in the specialized field. Evidence suggests that this influx of immigrants, both from abroad and elsewhere in the country, has been crucial in filling high-tech jobs in California and that California is a net importer of technical talent.

Key findings of the Critical Path Analysis for workforce immigration:

- **California employers hire foreign-born workers as a solution to shortages of skilled domestic workers.**
- **Individuals with graduate degrees receive a high percentage (41%) of H-1B visas, and the balance hold a B.S. or its equivalent.**
- **The rise in the use of foreign-born workers underscores the inability of the California education system to produce enough skilled labor.**

The H-1B visa system is a benefit to California since it provides elasticity to the labor supply. However, it does not substitute for the long-term development of the state's own people and resources through the education and training of Californians.

The Digital Divide

A complete picture of the ability of the state to produce a technically trained workforce is not complete without analyzing an individual's ability to access and use, in a meaningful way, computer and Internet-related technologies.

Key findings of the Critical Path Analysis for the digital divide:

- **Use of computers and the Internet is becoming a critical life skill.**
- **The digital divide is not just an issue of resources; it is also an issue of training.**
- **California's high number of under-qualified teachers, especially in low-performing schools, severely impacts the effectiveness of placing computers in the classroom.**

Raw access is not the same as appropriately guided instruction; few would expect student performance to improve by dropping a pile of books into a classroom with no further instruction, yet this is essentially what has happened at local schools when computers are plugged in. Those without the skills to use the Internet effectively run the risk of becoming a new underclass, without the practical ability to access and/or use many of our society's online resources.

Conclusions

California is faced with a critical public policy challenge. Our own citizens are not being prepared in adequate numbers for important, challenging – and well-paid – science and technology jobs in the state's new economy. In the long run, this threatens to put at risk California's ability to compete in the global economy. Given the state's leading role in the technology sector, it will also jeopardize our national prosperity and security. Our continued way of life as a free, democratic society may well depend on how well we address this critical challenge. As the U.S. Commission on National Security concluded in 2001:

> *"Education is the foundation of America's future. Quality education in the humanities and social sciences is essential in a world made increasingly "smaller" by advances in communication and in global commerce. But education in science, mathematics, and engineering has special relevance for the future of U.S. national security, for America's ability to lead depends particularly on the depth and breadth of its scientific and technical communities."* [8]

[8] *The United States Commission on National Security for the 21st Century 2001*, p.39.

The challenge to the state is heightened by the fact that the state's emerging new majority (Latino, African American and Native American) is traditionally underrepresented in its colleges and universities and especially in S&E fields of study (and related careers). Absent concerted and collaborative effort by the segments of the state's educational system (K-doctoral), with the support of the state government, the numbers of students who participate in S&E programs is likely to continue to decline.

Policies must therefore be developed to support a comprehensive state education strategy to significantly increase participation by Californians in the S&T workforce, through pursuit of the following overarching goals:

GOAL 1 Increase student participation and success in mathematics, science, and technology subjects at all levels from kindergarten through the doctoral level. To achieve this goal, priority should be given to: (a) expanding student awareness of S&T career opportunities available through study of science, mathematics, and technology; (b) educating a new generation of science, mathematics, and technology teachers and faculty and ensuring that all schools and institutions of higher education are staffed by qualified teachers and faculty; and (c) propagating effective pedagogical models, with the ability to excite and engage students in the study of science, mathematics, and technology.

GOAL 2 Achieve targeted increases in college and university S&E program enrollments, degrees, and quality indicators, at the associate, baccalaureate, master's, and doctoral levels, through comprehensive, collaborative, focused and sustained efforts by the community colleges, UC, CSU, and Independent university sectors to plan for, implement, and evaluate S&E programs. This includes leveraging federal and private support for public and private institutions as well as state support, and encouraging industry sector-specific initiatives that seek to vertically integrate public-private investments in education with the workforce needs of industry.

GOAL 3 Overcome the resource adequacy problems related to the maintenance and expansion of higher cost college and university science and engineering programs in public institutions.

GOAL 4 Expand the state's capacity to gather data on and plan for the varieties of institutions and programs addressing California's S&E continuing education and training needs.

To achieve these strategic goals, it is recommended that the state of California and its educational segments consider a number of specific objectives and actions, as follows:

K-12 Recommendations:

1. **Allocate additional resources to low-performing schools to strengthen quality of teaching and increase educational/career counseling. For example:**

   - To bring more talented, dedicated teachers to these schools, encourage school districts and teachers' unions to remove first-right-of-transfer clauses from collective bargaining agreements.
   - Offer further financial incentives to experienced teachers who agree to teach in low-performing schools through increasing salary bonuses and non-salary bonuses such as tax-relief, housing subsidies and so on. Local districts and teachers' unions could further enhance this through appropriate modification of their local bargaining agreements.
   - Provide grants for establishing programs for S&T education targeted at schools and community institutions in areas with significant underserved populations. These could be after-school programs based in community technology centers (such as the federal program through the U.S. Department of Education) which highlight access and learning with technology, and focus on mathematics and science topics.
   - Establish a regionally based "local mentors" database program that could function like the NetDay website did (posting California school needs and providing sign-up and logistical support for local companies who would like to help meet their needs).

2. **Work to improve the quality of California's reading, science, mathematics, and technology teaching. For example:**

   - Make it a top priority to attract and retain more qualified mathematics, science, and technology teachers, as recommended by both the Glenn Commission and the U.S. Commission on National Security for the 21st Century.
   - Explore additional targeted incentives to encourage prospective teachers to choose mathematics, science, and technology disciplines (e.g. training grants, signing bonuses, differential salary scales for S&T disciplines, etc.).
   - Maintain and strengthen efforts to update science, mathematics, and technology curricula and pedagogical strategies – and to provide opportunities for ongoing teacher professional development.

3. **Develop strategies to motivate students to fulfill the basic requirements necessary to enter college and pursue science, mathematics, and technology majors. For example:**

- Expand marketing and communication outreach programs, such as web-based materials and "life-course" simulations to make clear to counselors, teachers, parents, and especially students that mathematics, biology, physics, chemistry, and technical subjects provide background knowledge and skills that are necessary to pursue S&T careers.
- Because the majority of students now entering the California K-12 system are from populations traditionally underrepresented in higher education and in all S&T fields, the state should develop culturally specific strategies to increase the mathematics and science capabilities of these populations and increase their future consideration of S&T careers. Special emphasis should be given to parent outreach.
- Expand support for the Middle College High School Program and related programs, which currently exist at a very small pilot level in California.
- Align the 11th grade California Standards test with collegiate placement tests; juniors who do not meet the performance levels would then be able to focus their senior year on targeted remediation.
- Consider a "bounty" incentive award program for high schools that demonstrably increase their production of S&T discipline college majors.

4. **Develop strategies to increase student access to effective academic and career counseling. For example:**
    - Develop tracking tools that can take the role of counselors, such as a more automated and accessible decision-making support system. For example, the state could provide infrastructure and locally customizable web-based and/or mail 'report cards' for providing regular updates on students' progress toward required a-g requirements for college.

Community College Recommendations:

1. **Give greater priority to expansion of S&T enrollments and degrees in the allocation of incremental new state operating and capital budget funds.**
2. **Increase cooperation of community colleges with high schools.**
    - Expand partnerships such as the Middle College High School program, which allow easy transitions between the two.
3. **Increase transfer numbers in the S&T areas.**
    - Encourage similar programs to the "Partnership for Excellence."
    - Encourage community college students to select science and technology options during the first two years in preparation for transfer.

4. **Strengthen collaboration with four-year institutions.**

   - Permit community college students to enroll concurrently in lower division science and engineering major courses when not readily available in the community colleges.

5. **Promote high-end articulation efforts such as the following programs:**

   - ASSIST [9]
   - CAN (California Articulation Numbering system) [10]
   - IMPAC (Inter-segmental Major Preparation Articulated Curriculum) [11]

6. **Increase opportunities for part-time degree study in the state's universities to cope with community college transfer students who are working full and part-time.**

7. **Develop differential salary scales for S&T faculty that reflect the marketplace for these skills.**

Baccalaureate Recommendations:

1. **Achieve targeted increases in the number of S&E degrees.**

   - Address the significant attrition rate in S&E enrollments, particularly at CSU.
   - Increasing enrollment, lowering attrition and increasing degree completion should be a greater priority in the allocation of incremental new state operating and capital budget funds and in the universities' strategic plans.
   - Strengthen diagnostic testing and expand the role of community colleges to include offering remedial instruction to students when needed, especially in the CSU system.
   - More scholarships should be considered to achieve specific increases in the number of students statewide who receive undergraduate degrees in engineering, computer science, mathematics, and the physical sciences.

2. **Develop more appropriate funding and budget allocation strategies for the S&E programs in the CSU and the community colleges.**

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[9] ASSIST is an online student-transfer information system that provides up-to-date information on course transferring between post-secondary institutions (www.assist.org, accessed 1/10/02).

[10] CAN is a cross-reference course identification system for many lower division, transferable courses (www.cansystem.org, accessed 1/10/02).

[11] IMPAC is a program funding regional and state-wide faculty discussions to ensure that students transferring from the community colleges to UC and CSU are prepared for work in their chosen major (www.cal-impac.org, accessed 1/10/02).

- This will help attract and retain the faculty necessary for instruction in S&E programs, equip and maintain the instructional laboratories and provide the necessary instructional technical support staff.
- In developing these funding and budget allocation strategies, recognize the differing programmatic/disciplinary mixes of campuses.

3. **Continue to expand higher education outreach, teacher education and professional development initiatives.**
   - Sustain and strengthen college and university outreach programs that promote student awareness of science and engineering study and career opportunities.
   - Develop targeted programs with those high schools that send the UC, CSU and Independent institutions the most students in need of remediation.
   - To ensure quality instruction in science and mathematics, strengthen science and mathematics teacher training and professional development programs.
4. **Provide the research-related start-up costs (for laboratories, etc.) associated with hiring of new and replacement faculty.**
   - This will help both the UC and CSU systems remain competitive in attracting and retaining faculty in science and engineering. No funding currently exists to achieve this.
5. **Improve counseling availability and guidance for students to appropriately plan course sequences.**
6. **Recognize and support the pivotal role of the community college system for transfer students.**
   - Increase collaboration with the UC and CSU (e.g., by facilitating concurrent enrollment by California Community College S&E students in lower division courses at UC and CSU campuses, where those courses are not readily available at area community colleges).
7. **Improve alignment of K-12 learning outcomes with university placement assessment expectations.**
   - Align what is taught with what is tested.
8. **Encourage the federal government to raise caps on Pell Grants, and further increase the state's own Cal Grant program.**[12]

[12] Pell Grants are a form of federal financial aid available to undergraduates; they are awarded based on financial need (http://www.pellgrantsonline.ed.gov/ accessed 3/5/02). Cal Grants are a form of state financial aid available to undergraduates awarded based on financial need and academic performance (http://www.csac.ca.gov accessed 3/5/02).

Master's Recommendations:

1. **Encourage more California students to pursue graduate education to the master's level.**

    - Initiate a Cal Grant type of program for students pursuing a master's degree in science or engineering.
    - Explore a two year post-graduate entry degree in S&E along the lines of the MBA.

2. **Increase graduate enrollment rates for students who entered university as community college transfers.**

    - Develop more support for those who continue their education beyond the baccalaureate in S&E fields.

3. **Expand terminal/professional master's degree options within UC and CSU, and encourage same in the Independent institutions.**

4. **Encourage closer connection to industry in graduate training programs.**

    - Create graduate training programs in areas such as bio-informatics and manufacturing engineering, where private sector demand for graduates is high, or programs that involve new types of training, such as internships in private firms.

Doctoral Recommendations:

1. **Encourage more California students to pursue graduate education to the Ph.D. level.**

    - Support the adoption of the six key recommendations from the recent UC Commission on Graduate Education and Support.[13] These include increasing the annual level of fellowship stipends; creating a program of repayable fellowships; incentive grants; industry-university internships; and more funding for non-resident graduate students. The Commission also recommends fundraising for a new graduate fellowships endowment.
    - Initiate a Cal Grant type of program to provide funding for students pursuing a doctoral degree in science or engineering.

[13] University of California Office of the President, Committee on Educational Policy Discussion Item 308, *Report of the Commission on the Growth and Support of Graduate Education*, September 13, 2001, page 1.

2. **Improve doctoral completion rates for underrepresented populations.**
    - The demographic shift increasing the percentage of Latinos and other underrepresented students in the state has not been reflected in the number of Ph.D.'s awarded.

3. **Improve preparation for Ph.D.'s to enter industry in fields such as biological sciences and physics, for example, through programs involving industrial internships.**

Continuing Education Recommendations:

1. **Assign a state entity to comprehensively analyze the continuing education system.**
    - Centralize responsibility for gathering data on the varieties of institutions and programs addressing the science and technology continuing education and training needs of the state to an entity within the state of California.

2. **Reassess the state's role in continuing education.**
    - Direct the state to address such issues as what role it should play in providing access to these programs. Document the results and ensure that these programs adequately meet the training needs of the state's high-tech workforce.

3. **Encourage industry to expand support for employee participation in continuing education.**

CHAPTER 1 - INTRODUCTION

California is the nation's leading science and technology state. Science and technology are the reason for California's leadership in agriculture, aerospace and defense, electronics, computers, software, movie production, multimedia entertainment, biotechnology, medical devices, environmental technologies, and telecommunications. This leadership provides jobs, sustains a high standard of living, and offers innumerable other benefits to California residents.

To better understand how the state should respond to the changing technology environment, the California Council on Science and Technology (CCST) two years ago conducted a comprehensive evaluation of California's high-tech infrastructure. *The California Report on the Environment for Science and Technology* (CREST) analyzed the state's science and technology infrastructure to determine if California has the people, capital investment and necessary state policies to maintain California's leadership in the face of increasing worldwide competition.

THERE IS A WIDENING "GAP" BETWEEN THE STATE'S WORKFORCE NEEDS AND THE EDUCATIONAL SYSTEM'S ABILITY TO RESPOND.

A major finding of the CREST report was that the California labor market for science and engineering workers is increasingly tight and that California's educational system is not producing the science and engineering graduates needed to meet industry's growing requirement for skilled workers. There is a widening "gap" between the state's workforce needs and the educational system's ability to respond. Although California science and engineering labor market demand thus far has been addressed by recruiting skilled labor from other states and nations, California's ability to produce science and engineering graduates for high-skill/high-wage technology sector jobs will be critical to the state's long-term ability to remain a global high-tech leader. It will be critical to the internal social stability of our increasingly diverse state. Ultimately, it will be critical to the security of our nation, with its growing dependence on science and technology.[14]

California is not alone in facing this science and engineering workforce gap. A number of recent reports have called attention to the growing nationwide gap between the labor market demand for science and engineering workers and the capacity of the educational system to graduate students in relevant fields.

For over a decade, the National Science Foundation has documented problems in the educational "pipeline" leading to further study in science and engineering. While rates of K-12 student participation in mathematics and science have increased in recent years, international comparisons of mathematics and science achievement, such as the 1995 "Third International Mathematics and Science Study" (TIMSS), suggest that although our youngest students are competitive internationally, the per-

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[14] *Road Map for National Security: Imperative for Change, the Phase III Report of the U.S. Commission on National Security for the 21st Century*, February 15, 2001, p. 9.

formance of our middle school (8th grade) students lags behind their international peers in mathematics, and high school (12th grade) students score below their peers in both mathematics and science.[15] At the college level, the need for remediation in mathematics and science remains high nationwide, even among science and engineering majors.[16] Nationwide, from 1986 to 1996 the number of baccalaureate graduates in engineering declined by 18% and the number in mathematics and computer science by 36%.[17] Today, Asia and Europe each produce more science and engineering baccalaureate-equivalent degrees than does all of North America; and growth rates in science and engineering degrees remain positive in these regions, but they continue to decline in the United States.[18]

The National Science and Technology Council (NSTC) released a report in April 2000, *Ensuring a Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century*. It warned that a significant proportion of the country's population growth will occur among ethnic groups presently underrepresented in science and engineering programs – and groups whose members graduate from college at lower rates. Its principal conclusion was that it is in the national interest to increase the rate of college attendance and participation of all ethnic and gender groups if a strong S&T workforce is to be ensured.

The workforce gap is also emerging as a major national security concern. The January 2001 final report of the U.S. Commission on National Security for the 21st Century warned that the strength of the U.S. economy is the basis of American national security and that "the nation is on the verge of a downward spiral" of increasing shortages of professionals and teachers. Unless these "negative educational trends" are reversed, according to this report, the United States will lose its position of global leadership within 25 years.[19]

Evidence indicates that the shortage of science and engineering graduates is a relatively recent phenomenon. The United States has enjoyed rapid technological progress throughout the 20th century that drove unprecedented growth in outputs and standards of living. Many scholars and policymakers believe that the American educational system fostered this progress, providing an essential flow of people trained in the scientific method and in the state of the art in their area of specialization.

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15 *National Science Board, Science & Engineering Indicators – 2000*, p. 5-18.
16 *National Science Board, Science & Engineering Indicators – 2000*, p. 4-13.
17 *National Science Board, Science & Engineering Indicators – 2000*, Appendix Table 4-17.
18 *National Science Board, Science & Engineering Indicators – 2000*, Figure 4-12.
19 *Road Map for National Security*, pp. 40-41.

Currently, a number of government programs attempt to help meet the demand for scientists and engineers. To succeed, however, they depend on a positive supply response that the educational system seems incapable of providing. The total quantity of scientists and engineers has not been affected, and the skilled workforce shortage remains. We are still failing to capture the interest of our youth to develop proficiencies with scientific, mathematical, and technological concepts and skills.

Importing skilled foreign labor is a short-term solution. It does not absolve our schools and university systems from the responsibility to educate our children.

The nation has long been an importer of skilled labor. Since the Hart-Cellar Act in 1965, which allowed immigration based on the possession of scarce skills, tens of thousands of engineers and scientists immigrated to the nation's high-tech areas. In the Silicon Valley area today the foreign-born population in the area is nearly 350,000.[20] Our ability to engage foreign science and engineering workers in productive roles is a strength of our country. However, the importation of skilled foreign labor is a short-term solution. It does not absolve our schools and university systems from the responsibility to educate our children so that they can take full advantage of the high-skill/high-wage job opportunities in the high-tech economy.

As the CREST report demonstrated, and as this report documents further, the science and engineering workforce gap is a problem of particularly critical significance for the state of California. Given the state's heavy dependence on science and technology, given its extraordinary and rapidly increasing diversity, and given serious weaknesses in its educational system, California faces special challenges, if it is to sustain its position as a global leader in high-technology.

This report presents a critical path analysis for the production of a science and technology workforce in industries key to maintaining California's economic vitality. In this context, we define our critical path analysis as a complete examination of the entire California educational system, from kindergarten through graduate school, designed to assess the current status of the system and determine why more students are not receiving S&E degrees. Data from multiple sources are presented on the trends in science and engineering education at the K-12, associate's, baccalaureate, master's, and doctoral level, taking into account population growth, demographics and changes in California's employment. These data are then used to create a critical path model from which policy makers can have insight into factors that influence and control inputs, outputs, and linking mechanisms throughout the state's education system.

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[20] AnnaLee Saxenian, *Silicon Valley's New Immigrant Entrepreneurs* (San Francisco: PPIC, 1999), p.10.

The project goals are to:

- Develop a common set of baseline workforce indicators;
- Define and quantify the workforce gap by examining the current trends in supply and demand;
- Identify factors that influence the shortfall; and
- Suggest how to increase the supply of science and technology workers.

1.1 The Science and Engineering Workforce Supply Gap

The Critical Path Analysis argues that there is a growing science and engineering workforce gap. The magnitude and nature of this gap is the subject of much uncertainty and disagreement. While this report sheds additional light on this matter and concludes that the gap is real, we acknowledge that the debate will continue and that the effort to predict future labor market demand with certainty remains fraught with difficulties.

What is clear is that the California educational system has steadily fallen behind in the production of science and engineering graduates over the past two decades. Outstanding jobs in California's high-tech sector are going to graduates from other states and countries. Our dependence on the importation of skilled workers will place us at a growing disadvantage in a global economy in which there is increasing competition for skilled labor.

Many studies have pointed to the decrease in the number of graduates with science and engineering degrees as evidence that supply is not responding to the growth in demand. While California's population increased approximately 10% between 1990 and 2000, and the number of associate's and baccalaureate degrees awarded increased overall by approximately 20%, the number of degrees produced in engineering, computer science, physical science, and mathematics have declined or stagnated.

Despite the recent alarms sounded, very little research has been devoted to understanding the waning production of degrees in these fields.

1.2 What Factors Affect the Gap?

This report considers specific factors affecting the workforce gap in California, which include:

- Changing state demographics and the challenge of making science and engineering studies accessible to diverse populations lacking a tradition of college attendance and involvement in science and mathematics;
- Lack of mathematics and science preparation in middle and high schools;

- Lack of qualified mathematics and science teachers;
- Lack of understanding of science and engineering career opportunities and lack of motivation or interest to enter college level science and engineering programs;[21, 22]
- Lack of applicable mathematics and science background for science or engineering programs;[23]
- Decrease of community college transfers into four-year science and engineering programs;[24]
- Budget realities within the state's public universities, which constrain and limit the ability of university science and engineering programs to respond to industry and student demand; and
- Inadequate partnerships with industry initiatives.

Outstanding jobs in California's high-tech sector are going to graduates from other states and countries.

A rapidly changing technology base usually means a rapidly changing set of skill requirements for workers. Because technology changes, career paths in growth areas such as information technology, manufacturing engineering, and biotech tend to be nonlinear.[25] In the traditional linear career path, a prospective worker begins training through formal education, then gets a job in his or her field of concentration and works his or her way through the ranks. In the nonlinear model, workers move between education and work throughout their careers. To succeed in this new model, workers need strong basic skills and opportunities for lifelong learning. The state's public K-12 system is not providing this strong basic skill set to enough students and its higher education institutions may not be adapting to these dynamic needs rapidly enough.

1.3 What Can be Done to Address the Problems?

California already has some mechanisms for expanding student participation in S&T careers and related courses of study. The state government, schools, academia, and industry have taken steps to expand existing programs and

[21] A survey of high school students in Silicon Valley found that even in the high-tech capital of the world there was a low awareness of careers in high-tech and a lack of interest in mathematics and science. (A. T. Kearney, *Silicon Valley Joint Venture Workforce Initiative Study: Findings and Recommendations,* May 18, 1999).

[22] There is a special need for outreach programs to increase interest in these fields for African Americans, Latinos and women of all ethnicities. All three groups continue to be under represented in science and technology fields of study (*National Science Board, Science & Engineering Indicators - 2000*, Figure 3-12).

[23] The lack of mathematics proficiency means that there are fewer students prepared to enter training and certificate programs for jobs such as electronic technicians and fewer students prepared to major in mathematics, science and engineering fields in college.

[24] For much of the population, higher education begins at a local community college. There are approximately 1.6 million students attending the California Community College system. However, only a small number are destined to receive a science or technology based degree or certification and a very small number are destined to go to a four-year institution (see chapter 6, section 6.1).

[25] Peter Freeman and William Aspray, *The Supply of Information Technology Workers in the United States*, Washington, DC: Computing Research Association, 1999.

create new programs. For example, the outreach programs of UC and CSU and the Independent academic institutions are expanding, as are the teacher education programs for science and mathematics. Industry is also responding to the challenge with a variety of mentoring programs guiding students from high school through college and beyond. For example, the Boeing Corporation has partnered with the School of Aviation Research in Buena Park Vista High School, providing volunteers and mentors to help students chart career paths and keep them engaged in the field of aviation.[26] In addition, the Semiconductor Industry Association has initiated programs to help teachers attract students into technology careers. New partnerships are also growing between the schools and industry such as the Center for Advanced Research and Technology in Fresno.[27]

The effectiveness of these and other existing programs must be recognized and given appropriate weight in developing recommendations for expanding and strengthening participation by California students in science, mathematics, and engineering programs.

In a larger sense, though, the science and engineering workforce gap is a problem for the state of California that has gone largely unrecognized at the highest levels of government. Industries have responded to the tight labor market by recruiting high-tech workers from other states and by advocating stop-gap solutions – most notably the H-1B visa program. Higher education has only begun to acknowledge the challenge and to consider comprehensive strategic enrollment and program planning/budgeting solutions. And despite recent increases in funding, the K-12 public education system lacks the organizational and resource strategies required to prepare a new generation of increasingly diverse students for further study and employment in science and engineering fields.

The CCST Critical Path Analysis documents the need for a more comprehensive, systematic approach to the science and engineering workforce gap. All along the educational pipeline, from kindergarten through graduate school and beyond, concerted effort is required to expand and strengthen student participation in science, mathematics and engineering. Industry, state government, and each of the educational segments have critical roles to play. And greater cooperation among them is urgently needed. This cooperation could be greatly enhanced by coupling public sector supported efforts to industry sector-specific initiatives. California's economic future, social stability – and even our domestic security – depend upon our ability to meet this critical societal challenge.

[26] http://buenapark.seniorhigh.net, accessed 4/2/02.
[27] http://www.cart.org, accessed 4/2/02.

CHAPTER 2 - CRITICAL PATH ANALYSIS FOR WORKFORCE PRODUCTION

A critical path analysis process is often used for project planning and management processes. In this context, we define our critical path analysis as an examination of each component of the California educational system, from kindergarten through graduate school, designed to assess the status of the system, identify strengths and weaknesses, and find the bottlenecks in the educational pipeline that are preventing more young Californians from obtaining college degrees.

2.1 Components of the CCST Critical Path Analysis

In order to conduct this project, over a period of a year, many education, industry and government groups and individual experts were consulted. Research papers were also prepared by principal investigators. To initiate this project, CCST held two forums. The first was an education workshop at Stanford University on July 27, 2000. At the meeting, a prototype critical path description for the production of engineers was developed. This framework was used in the project. A second forum on the Digital Divide was also held at Stanford University on December 9, 2000. At this forum, the impact of computers and the Internet was explored. Forum topics included: (1) Measuring the effectiveness of providing computers to elementary schools; (2) Universal telecommunications service; and (3) Providing equal access to computers and the Internet to all citizens.

Selected publications from these two forums compose part of the Critical Path Analysis report. In addition, six principal investigators and CCST researchers have conducted six individual research projects. Two of the projects update workforce and education data initially developed for CREST (California Report on the Environment for Science and Technology).[28] Descriptions of the six projects follow.

2.2 Research Project Descriptions

Project 1: The Science and Technology Sector's Demand for Workers

Principal Investigator: Cecilia A. Conrad, Associate Professor of Economics, Pomona College

Project Summary: This project investigates the demand for skilled labor in the science and technology sector in California. Updating the CREST report, the study examines employment trends. In addition, it broadens the analysis to include science and technology educators and provides descriptive data on the

[28] California Council on Science and Technology, *California Report on the Environment for Science and Technology*, November 1999.

demographic composition of the current workforce. A limitation of the CREST report was its reliance on broad occupational categories, (e.g., computer programmers). This study collects more detailed information on skills required by employers and identifies employer demand for more narrowly defined occupational categories. It also analyzes the demand for training programs, including their costs to workers and employers.

Project 2: A Critical Path Analysis of California's K-12 Sector

Principal Investigator: Julian Betts, Professor of Economics, University of California, San Diego

Project Summary: This project provides a detailed portrait of California's public schools from an input-output perspective. It compares resources being put into California schools and other states and examines resource issues within the state of California, such as distribution across the state and teacher quality (mathematics and science). In addition to tracking the student attrition rate in high school, the report looks at several other criteria for evaluating student success. Does inequality in resources reduce the chance of some students attending college? What reforms would be most likely to increase the number of high school students who go on to attend California universities? This report seeks to address these questions by looking at the evidence of the link between school resources and student achievement, and discussing what the policy implications are for California's schools.

Project 3: The Role of Universities and Colleges in California

Principal Investigators: Lynne Zucker, Professor of Sociology and Policy Studies, University of California, Los Angeles and Michael Darby, Professor of Money and Financial Markets, University of California, Los Angeles

Project Summary: This project provides a view of higher education in California and a set of analyses using several different data sets that look at higher education over time. The project investigates four-year educational institutions, focusing on S&T relevant areas and graduate education to the extent that data permit. It provides descriptive information on the number of students at different degree levels, and ethnic and gender breakdowns. Descriptive information on output includes graduation rates for undergraduates (for NCAA schools only), the number of students graduating with specific advanced degrees in S&T relevant areas, and ethnic and gender breakdowns. This project collects aggregate data on all fields of study in California's colleges and universities. Data are collected on the quality of undergraduate and graduate education. Comparisons to other high-technology states (New York and Massachusetts) are made for some selected pathways where data are available.

Project 4: Issues Impacting Baccalaureate Degrees in Science and Engineering

Principal Investigators: CCST researchers with assistance from the University of California, California State University, and the Association of Independent California Colleges and Universities

Project Summary: The other five projects described here shed light on many aspects of the educational process. However, it is clear that this project is missing some important data that are not available from data sources principal investigators are using. Therefore, in addition to the other projects conducted for the Critical Path Analysis study, CCST looks at a range of issues specific to the state's universities and colleges and assesses their impact on the production of baccalaureate degrees in science and engineering. These issues include application and enrollment trends in science and engineering programs; rates of retention/graduation of science and engineering students; and impediments to student success and progress to receiving a degree.

Project 5: Alternative Paths to Competency: Continuing Education And Lifelong Learning

Principal Investigators: Mary Walshok, Associate Vice Chancellor for Public Programs, University of California, San Diego and Carolyn Lee, Coordinator of Public Programs, Extended Studies and Public Programs, University of California, San Diego

Project Summary: The purpose of this research effort is to document the little understood education and training resources available to California's technology workforce through non-degree programs such as UC's Extension divisions, CSU's Colleges of Extended Studies and the California Community College System's community service programs. All three institutions provide thousands of adult students with education and training relevant to the skills required in the new knowledge-based companies developing in the state of California. This research begins to document the size and range of these programs throughout the state by reporting on overall enrollments in all three systems, and in particular, in science and technology-related professional education and training programs. Further analysis of two regional areas describes in more depth the curriculum areas in which these technology-related certificate and education programs are developing and the extent to which education and training are being sponsored by private sector payees.

Project 6: Bridging the Digital Divide

Editor: Roger G. Noll, Morris M. Doyle Professor of Public Policy in the Department of Economics, Stanford University

Project Summary: California leads the nation in technology innovation and the growth of new high-tech industries. However, there is a growing gulf between the technological haves and have-nots. This digital divide affects the great majority of children within California's schools, and is impinging on the state's ability to produce a technologically competent workforce. This complex problem was the focus of a roundtable discussion presented at a forum co-sponsored by Hitachi and CCST at Stanford University on December 9, 2000. Components of the forum are used in this publication. It consists of four papers which address the definition of the digital divide; universal service; technology and K-12 learning; and policy options.

CHAPTER 3 - IMPORTANCE OF HIGH TECH AND DEMAND FOR S&T WORKERS

The National Science and Technology Council found in its April 2000 report that science, technology, and engineering (ST&E) workers are essential contributors to both the national private and public sectors. In the private sector, they help propel many parts of the industrial economy and provide valuable services, such as healthcare. In the public sector, ST&E workers support important federal missions, such as maintaining a strong U.S. science and engineering enterprise and advancing biomedical research, national defense, environmental protection, energy conservation efficiency, food supply safety, and space exploration.[29]

3.1 Science and Technology Sector in the California Economy

California's share of total U.S. employment has hovered near 11% for the past 20 years while its share of U.S. science and technology employment has ranged from 15-18% over the same period. High-tech jobs represent approximately 11.4%[30] of total employment in the state, making it the second largest California

Table 3.1 High-tech jobs, 2000, United States and California

Industry	All U.S. Jobs	All California Jobs	All California % of U.S.
Pharmaceuticals	305,200	39,600	12.98%
Computer Manufacturing	363,200	95,000	26.16%
Communications Equipment	270,800	42,000	15.51%
Electronic Components	667,000	163,200	24.47%
Aircraft & Missiles	546,900	96,500	17.64%
Scientific Instruments	846,600	178,600	21.10%
Communications	1,612,000	195,800	12.15%
Computer Programming	1,941,200	370,600	19.09%
Engineering & Management Services	3,413,200	468,700	13.73%
Total of High Tech Shown Here	9,966,100	1,650,000	16.56%
Total Private Nonfarm Jobs	131,418,000	14,518,600	11.05%
High Tech As % of Total Private Nonfarm Jobs	7.58%	11.36%	

Source: http://www.bls.gov/sahome.html, via links for "National Employment, Hours, and Earnings," and "State and Area Employment, Hours, and Earnings," retrieved 3/20/01-3/28/01

economic sector (after retail trade) and larger than the third and fourth sectors (wholesale trade and transportation) combined.

High-tech jobs require a highly skilled workforce. Forty-one percent of jobs in California S&T industries require a baccalaureate degree or higher; for 23% of those, a baccalaureate degree or higher in a science and engineering field is preferred. Jobs that require an associate's degree account for another 5% of

[29] National Science and Technology Council, *Ensuring a Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century*, April 2000, p.4.

[30] U.S. Bureau of Labor Statistics, March 2001.

employment. Even jobs with lower degree requirements demand an understanding of mathematics and scientific methods. Although some skills may be acquired through a variety of post-secondary education experiences, others require specific technical training and certification. California's science and technology sector employs a large number of workers. As can be seen in Table 3.1, high-tech industries account for a much larger share of all jobs in California than they do across the U.S. This means that these sectors are more prominent within the California economy than they are nationwide. What is more, these sectors provide a source of high-income jobs essential to supporting California's tax base. The most recent economic census data show high-tech wages in California average over $73,500 per worker, compared to an average payroll of approximately $37,300 for all other private non-farm industries.

As Figure 3.1 shows, between 1995 and 1999 total S&T job growth was significantly higher than growth in all non-farm jobs in California. Despite

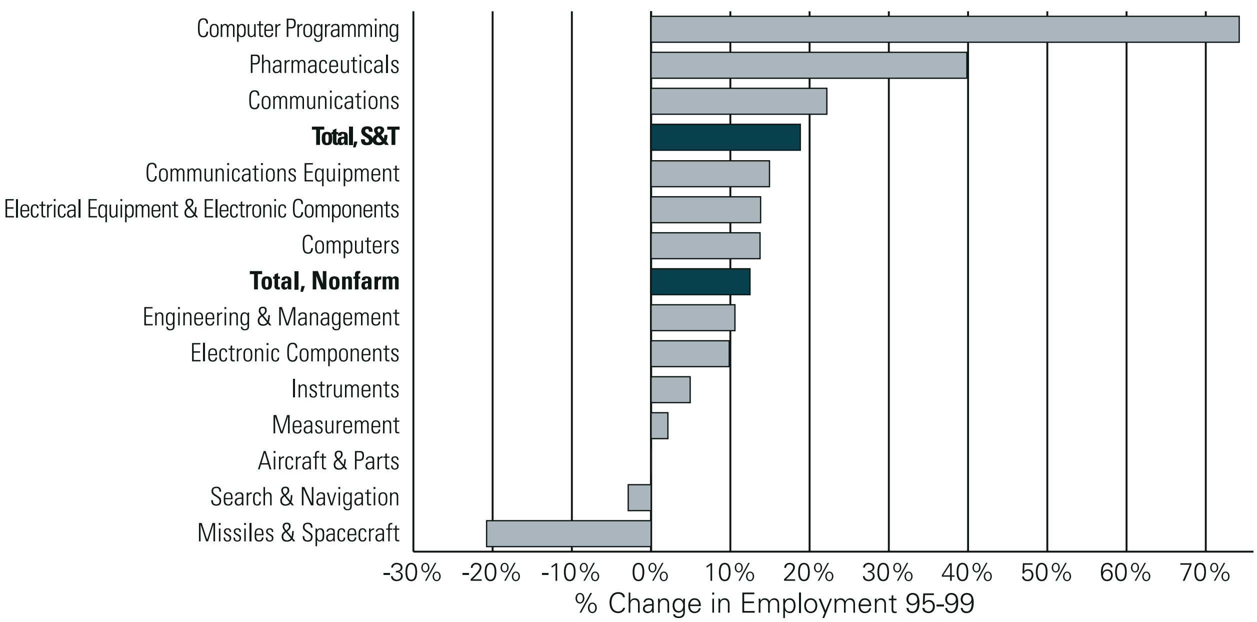
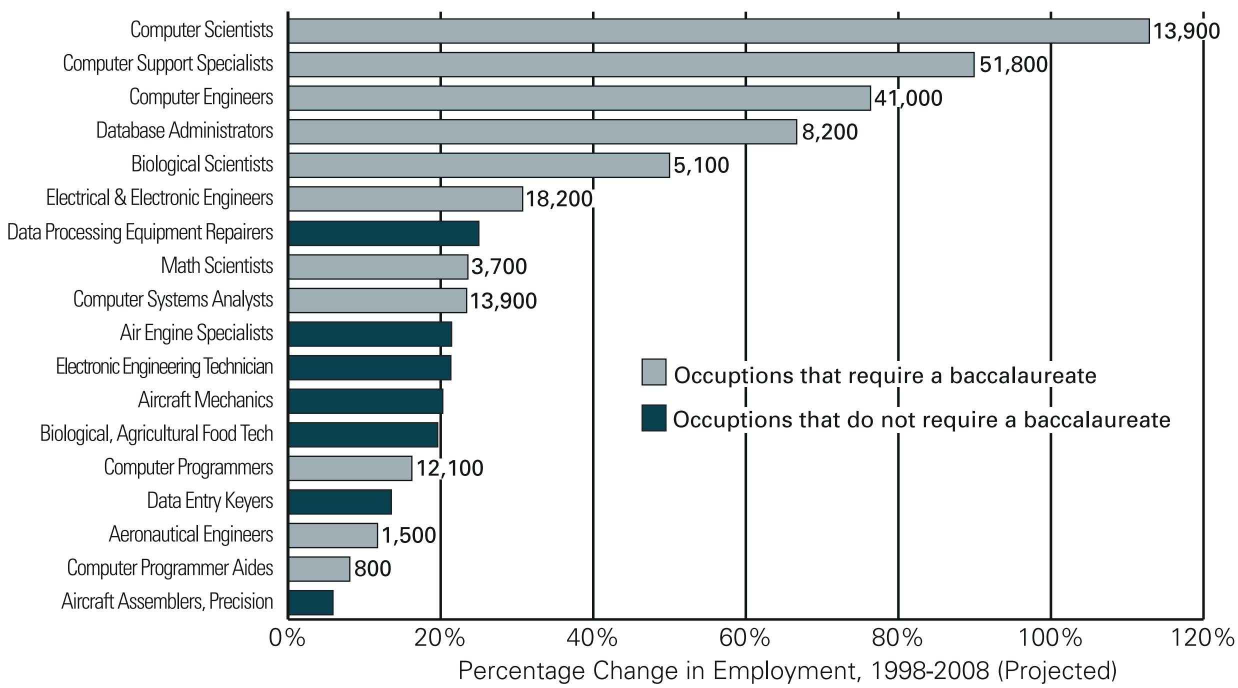


Figure 3.1: California job growth between 1995 and 1999 for selected industries
Source: State of California, EDD

the recent economic slow down in the high-tech sector, demand for science and technology workers is likely to remain strong. Conservative estimates presented in Figure 3.2 suggest a continued increase in California's high-tech employment of 193,000 workers between 1998 and 2008 in occupations requiring baccalaureate degrees, and an increase of 24,000 in occupations requiring associate's degrees.

Most of the employment growth in California's science and technology sector will come from jobs that require a baccalaureate degree or higher in a science or engineering field. Although complaints of shortages of skilled labor have receded for the moment thanks to a slight decrease (about 2%) in some high-tech industries in 2001, these complaints are unlikely to disappear. For a worker with those skills, the science and technology sector offers employment at high wages. A worker without these basic skills will find his or her employment prospects in this sector extremely limited.[31]

HIGH-TECH INDUSTRIES ACCOUNT FOR A MUCH LARGER SHARE OF ALL JOBS IN CALIFORNIA THAN THEY DO IN THE U.S.



Note: Numbers refer to total number of jobs predicted to be created over a 10 year period.

Figure 3.2: Growth in selected high-tech occupations in California between 1998 and 2008

Source: State of California, EDD

Partly fueling this high-tech job growth is venture capital. Venture capital (VC) funds directed to California are large and have a significant effect on industry growth. From 1995 to 2001 over $97 billion in VC funding has come to California. Although there were significant decreases in VC funding during 2001, by the 4th quarter, it was again increasing and California's share of total U.S. VC funding has remained fairly constant at approximately 40%.[32]

[31] Cecilia A. Conrad, *California's Demand for a Science and Technology Workforce*, CCST, June 7, 2001.

[32] *MoneyTree Survey, Investments by Region 1995-2001,* www.pwcglobal.com, accessed 4/2/02.

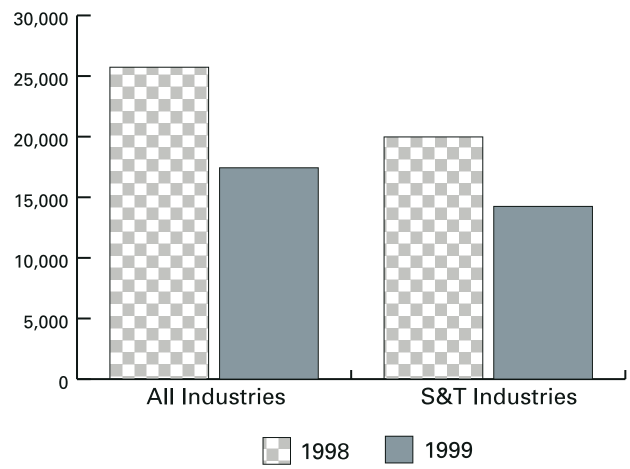


Figure 3.3: Workforce gap, vacancies requiring baccalaureate degrees, all industries & S&T industries, 1998 & 1999
Source: Conrad, 2002

3.2 Demographics of Science and Technology Labor Market

By several indicators, African American, Latinos, and women of all races are underrepresented in the science and technology workforce. On the supply side, African Americans and Latinos have lower rates of college completion than white or Asian American men. White women have rates of college completion similar to those of white men, but women, as a group, are less likely to major in science and engineering fields other than social science. On the demand side, employers may have different perceptions of the skills of these groups either because of lack of information or prejudice, alternatively these workers may not be part of employers' recruitment networks. These demand side obstacles may lead to lower earnings or higher rates of unemployment, holding skills constant, and, in the longer term, may reduce the flow of minority and women workers into the industry.

> **Since it takes many years to train a scientist or engineer, we must invest now to guarantee that the S&T workforce for the future reflects the ethnic and gender distribution in the state.**

The present underrepresentation of these groups in the science and technology workforce, combined with their rapid emergence as a new majority in California, creates the potential for the science and engineering workforce gap to continue to grow, with significant negative consequences for the state and nation, if effective policies, programs and resources are not put into place. Since it takes many years to train a scientist or engineer, we must invest now to guarantee that the S&T workforce for the future reflects the ethnic and gender distribution in the state. In fact, the National Science and Technology Council concluded that it is in the national interest to "vigorously pursue the development of domestic ST&E workers from all ethnic and gender groups." [33]

[33] National Science and Technology Council, *Ensuring a Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century*, April 2000, p.5.

Moreover, the broader economic and social consequences which could arise from not bringing more women and minorities into the ST&E workforce need to be considered.

3.3 Worker Training Issues

The accessibility of training resources for experienced workers affects the dynamics of the science and technology workforce. Potential impediments include lack of supply, imperfect information about program quality, and lack of financing.

Many science and technology employers appear to be willing to invest in training that develops skills which are portable among employers. This is curious because in a competitive labor market employers should prefer to invest in firm-specific training, but not more general training which would enhance an employee's performance at any future job. Firm-specific training increases a worker's productivity at his current employer, but loses value when the worker changes jobs. Lee and Walshok[34] report that two-thirds of the students in extension courses at University of California at San Diego received some employer subsidy, and over half received 100% funding.

The existence of these employer subsidies, together with the popularity of H-1B visa programs, suggests a slow response of labor supply to changes in demand. It is reasonable to expect that employers will continue to pursue such short-term measures as additional training and H-1B immigrant labor where the workforce gap remains.

3.4 Workforce Gap Measurement

There are different measures of the gap in supply and demand of an S&T workforce, but all suggest a serious problem. The Information Technology Association of America (ITAA) recently assessed the workforce gap in IT in 2001 at 116,505 jobs in the Western region of the U.S., and a nationwide gap of over 425,000 jobs.[35] This does represent a drop from 2000, but as the study asserts, "skilled IT workers are still both in demand and in short supply."

A more targeted estimate of the workforce gap in California estimates a shortfall of over 14,000 workers with baccalaureate degrees in S&E (Figure 3.3). In other words, approximately 14,000 jobs requiring these degrees went unfilled. While this is an improvement over 1998 numbers, it remains extremely serious given the fact that fewer than 20,000 S&E graduates are produced each year. The number of S&E baccalaureates produced in California would need to increase by nearly 70% to make up for this shortfall.

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[34] Carolyn W.B. Lee and Mary L. Walshok, *Critical Path Analysis of California's S&T Education System: Alternative Paths to Competency Through Continuing Education and Lifelong Learning*, CCST, May 2001, p. 26.

[35] Information Technology Association of America, *When Can You Start? Building Better Information Technology Skills and Careers*, 2001, pp.13-14.

CRITICAL PATH OF DEMAND FOR S&T WORKERS

- **High-tech industry is a crucial and growing component of the California economy and will be for the foreseeable future.**
- **California is not producing sufficient skilled labor to meet demand. There is a particularly acute shortage of women and minorities in the S&T workforce.**
- **Hiring foreign-born workers fails to address the structural problem and cannot be relied on as a long-term solution.**

CHAPTER 4 - WORKFORCE SUPPLY

The Critical Path Analysis divides the high-tech workforce production process into six sub segments. These include the public elementary and middle schools (grades K-8) and the high schools (grades 9-12); the California Community Colleges; baccalaureate degree production at public and private institutions; graduate degree production (M.S. and Ph.D., at public and private institutions); and continuing education. The highlights given in this document are largely drawn from the six detailed reports prepared for this study.

Figure 4.1 is a highly simplified flow diagram of the overall process. The diamonds indicate the institution where the student or worker is pursuing an educational goal while the dashed boxes identify what the person is pursuing while at that institution. Each institution also represents a decision point in a person's life.

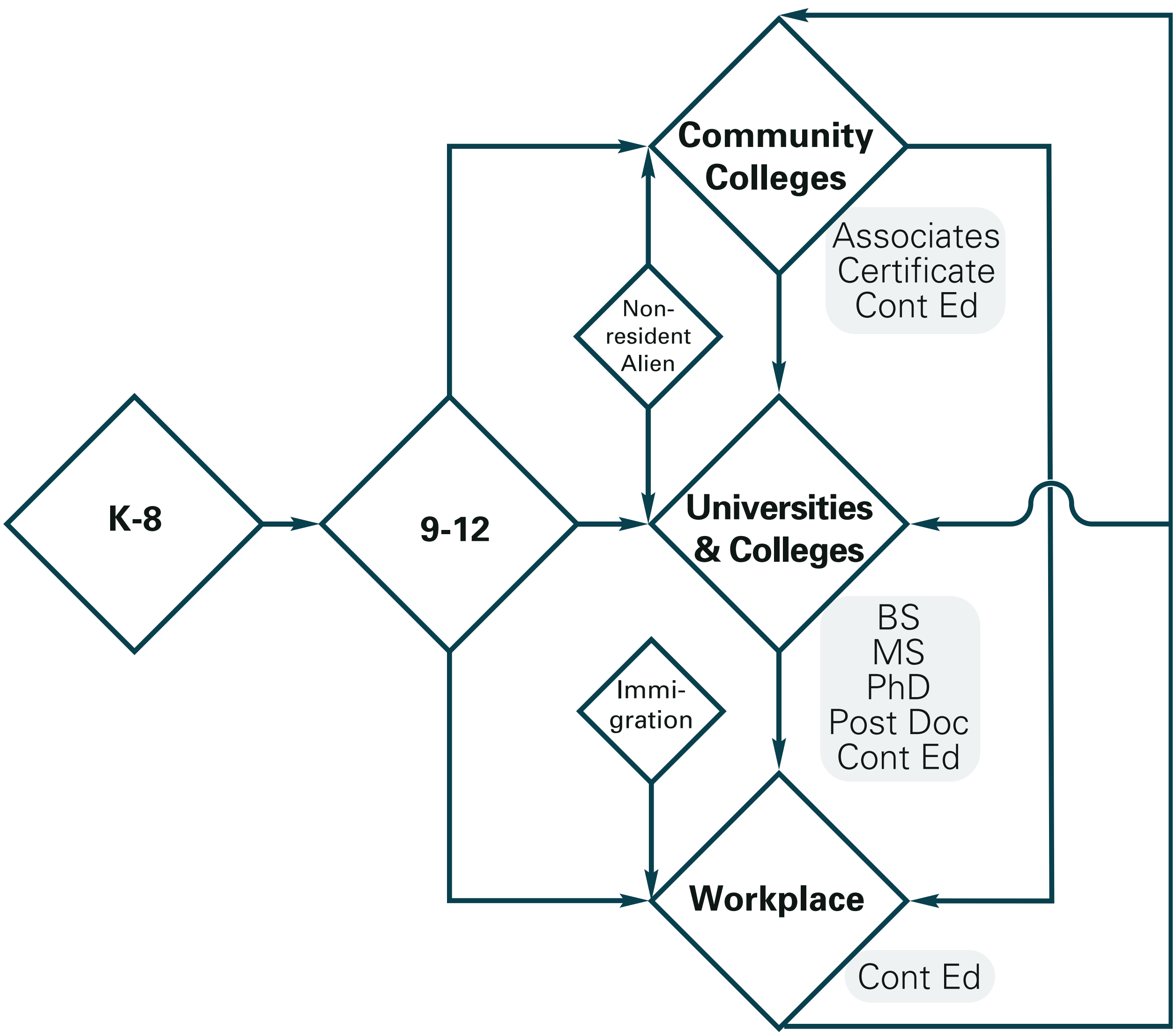

Figure 4.1: High-tech workforce production process flow diagram

This report examines the flow of students through the education system. It is important to note that by taking this integrated, systems approach it becomes readily evident that changing the parameters affecting one part of the system affects the student flow at a later stage.

CHAPTER 5 - K-12 PROCESS

The academic preparation K-12 students receive, especially in mathematics, science, and reading, is critical to their ability to enter the S&T workforce or pursue further study in S&E fields. Although the K-12 public education system has received considerable attention in recent years, evidence suggests that significant problems remain in the preparation students receive at this level.

Data in this integrated report are presented for the total K-12 system. It should be noted that the state funding for grades K-8 and 9-12 are somewhat different and that teacher preparation for teaching in high school is different than for lower grades. Therefore, the flow of students in the K-12 segment is broken down into two stages.

5.1 Relationships

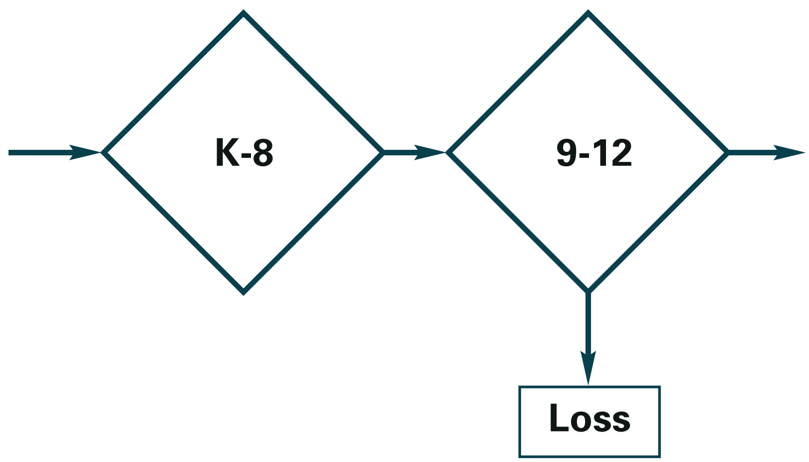

Figure 5.1: Flow of students from K-8 through high school

5.2 Quantity

In 2000, there were over 6 million students enrolled in the K-12 system, an increase of over 22% since 1990. There has also been a significant demographic shift over the past 10 years. Latino students have increased as a proportion of the total student population, while white students have declined and other groups have remained relatively steady. Latino students are now the single largest ethnic group in the school system, with 43% of high school enrollment (compared to 36% white) and nearly 50% of kindergarten enrollment (compared to just over 31% white).

> **Latino students are now the single largest ethnic group in the school system, with 43% of high school enrollment (compared to 36% white) and nearly 50% of kindergarten enrollment.**

The attrition rate between 9th grade enrollment and graduation has increased over the last decade. In the 1991-1992 school year, 79.6% of students enrolled in 9th grade three years earlier actually graduated. By 1999-2000, this number had sunk to 68.8% (Table 5.1). Because of a lack of data, we do not know for certain what happens to all these students; it is possible that many may have moved to other states before graduating, and others from immigrant families may have returned to their original country. Still, the fact that nearly a third of high school enrollees never graduate demands attention. For example, if we are losing these prospective high school graduates due to their need to earn low-income wages to support their families, a program that provides financial incentive to finish high school, and even guarantees S&T-related work if specific credentials are attained, could provide effective policy responses.

Table 5.1: Student attrition in high school

Enrollment and Graduates as % of Grade 9 Students Three Years Earlier [36]

Year	Grade 12 Enrollment	Graduates	Graduates Fulfilling a-f with Grade of C or Better
1991/1992	88.40%	79.60%	26.50%
1992/1993			
1993/1994			
1994/1995	82.60%	73.90%	23.90%
1995/1996	81.70%	73.10%	25.60%
1996/1997	81.00%	71.00%	25.30%
1997/1998	79.80%	68.70%	24.90%
1998/1999	81.30%	68.70%	25.10%
1999/2000	79.90%	68.80%	24.50%

Figure 5.2 shows the student enrollment in California's public high schools broken down by ethnicity. For simplicity, the ethnic groups are represented as White, Black, Latino and "Other" (including American Indian, Asian, Filipino, Mixed and Pacific Islander). Data are represented for 1990, 2000 and projections from the California Department of Finance for 2010. Figure 5.3 shows similar data for graduation rates. The data show that the total number of students enrolled in high school is increasing from 5,865,000 to 6,106,000 (approximately 10%) over the next decade. Most of this growth can be attributed to the increase in Latino student enrollment (from 2,481,000 in 2000 to 3,143,724 in 2010). However, the graduation rate for Latino students is only 57%; this means that the overall percentage of high school students who graduate is likely to decline even further.

The fact that a third of high school enrollees never graduate demands attention. The graduation rate is even worse for Latino enrollees, 43% of whom do not graduate.

[36] Julian R. Betts, *A Critical Path Analysis of California's K-12 Sector, CCST,* April 2001. Note that the a-f requirements (courses needed to qualify for college admission) have been redesignated the a-g requirements.

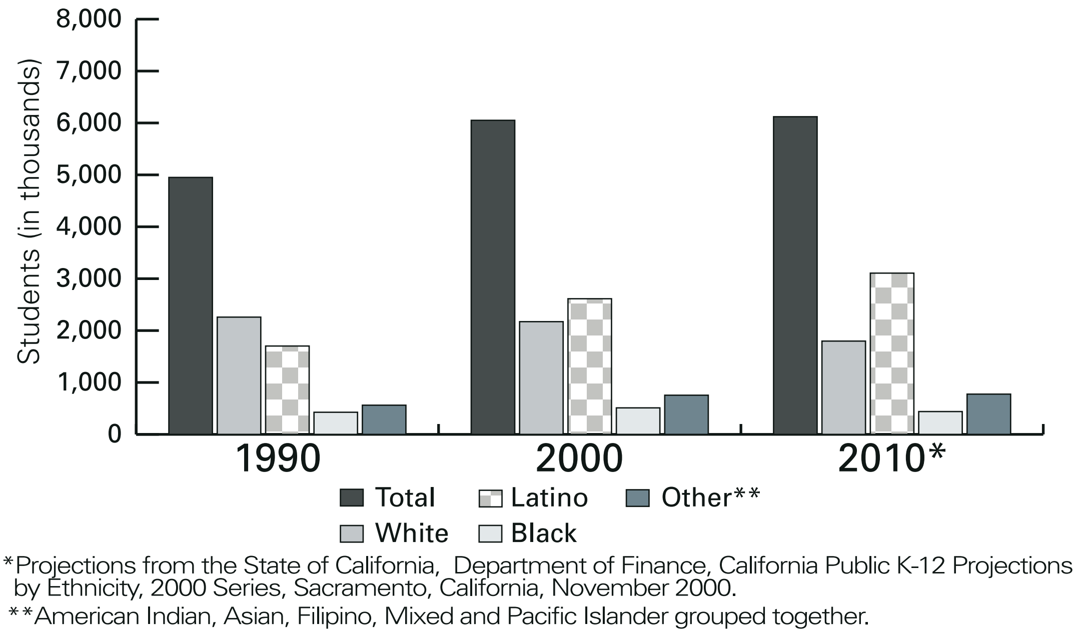

Figure 5.2: Enrollment in California public schools 1990, 2000 and projections for 2010

Source: CBEDS – California Basic Educational Data System, www.cde.ca.gov, accessed 8/17/01.

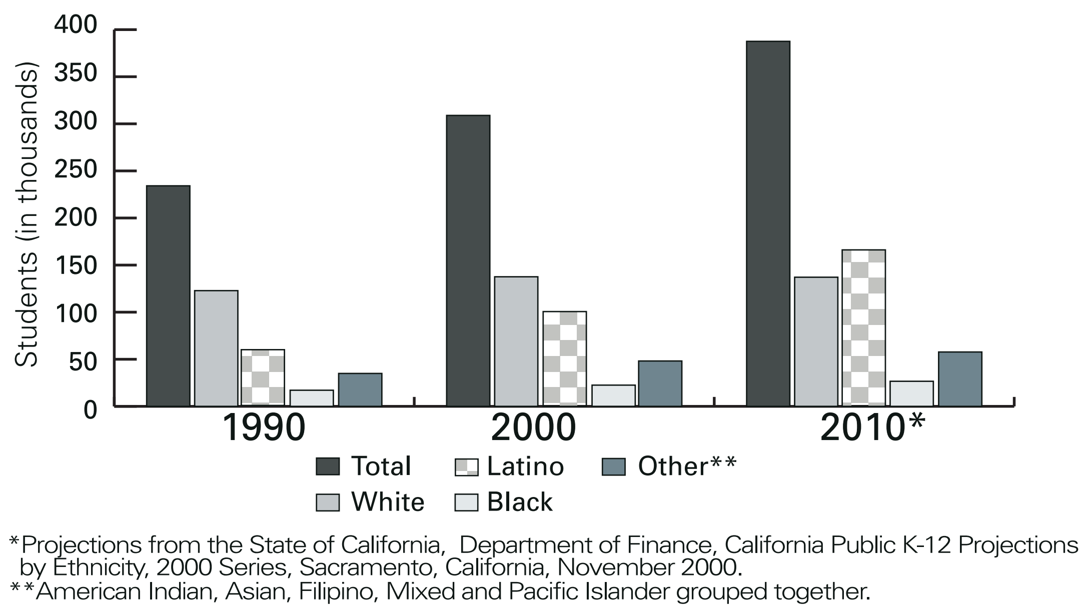

Figure 5.3: Graduation from California public high schools 1990, 2000 and projections for 2010

Source: CBEDS – California Basic Educational Data System, www.cde.ca.gov, accessed 8/17/01.

The above data pertain to students enrolled in school. There are of course students who do not graduate from high school who return, usually through the community college system, to complete their high school certificate. However, this does not make up for the fact that the high school graduation rate in California is quite low. In 1998, 80.1% of Californians between 18 and 24 had completed a high school diploma. This puts California behind other high-tech states including New York (81.5%) and Massachusetts (85.6%). In fact, California ranks 39th in the country.

Where do students who drop out of high school go? While obviously many join the workforce, one potentially significant factor affecting student attrition in high school is involvement with the criminal justice system. Although the California Youth Authority has just over 7,000 juveniles incarcerated, over 243,000 juveniles aged 11-17 were arrested in 2000. Even accounting for the fact that many are arrested multiple times, this reflects a significant percentage of the state's high school population. While most of these juveniles are either not charged or, if sentenced, placed on probation, the impact of being arrested on participation in school must be considered. To address these needs, in 1997 a new state agency, the California Education Authority, was formed specifically to administer a correctional school district capable of providing a high school education meeting state curriculum standards for incarcerated juveniles. This embryonic, but potentially very important system is still in the process of refining its curriculum.[37]

Despite the ongoing development of the California Education Authority curriculum, it must be remembered that it costs less to educate California's youth than it does to incarcerate them.

5.3 Quality

In California, poor student performance manifests itself as early as first grade. In fact, half of the variability in high school seniors' test scores corresponds to differences that were already apparent in first grade.[38]

In the K-8 segment, California students rate extremely poorly in science and mathematics compared to the nation. A recent assessment by the U.S. Department of Education rated California 4th and 8th grade students last in science proficiency among all 40 states participating in the 2000 study.[39] Mathematics ratings were not much better, with 4th and 8th grade California students ranked 34th and 32nd respectively.

[37] Department of the Youth Authority, California Education Authority, www.cya.ca.gov, accessed 4/2/02.

[38] Elizabeth Burr and Bruce Fuller, "Early Education and Family Poverty", *Crucial Issues in California Education 2000*, Policy Analysis for California Education 2000, p.9.

[39] U.S. Department of Education, Office of Educational Research and Improvement, National Center for Education Statistics. *The Nation's Report Card: State Science 2000, Report for California*, NCES 2002-453 CA, by C. Solomon, L. Jerry, and A. Lutkus. Washington, DC: 2001.

As we have already shown, in high school there is significant overall attrition. In addition, the number of students who go on to complete a-g course requirements with grades of C or better is low and has not improved in the past decade. Throughout the 1990s, this percentage hovered at approximately 35% of graduates. Given that not everyone graduates, only a quarter of students entering high school eventually graduate with the a-g requirements needed for college.

Only one in four high school students completes the basic university requirements.

Only one in 10 can start college without remediation after four years of high school.

Only one in 20 Latino students is ready to start college without remediation after four years of high school.

Even these students may not be well prepared to pursue baccalaureates. In 2000, over 45% of CSU freshmen failed the entrance test in mathematics and English.[40] While CSU is only part of the system, this statistic suggests that barely half the students completing their a-g requirements[41] are actually prepared for college. This would mean that of all students entering high school, just over 11% actually graduate with adequate skills in mathematics and English to begin college without remediation.

The numbers are even worse for Latinos, the newly dominant ethnic group in the K-12 system. Only 12% of Latino students entering high school graduate with the a-g requirements, and over 60% of Latino CSU freshmen failed the entrance tests in mathematics and English. Effectively, less than 5% of Latino high school students graduate with college-ready skills.

5.4 Resources

By 2001, California's per-pupil spending reached the national average for the first time in over a decade. This significant achievement is, however, only the first step in making up for years of relatively low spending. During most of the past ten years, school spending growth in California did not keep pace with the nation, largely due to limits on property tax revenues.[42] California's per-pupil spending lagged the national average from 15%-20% throughout the 1990s, despite the fact that real spending per pupil in California increased by just over 50% from 1970 to 1996. It will take time to make up for this legacy.

School spending in California lagged the nation for a decade.

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[40] Betts, Table 5.1

[41] These are a specific series of classes considered a prerequisite for admission to the University of California and the California State University. They include history, English, mathematics, laboratory science, foreign language, and college preparatory electives. A similar set of courses is required for admission to many private institutions, especially those that are highly selective.

[42] The reasons are complex, but include Proposition 13 (1979), which set strict limits on property taxes and the rate at which they were allowed to rise (Betts, p. 3).

California teachers are less well educated than the national average, and the percent of California teachers holding master's degrees or higher (40%) trails behind other high-tech states like Massachusetts (59%) and New York (75%). The ratio of pupils to teachers in California is 29% above the national average. The ratio of pupils to counselors in California by the late 1990s was more than twice as high as the nation as a whole. This raises serious questions about whether California's students are receiving good advice in course selection and career preparation, and could be partially responsible for the a-g course requirement weaknesses of students graduating from high school. California also has had four to six times as many students per librarian compared to the rest of the country, which raises questions about whether students are receiving adequate preparation and support in information search and retrieval. Disparities in resources and curriculum also arise among urban, suburban and rural schools, with suburban schools generally having the most resources and richest curriculum.

The ratio of pupils to counselors in California is over twice the national average. California also has four to six times as many students per librarian compared to the rest of the country.

However, the most critical resource shortage is investment in California's teachers. Over the past three decades they have come to earn up to 10% more than teachers in other states, but this is largely due to the higher cost of living in California. California's teachers are still not well paid compared to other workers with comparable qualifications. Nationwide, teachers earn 29% less than other workers with baccalaureates,[43] and for ensuring quality of preparedness, many teacher certification requirements now make a fifth undergraduate year compulsory. Even making 7-10% more than the average U.S. teacher, California teachers overall make almost 20% less than they could in other professions. In addition, there is no salary differential between science and mathematics teachers and other disciplines, despite the fact that average salaries for those with S&E degrees in the general workforce are higher than for other disciplines. In other words, while teacher's salaries compare poorly to the general workforce overall, they compare even more poorly in the crucial disciplines of science and mathematics.

The Committee on Science and Mathematics Teacher Preparation (CSMTP) found that studies conducted over the past quarter century increasingly point to a strong correlation between student achievement in K-12 science and mathematics and the quality of teachers in these subjects. Studies demonstrate that many teachers who teach in grades K-8 do not have sufficient content knowledge or adequate background for teaching science or mathematics. This is important because while there

[43] Glenn Commission, *Before it's too late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*, September 27, 2000, p.36

have been numerous recent initiatives to address the issue of teacher qualifications, the issue of relatively greater underqualification in these key subjects has not been adequately addressed. The 2000-01 budget, for instance, added $26 million to specifically support Reading and English Professional Development Institutes for K-12 teachers, but only $19.7 million for comparable mathematics programs.

Fourteen percent of all California's teachers are under-qualified (over 40,000) with emergency permits or waivers. Twenty-four percent of schools have 20% or more under-qualified teachers.

Increased demand for teachers has exacerbated growth in the number of under-qualified teachers. One factor driving demand up has been the mandated reduction in class size in K-3. While correlated with a very modest increase in student achievement,[44] the reductions in class size have helped bring about an increase in the number of uncertified teachers, particularly in disadvantaged schools as opposed to suburban schools (Figure 5.4). As detailed in the recent report from the Center for the Future of Teaching and Learning[45] overall, 14% of all California's teachers are under-qualified (over 40,000), with emergency permits or waivers. Twenty-four percent of schools have 20% or more under-

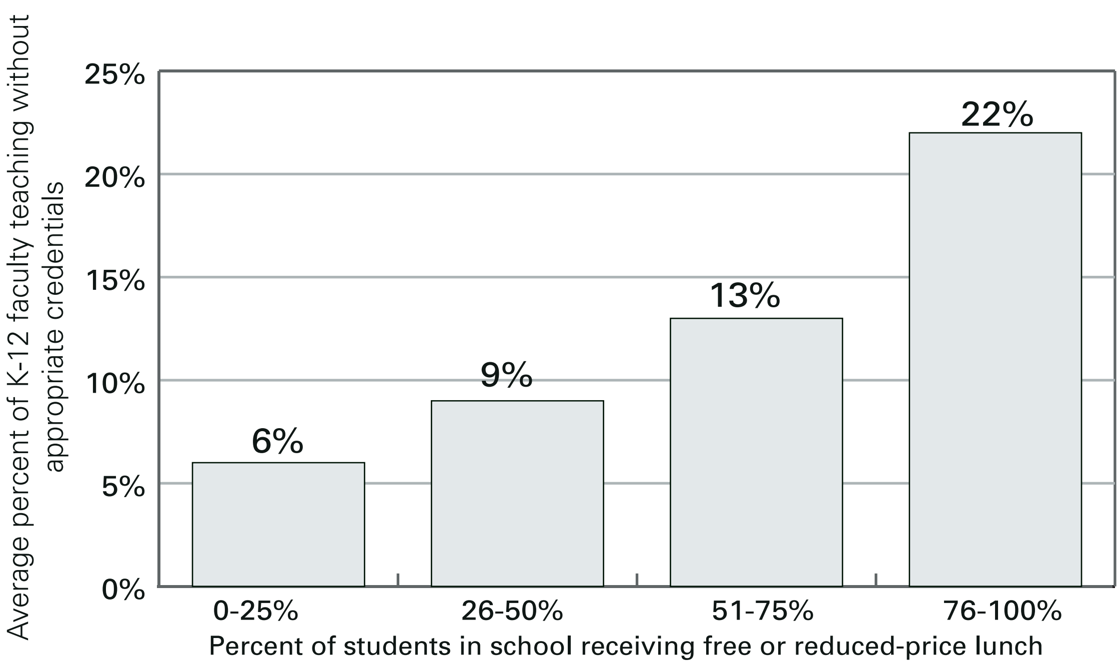

Figure 5.4: Under-qualified teachers and student's API scores, 1999-2000
Source: CDE (2000), API (2000), SRI analysis.

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44 Class Size Reduction Research Consortium, http:www.classize.org, accessed 3/12/02.

45 The Center for the Future of Teaching and Learning (CFTL), *The Status of the Teaching Profession 2001*, www.cftl.org, accessed 3/12/02.

46 Policy Analysis for California Education (PACE), *Crucial Issues in California Education 2000: Are the Reform Pieces Fitting Together?*

qualified teachers. This is critical since teachers' experience is the measure of school resources that most regularly has been found to be significantly and positively related to student achievement. Moreover, an examination of 60 studies found that spending money to increase teacher education was the most financially efficient way to boost student scores.[46]

CSU produces approximately half of the teachers in California. A 1998 resolution from the CSU Board of Trustees mandated improvements to its teacher education programs including better access; modified curricula; improved admission standards, made more consistent among CSU campuses; and increased collaboration with schools. By 2000, according to its annual report on teacher education, CSU had achieved these goals. One mark of success was increasing the number of teachers recommended for credentials by 25%. In addition, a $9 million increase was approved for the 2000-01 budget for CalTeach, a CSU-led teacher recruitment and referral center.[47]

At UC, which produces approximately 10% of the teachers in California, efforts to address the shortage of qualified S&T teachers in the 2000-01 budget included $8 million to establish professional development institutes for high school mathematics teachers (compared with $12 million for English teachers); $2.5 million to establish the California Algebra Institutes, and $7.5 million to initiate the Elementary Mathematics Professional Development Institutes, which are intended to provide training to approximately 5,000 teachers. The California Subject Matter Projects, of which mathematics and science are components, had an increase of $20 million, to a total of $35 million. As yet there is little data on the success of these initiatives.

UC, CSU and Independent colleges and universities also work directly with students via extensive and expanding outreach programs such as the UC MESA[48] (Mathematics, Engineering, Science Achievement) program. Although MESA is a successful program, the 21,000 students it serves annually represent a miniscule percentage of the 6 million students in the K-12 system. It is simply not large enough to make a substantial difference.

Other state initiatives in the 2000-01 budget include the Loaned Teacher Tax Credit, intended to encourage employers to "lend" employees to public schools to teach mathematics and science, and $5 million for the Mathematics and Science Challenge Grants, a matching grant program intended to support partnerships that increase the interest and performance of K-12 students.

5.5 Discussion

California high schools are not producing enough qualified graduates to meet the demand from industry and feed into the state's baccalaureate programs.

[47] *The California State University Teacher Education Annual Report, 1999-2000.*

[48] http://mesa.ucop.edu, accessed 11/5/01.

California spending per pupil lagged behind the rest of the country for years, its teachers are less highly educated than the national average and a significant number of teachers lack full appropriate credentials. Within the state, there is considerable inequality in resource allocation among schools (including teacher education, experience, credentials, class size) and achievement, e.g. course completion in the "a-g" courses required for admission to the University of California and the closely related courses required for admission to the California State University system or Independent universities, and completion of Advanced Placement exams that qualify students for college credit. Teacher salaries are not differentiated for science or mathematics, although baccalaureate recipients in S&E disciplines have more earning potential in the general market than other disciplines.

Students begin to fall far behind before they reach high school. To have a positive impact on the divergence in high school academic performance requires intervention in affected districts at the elementary and middle school level as well as at the high school level. Acquiring literacy by the 3rd grade and completing algebra in middle school are essential requirements for entering high school on a track leading to a science or engineering career. Literacy skills in particular represent a crucial skill bottleneck for under-performing students, and immediate attention needs to be brought to this issue.

However, while literacy and mathematics skills are essential, a strong science curriculum is also necessary. In part because the standardized tests currently used by California don't test it, science has been de-emphasized in many districts in recent years, particularly in elementary school.

It should be noted that there is an awareness and concern about these problems at the state level and steps have been initiated to begin to address them. The Public School Accountability Act (PSAA), for example, is a recent act of legislation that has the potential to alter the dynamics of resource allocation and inequality in student achievement in California in fundamental ways:

- The high profile of the state's Academic Performance Index (API), a component of the PSAA, has dramatically increased public awareness of inequalities in achievement across California schools.[49]
- The Immediate Intervention Underperforming Schools Program (II/U.S.P.), to a limited extent, devotes additional resources (grants) to improve student achievement at schools in need.[50]
- The new mathematics and science standards could motivate students to take a richer and more technical set of high school courses. As Rose and Betts

[49] http://api.cde.ca.gov/, accessed 1/16/02.

[50] http://www.cde.ca.gov/iiusp, accessed 1/16/02.

[51] Heather Rose and Julian Betts, *Math Matters: The Links Between High School Curriculum, College Graduation, and Earnings* (San Francisco: Public Policy Institute of California, 2001)

have observed, "math matters": taking higher level mathematics in high school (algebra and geometry) can lead to significantly higher chances that the student will later graduate with a baccalaureate degree.[51]

- Perhaps most important of all, the new state accountability system has the potential to increase the efficiency with which districts spend their resources.

The external pressures created by the new accountability system may well induce school systems to find innovative new programs to boost student achievement. Only time will tell, but the state may have taken the first steps to increase the number of students graduating from high school with the right set of courses to attend college. In the future, the API may include the planned high school exit examination, as well as graduation rates and attendance rates (at present, it is based solely on the Stanford 9 test results that are gathered as part of the Standardized Testing and Reporting (STAR) system).

CRITICAL PATH OF K-12 SYSTEM

- **The overall attrition rate in high school is too high (more than 30%). Of those who do graduate, too few have the a-g requirements needed for college (approximately a third). The shortfall in academic preparation is particularly acute in science and mathematics.**
- **The college participation rate will likely get worse over time due to a change in demographics. Latinos, African Americans and Native Americans have become a majority in K-12. Their rates of college participation remain low. Currently only approximately 5% of Latino 9th graders complete high school fully ready for college. To improve college participation rates, significant intervention is needed.**
- **California is experiencing a growing shortage of qualified teachers, especially in science and mathematics, and many schools have exceptionally inadequate support systems and resources (e.g., counselors and librarians) compared to the rest of the country.**
- **Improving teacher quality, particularly at low performing schools, is an important key to improving student performance.**
- **Teacher salaries are not competitive with the labor market, and are particularly uncompetitive in science and mathematics.**

However, despite the promise that these programs hold, there are no convincing measures of success yet. The extremely poor rating California students have received from the National Assessment of Educational Progress demonstrates that the new standards have not yet had any tangible impact on its K-8 students. Per-pupil spending is near the national average today, but lagged the national average by 15-20% for nearly a decade; it will take years to recover from this legacy. In addition, the concentration of under-qualified teachers in low-performing schools, together with the numbers of students in these schools, presents a problem whose solution is yet to be found.

5.6 Policy Options

There are no quick fixes. Additional spending can alleviate some of the current problems but there has been inadequate work to define the interrelationships between the magnitude of the different K-12 pipeline problems we have reviewed, the costs of different strategies for tackling them per student, and the probable success levels, or benefits, of each strategy.

According to Betts,[52] radical reallocations of resources would be needed if policymakers held firm to the goal of all students meeting rigorous standards. Betts' contention is based upon past research, which has shown that the impact of school resources on student achievement is small relative to existing variations in student performance, which appear strongly linked to the level of affluence in the local community. California would have to increase resources in disadvantaged schools well above the levels enjoyed by schools in more prosperous areas. While such dramatic steps are not likely to be undertaken in the near term, current research suggests that a number of policy options have the potential to yield positive results:

K-12 Recommendations:

1. **Allocate additional resources to low-performing schools to strengthen quality of teaching and increase educational/career counseling. For example:**

    - To bring more talented, dedicated teachers to these schools, encourage school districts and teachers' unions to remove first-right-of-transfer clauses from collective bargaining agreements.
    - Offer further financial incentives to experienced teachers who agree to teach in low-performing schools through increasing salary bonuses and non-salary bonuses such as tax-relief, housing subsidies and so on. Local districts and teachers' unions could further enhance this through appropriate modification of their local bargaining agreements.
    - Provide grants for establishing programs for S&T education targeted at schools and community institutions in areas with significant underserved populations. These could be after-school programs based in community technology centers (such as the federal program through the U.S. Department of Education) which highlight access and learning with technology, and focus on mathematics and science topics.
    - Establish a regionally based "local mentors" database program that could function like the NetDay website did (posting California school needs and providing sign-up and logistical support for local companies who would like to help meet their needs).

[52] Betts, p.30.

2. **Work to improve the quality of California's reading, science, mathematics, and technology teaching. For example:**

    - Make it a top priority to attract and retain more qualified mathematics, science, and technology teachers, as recommended by both the Glenn Commission and the U.S. Commission on National Security for the 21st Century.
    - Explore additional targeted incentives to encourage prospective teachers to choose mathematics, science, and technology disciplines (e.g., training grants, signing bonuses, differential salary scales for S&T disciplines, etc.).
    - Maintain and strengthen efforts to update science, mathematics, and technology curricula and pedagogical strategies – and to provide opportunities for ongoing teacher professional development.

3. **Develop strategies to motivate students to fulfill the basic requirements necessary to enter college and pursue science, mathematics, and technology majors. For example:**

    - Expand marketing and communication outreach programs, such as web-based materials and "life-course" simulations to make clear to counselors, teachers, parents, and especially students that mathematics, biology, physics, chemistry, and technical subjects provide background knowledge and skills that are necessary to pursue S&T careers.
    - Because the majority of students now entering the California K-12 system are from populations traditionally underrepresented in higher education and in all S&T fields, the state should develop culturally specific strategies to increase the mathematics and science capabilities of these populations and increase their future consideration of S&T careers. Special emphasis should be given to parent outreach.
    - Expand support for the Middle College High School Program and related programs, which currently exist at a very small pilot level in California.
    - Align the 11th grade California Standards test with collegiate placement tests; juniors who do not meet the performance levels would then be able to focus their senior year on targeted remediation.
    - Consider a "bounty" incentive award program for high schools that demonstrably increase their production of S&T discipline college majors.

4. **Develop strategies to increase student access to effective academic and career counseling. For example:**

    - Develop tracking tools that can take the role of counselors, such as a more automated and accessible decision-making support system. For example, the state could provide infrastructure and locally customizable web-based and/or mail 'report cards' for providing regular updates on students' progress toward required a-g requirements for college.

CHAPTER 6 - CALIFORNIA COMMUNITY COLLEGE PROCESS

California's community colleges are publicly supported and locally oriented colleges that offer a wide range of programs suited to the community they serve.

Community colleges offer many services in addition to their credit programs for transfer and for occupational certificates and associate's degrees. Those services include:

- Non-credit continuing education;
- Community service or fee-based education (student pays the fee, with no state subsidy); and
- Contract education, which is paid for by an employer and is typically provided at the workplace.

At any given moment, 11% of California's workforce is taking a course in a community college. The average age of a community college student is 27. Most students are working either part-time or full-time.

In the context of this report, community colleges are a crucial point of entry into higher education for many students because they provide programs for transfer to a four-year college, remedial or "catch-up" programs for students who lack a strong educational background, and continuing education for skills improvement. Moreover, the Master Plan for Higher Education mandates that 60% of UC and CSU students be at the Upper Division Level, with the community colleges expected to provide transfer students that make this ratio possible.[53]

COMMUNITY COLLEGES ARE A CRUCIAL POINT OF ENTRY INTO HIGHER EDUCATION, PARTICULARLY FOR THOSE STUDENTS WHO LACK A STRONG EDUCATIONAL BACKGROUND.

A community college is a good choice for a student who may want to attend a four-year school later but who is not yet academically, personally, or economically ready to begin study at a university. In a community college, students can choose to work toward an associate's (two-year) degree; complete a one- or two-year or certificate or degree program in a choice of occupational fields, various health professions, and/or high-technology job fields; or complete requirements to transfer to a college or university to complete a baccalaureate degree.

6.1 Relationships

Community colleges are where we can begin to track students specifically enrolling in S&T programs. For this study, we consider S&T to encompass subjects including computer & information sciences; engineering; biological sciences; mathematics; and physical sciences. We recognize the many functions of the

[53] Liaison Committee of the Regents of the University of California and the California State Board of Education, *A master plan for higher education in California, 1960-1975*. Assembly of the State of California (1960).

community college system, but for the purposes of this study we have focused on students who graduate with a qualification in an S&T subject or who eventually transfer to four-year colleges (transfer students). Figure 6.1 documents the flow of students through the community college system.

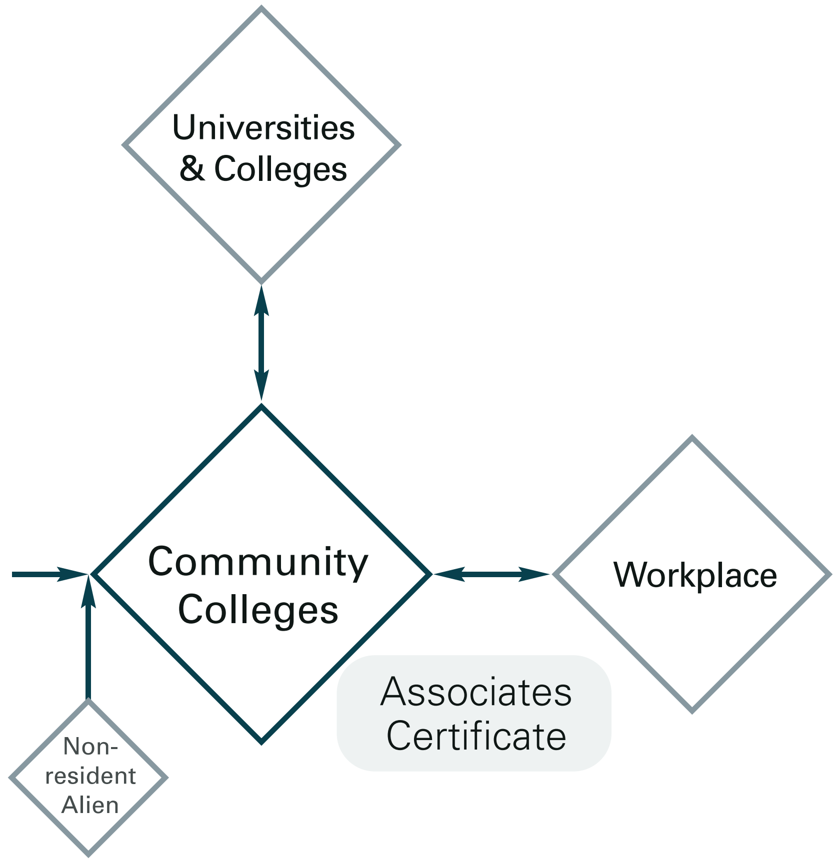

Figure 6.1: California Community College flow diagram

6.2 Quantity

In fall 2000 there were approximately 1.6 million students enrolled in the California Community College System (Figure 6.2). However, in 2000 only a small number, approximately 91,000, received an associate's degree or certificate and just under 6,000 completed an S&E related program.

> **California Community Colleges science and technology graduates account for just 6% of the associate's degrees and certificates awarded in 2000.**

Net community college fall enrollment has increased by 16% since 1995 with Latino enrollment rising most, from 15% to 26% while white enrollment dropped the most, 53% to 40% (Figure 6.3). The number of associate's degrees awarded in 2000 was up 69% over 1990 awards and 27% over the 1995 awards. However, very few of these degrees are in S&E. Only 6% of the 2000 community college graduates were in S&E, down from 12% in 1990. It is worth noting that funding is directly related to prior year enrollment and that the state is at risk of repeating the pattern of the early 1990s, when enrollment was forced down sharply due to funding decreases.

A large number of new students enroll in California's community colleges each year – over 360,000 in 2000, plus an additional 195,000 who transferred into community college from other institutions of higher education. Approximately

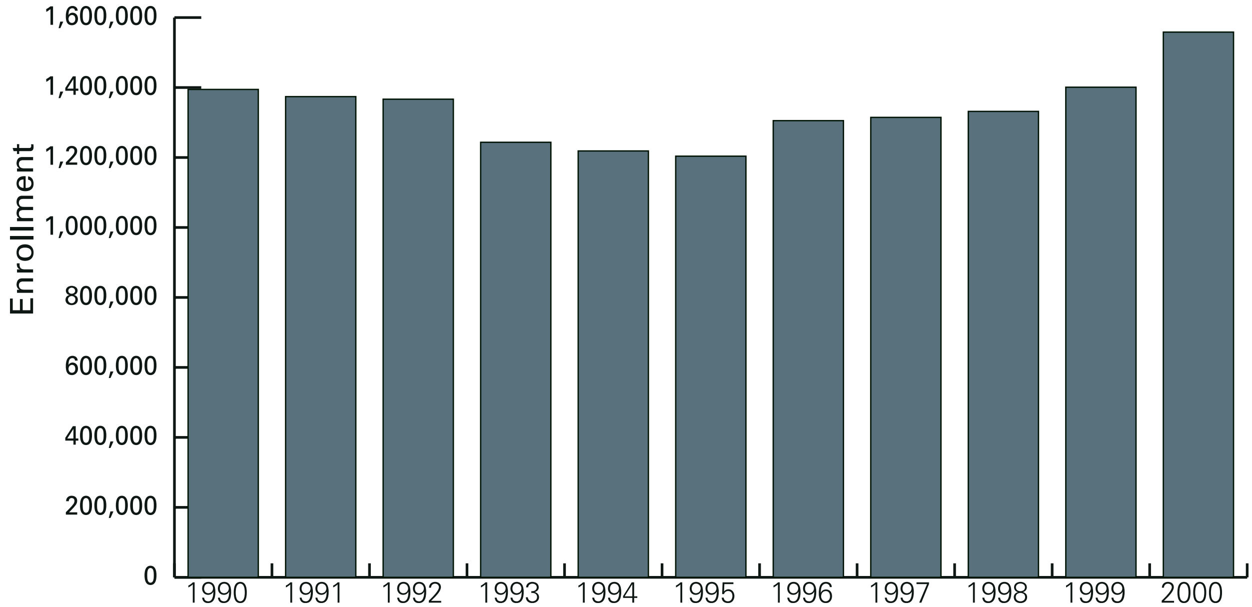

Figure 6.2: California Community College fall enrollment, 1990-2000

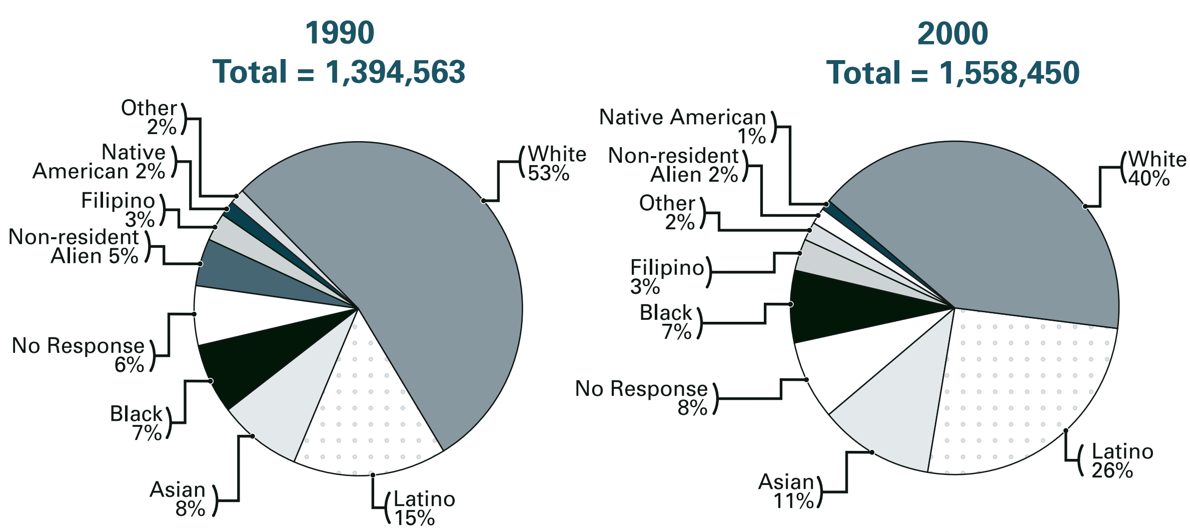

Figure 6.3: California Community Colleges: enrollment by ethnicity

Source: CPEC, www.cpec.ca.gov, accessed 8/17/01.

Table 6.1: Full year transfer student totals, 1989-90 and 1998-99

TOTAL (transfers to all 4-year institutions)			
1989-90 Transfers	59,492	1998-99 Transfers	57,912
CSU			
1989-90 Transfers	45,713	1998-99 Transfers	44,989
1990 Degrees Awarded	24,822	1999 Degrees Awarded	33,051
UC			
1989-90 Transfers	8,164	1998-99 Transfers	10,161
1990 Degrees Awarded	5,548	1999 Degrees Awarded	9,600
Independent institutions			
1989-90 Transfers	5,615	1998-99 Transfers	2,762
(No degree data available)			

Source: Student Profiles, 2000, CPEC, November 2000 and CPEC www.cpec.ca.gov, accessed 8/22/01.
Most recent full-year figures available.

93,000 of the new students entered the community college system directly from high school.

Transfer rates are critical. The percentage of first generation college goers for transfer students is nearly twice that for freshmen.

Despite the fact that enrollments have grown and the number of associate's degree graduates has increased overall, full year transfers to UC or CSU and Independent universities and colleges in California declined by more than 2.6%, from 59,492 in 1989-1990 to 57,912 in 1998-1999 (Table 6.1). However, data on transfers to UC and CSU for the 1999-2000 year show a reversal of this trend with an increase of close to 6%. Importantly, it is evident that once a student has transferred into the four-year college, they do well. Baccalaureate degrees awarded to transfer students have increased by 40% since 1990.

Transfer students are critical, as the community college has become the first point of entry to the university system for an increasingly large number of students in the state.

The transfer student population's demographic profiles involving gender, ethnicity, home location, and disciplinary area are all similar to the freshman profile. It is notable, however, that a study at University of California at San

Diego,[54] found the percentage of first generation college status for the transfer student to be nearly twice that for the freshman student.

A 1993 Community College Cohort Study provides insights about the transfer student population, including S&E transfers. Only 26% of the 1993 total cohort composed of 352,150 students completed a program of study. This share is comprised of 3.95% who transferred to UC, 11.81% who transferred to CSU, and 9.81% who graduated with an associate's degree or certificate.[55] The study also makes it clear that transferring from the community college system to a four-year institution is, for most, a four-year process, not two. The length of time needed by most transfer students to prepare to enter a four-year college at the junior level is largely due to two factors. First, 80% of community college students are working to support themselves – 40% are working full time. Second, many need remedial coursework at the community college.

Of every 10 transfers:

Six attend a CSU campus
Two attend a UC campus
One attends a Independent university in California
One attends an out-of-state university
Of the 10, 2 go on for further study in an S&E discipline

Although data are limited on students who transfer to Independent colleges, the total is relatively small compared to the public universities. However, this number has increased substantially in the past few years.

6.3 Quality

Transfer students do well after leaving the community college system. Once admitted into a four-year institution, first-year retention rates are approximately the same for transfer students and freshmen. Moreover, the first-year drop in grade point average is actually slightly greater for freshman entering from high school than it is for transfer students.

The quality of instruction in the community college system is generally high. The majority of California Community College faculty are teaching within their discipline area, and most have at least a master's degree. The total faculty numbers are comparable to the combined faculties of UC and CSU. Although a large number (40%) of California Community College classes are taught by part-time faculty, salaries for full-time tenure track faculty are comparable to CSU salaries.

[54] University of California, San Diego, Office of Academic Planning and Programs, *Transfer Student Task Force Report*, April 28, 1999, p. 3.

[55] Lee & Walshok, p. 40.

6.4 Resources

In 1998 the state of California and the California Community College System set forth a series of goals referred to as the "Partnership for Excellence" which aimed to increase, among other things, the transfer rate to four-year institutions and the number of degrees and certificates awarded. The state committed $100 million per year through 2005 to help the community college system achieve these goals. However, these annual funding increments halted after the third year.

In addition, the community colleges face resource challenges resulting from their funding mechanism, which is based upon outdated assumptions about the average cost of programs. In an era in which many, if not most, programs involve the use of technology, and especially those in the S&E area, this problem is exacerbated. In addition, community college student fees are not a resource option for a variety of reasons. A key factor in student access to S&E education and career options for students is adequate access to counseling assistance, and the student-to-counselor ratios in community colleges are quite high—from 500 to even 1,000 to one, again as a result of resource constraints.

6.5 Discussion

The California Community Colleges serve multiple roles in providing alternative paths from high school to competency. Not only do they provide short-term courses of study leading to certification in technical areas, they also serve as a cost-effective means for students to take college-level courses in preparation for transfer to UC, CSU, and Independent institutions.

- At this point, the community college system is California's best means of quickly addressing shortfalls in the higher education system because of its flexibility, short cycle time, and pre-existing role in remedial education.
- The extremely low number of S&E degrees awarded each year by the community college system suggests that more and better marketing is needed to make students aware of the opportunities available at the California Community College.
- Connections with high school and four-year institutions are very important. Outreach programs such as the Middle College High School programs,[56] First Year Experience,[57] and Puente Project[58] have all been very successful, although they are limited in scale. The Middle College program, in particular, which allows high-risk students to complete the last two years of high

[56] http://www.cccco.edu/cccco/ss/middlecollegehighschoolhomepage.htm, accessed 11/5/01.

[57] http://www.sc.edu/fye, accessed 11/5/01.

[58] http://www.puente.net/, accessed 11/5/01.

school on a community college campus with targeted counseling, is currently in a pilot phase and requires 50/50 funding matches.

- Resource constraints at California Community Colleges pose particular challenges for hiring quality S&E faculty (see baccalaureate section 7.4).
- Transfer students perform well. Their most serious impediment is lack of an effective counseling system to provide information, advice and support appropriate to their particular needs. It should be noted that funds for UC to place "transfer counselors" in community colleges were cut from the budget this year.
- The fact that most transfers occur at or after four years is partly due to the fact that 80% of community college students are working full or part-time.
- The majority of community college graduates are not pursuing training in science and technology-related subject areas. In fact, the single most popular area for associate's degrees in 2000 (nearly a third of the total) was the humanities. Science and technical degrees ranked far behind.
- The cost of doing remedial classes while enrolled at a UC, CSU or Independent university is significantly higher than doing remedial classes at a community college. Students needing remediation would therefore benefit from first enrolling at a community college to complete these requirements before entering UC or CSU.
- Fewer transfer students from community college continue on to graduate school than freshmen. Given the similar academic performance of transfer students, further attention should be given to possible causes and how they might be addressed to increase the rate of advanced study for transfer students. Possible factors that should be investigated are financial need and debt levels at graduation, degree of integration into the major department and the discipline, affiliation with faculty, participation in undergraduate research, family socioeconomic factors, and career objectives and aspirations.

CRITICAL PATH OF COMMUNITY COLLEGE SYSTEM

- **The number of S&E certificates and degrees granted is insufficient.**
- **The number of transfers to four-year institutions is too low.**
- **The community colleges have opportunities to expand their roles as bridges to work or further study; e.g., at-risk high school students benefit from programs which allow students to begin taking college courses and more aggressively prepare them for entrance to college.**
- **The community college S&E instructional capacity (lab, facility, teacher) is resource limited.**
- **The supply of counseling services is inadequate.**
- **There is no salary differential for faculty in S&E disciplines, despite the higher earning potential of S&E degree recipients in the labor market.**

6.6 Policy Options

Recognizing the problem of not producing enough graduates or transfer students, the community college system has joined with the UC and CSU systems to improve the transfer rates by 42% by 2005. There are also plans to increase the number of associate's degree and certificate graduates by 38%. While these are positive steps, it is not clear that there will be sufficient resources to achieve these goals. The community college system is already limited by capacity. It is also apparent that the community colleges and four-year colleges do not provide the level of advising and counseling needed to keep students on track through a complex system of course completion and transfer requirements.

Recommendations are as follows:

1. **Give greater priority to expansion of S&T enrollments and degrees in the allocation of incremental new state operating and capital budget funds.**
2. **Increase cooperation of community colleges with high schools.**
    - Expand partnerships such as the Middle College High School program, which allow easy transitions between the two.
3. **Increase transfer numbers in the S&T areas.**
    - Encourage similar programs to the "Partnership for Excellence."
    - Encourage community college students to select science and technology options during the first two years in preparation for transfer.

4. **Strengthen collaboration with four-year institutions.**
   - Permit community college students to enroll concurrently in lower division science and engineering major courses when not readily available in the community colleges.

5. **Promote high-end articulation efforts such as the following programs:**
   - ASSIST [59]
   - CAN (California Articulation Numbering system)[60]
   - IMPAC (Inter-segmental Major Preparation Articulated Curriculum)[61]

6. **Increase opportunities for part-time degree study in the state's universities to cope with community college transfer students who are working full and part-time.**

7. **Develop differential salary scales for S&T faculty that reflect the marketplace for these skills.**

[59] ASSIST is an online student-transfer information system that provides up-to-date information on course transferring between post-secondary institutions (www.assist.org, accessed 1/10/02).

[60] CAN is a cross-reference course identification system for many lower division, transferable courses (www.cansystem.org, accessed 1/10/02).

[61] IMPAC is a program funding regional and state-wide faculty discussions to ensure that students transferring from the community colleges to UC and CSU are prepared for work in their chosen major (www.cal-impac.org, accessed 1/10/02).

Chapter 7 - Baccalaureate Degree Production

A baccalaureate degree is considered the minimum qualification necessary for nearly half of the high-tech jobs. As seen in Figure 3.2 (Chapter 3), many of the high-tech occupations projected to grow the fastest in California during the next decade require a baccalaureate degree. This is also the point at which students begin planning for graduate degrees.

Baccalaureate degrees are granted by the California State University system (about 50% of total), the University of California system (about 25%), and Independent institutions (about 25%). The California Master Plan for Higher Education[62] specifies admission standards for CSU and UC based on a philosophy of broad, affordable access. The top third of public high school graduates are eligible for the CSU system; the top eighth are eligible for placement in UC. Admissions are checked retroactively every five years to verify whether these percentages are being met. Independent institutions set their own admission standards, which vary widely.

The admission process for UC and CSU is complex and involves various factors. For our analysis, we are using the completion of the "a-g" series of required high school courses as a key indicator of high school graduates prepared to begin baccalaureate studies. These courses must include, at a minimum, four years of English; three years of mathematics; and two each of history, laboratory science, a language other than English, an arts course, and college preparatory electives.

A detailed examination of baccalaureate degrees by level, gender, and ethnicity can be found in Project 3, *The Role of Universities and Colleges in California*.[63]

7.1 Relationships

Students can enter a baccalaureate program from high school or via a transfer, typically at the junior level, from a community college. There is also an inflow of foreign students on student visas. The effect of the non-resident alien numbers show more at the master's degree level, but are also a somewhat significant factor to consider at the baccalaureate level.

Students can enter the workforce upon completion of a B.S. degree, or they can choose to continue into a graduate program. Figure 7.1 shows flow through the baccalaureate degree process.

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[62] *A master plan for higher education in California, 1960-1975.*

[63] Zucker & Darby, 2002.

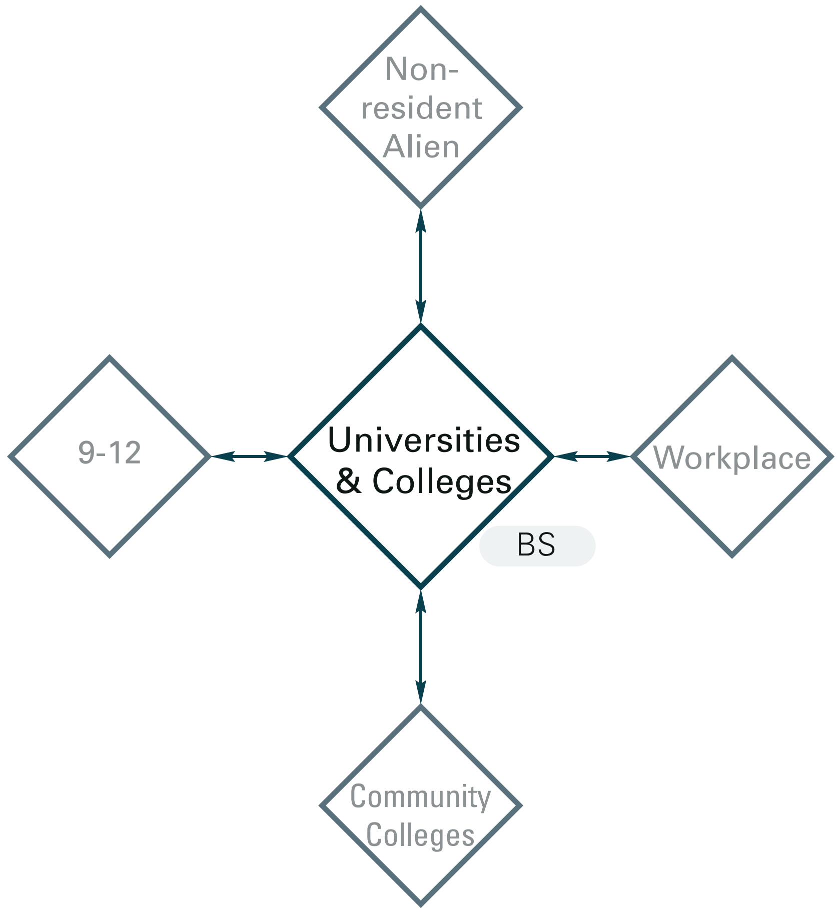


Figure 7.1: Baccalaureate degree production flow diagram

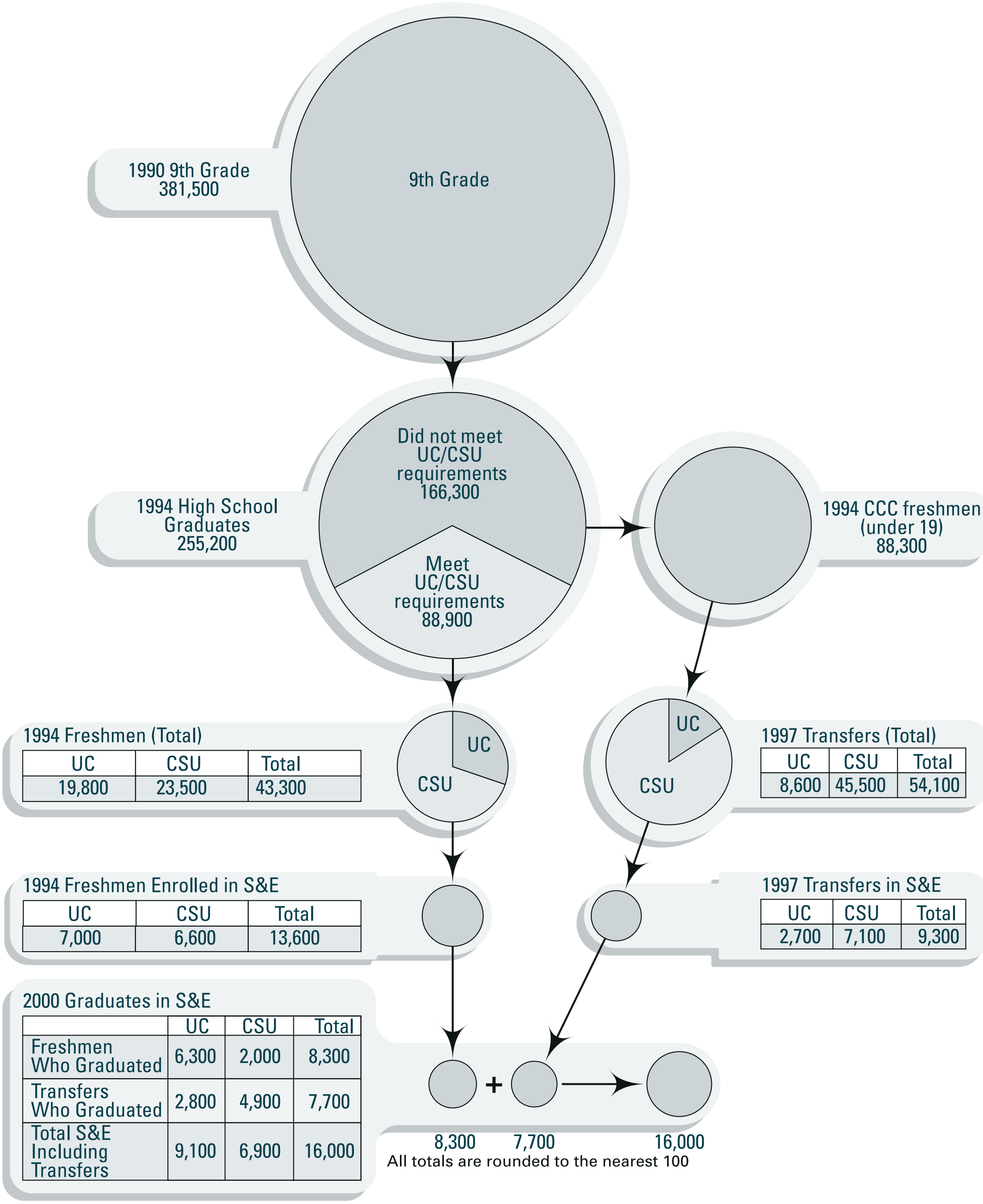
7.2 Quantity

The overall production of S&E baccalaureate degrees in California lags behind many other states and countries. Worldwide, in 1997 the United States ranked sixth in the percentage of 18 to 24 year olds holding S&E baccalaureates, behind the United Kingdom, South Korea, Germany, Japan, and Taiwan. This represents a decline from 1975, when the U.S. ranked second only to Japan.[64] Despite California being the nation's technology leader, the state ranks only 9th in percentage of baccalaureates granted in S&E in the United States.

California, the nation's technology leader, ranks only 9th in S&E baccalaureates granted in the U.S.

In California, attrition is significant from high school through the undergraduate system. Less than 3.3% of 9th grade students enrolled go on to complete a baccalaureate in S&E (Figure 7.2). About half of students who enroll in S&E actually complete a baccalaureate in the same field, although some who do not complete S&E degrees complete their baccalaureate in a different field.

[64] *National Science Board, Science & Engineering Indicators – 2000*, Figure 4-15.



1994 Freshmen (Total)

UC	CSU	Total
19,800	23,500	43,300

1997 Transfers (Total)

UC	CSU	Total
8,600	45,500	54,100

1994 Freshmen Enrolled in S&E

UC	CSU	Total
7,000	6,600	13,600

1997 Transfers in S&E

UC	CSU	Total
2,700	7,100	9,300

2000 Graduates in S&E

	UC	CSU	Total
Freshmen Who Graduated	6,300	2,000	8,300
Transfers Who Graduated	2,800	4,900	7,700
Total S&E Including Transfers	9,100	6,900	16,000

Figure 7.2: Longitudinal study of students in public school system, 9th grade through S&E baccalaureate, 1990-2000

Sources: CSU Office of the Chancellor, UC Office of the President, CCC Office of the Chancellor, CPEC, CBEDS

Nationally, over 20% of students fail to complete college.[65] Although survey data is somewhat sketchy, California appears to be doing no better than this average, and probably somewhat worse.

Figure 7.2 is a longitudinal study of students who graduate from the UC and CSU systems, which grant approximately 75% of all baccalaureates. It does not include the contribution of Independent institutions, which grant 25% of baccalaureates. It is important to note that these data must be viewed as only approximate because it does not track a specific cohort. Data are represented as totals for that year.

In 1990, approximately 381,500 students were enrolled in 9th grade. Four years later, only 255,000 students graduated. Of the graduating students, only 89,000 completed the a-g course sequence required for college admission. Approximately 50% entered CSU or UC, of whom less than a third enrolled in S&E. The number of S&E degrees earned six years later by students who entered as freshmen was approximately two-thirds as large (close to 8,300).

The chances that a 9th grader will graduate, go straight to UC or CSU and earn a degree in S&E are less than 2.2%.

As the figure shows, an additional 7,700 S&E baccalaureates were earned by students who detour through the community college system first. These S&E transfer students represent approximately 17% of total transfer students, who in turn comprise approximately half of the students who went straight to community college after high school. In short, the number of S&E baccalaureates granted in 2000 was close to 4% of the ninth grade enrollment total in 1990. The approximately 8,300 S&E degree recipients who were able to enter UC or CSU directly from high school represent just over 2% of the ninth grade class total from 1990.

Despite the limitations of this figure, it highlights three key aspects of baccalaureate production in California. First, the number of S&E baccalaureates produced represents an extremely small percentage of the students who begin 9th grade. The total number of degrees produced (16,000) is only 4% of the starting total 10 years previously. Second, a significant number of students in CSU who enroll in S&E do not complete an S&E degree (over two thirds). Third, the community college system contributes significantly to the actual number of S&E baccalaureates produced in the public university system. In 2000, nearly half of S&E degrees were earned

Community College transfers contribute significantly to the total number of baccalaureates produced.

[65] *National Science Board, Science & Engineering Indicators – 2000*, Figure 4-26.

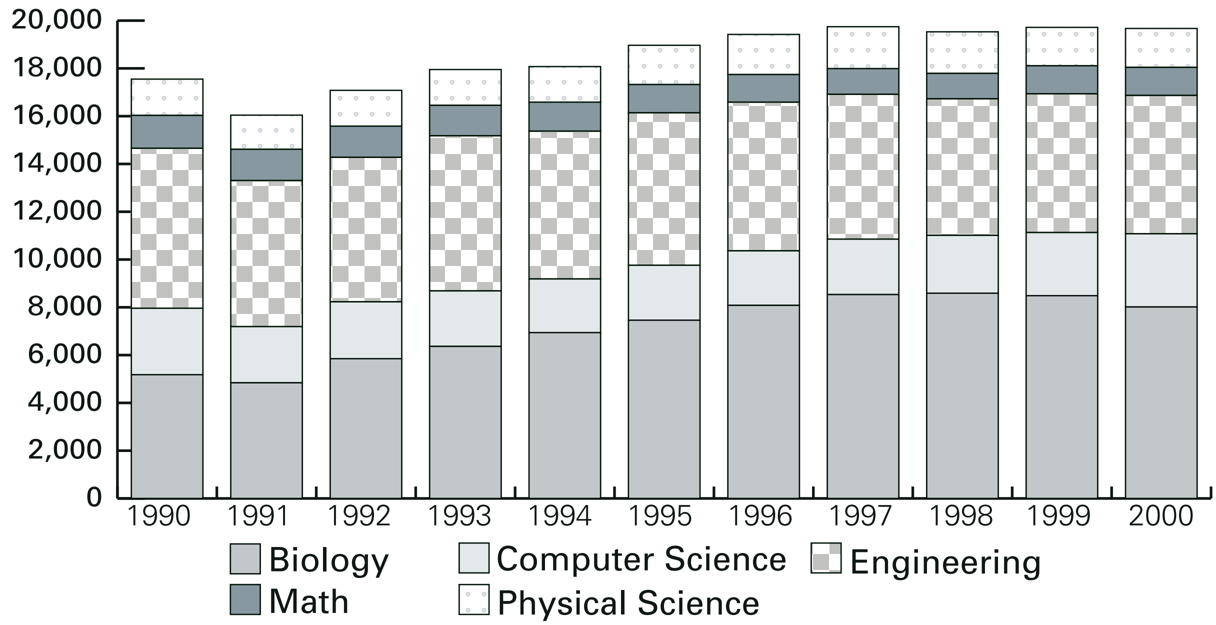


Figure 7.3: Total S&E degrees, all four-year institutions, 1990-2000
Source: CPEC, December 2001.

by transfer students; at CSU, transfer students actually comprised over 70% of the total.

BETWEEN 1990 AND 2000, ENGINEERING DEGREES DROPPED BY MORE THAN 13%.

Overall, baccalaureate production in California has been rising steadily. However S&E degrees in California increased at a slower rate than the general trend. Baccalaureate degrees awarded in all subjects at all California colleges and universities increased approximately 14% between 1990 and 2000 while the science and engineering component of that increased only 12% (Figure 7.3). Private colleges and universities saw an increase of only 5% in S&E degrees during this period. Overall, in 1998-1999 when the state's population was over 12% of the total U.S. population, California awarded just 10% of the U.S.'s engineering baccalaureate degrees.

The modest overall increase in S&E degrees masks stagnant or negative growth trends in a number of key disciplines. Nearly all of the increase in S&E degrees was concentrated in biology, which enjoyed a 55% increase in the number of degrees awarded in 2000 versus 1990 (Figure 7.4). Computer science degrees rose a modest 10%. Mathematics and engineering baccalaureates fell by 13% during this time.

There has been particular weakness in S&E degree production trends within the California State University. During this 10-year period, UC awarded 43.5% of the science and engineering baccalaureate degrees, CSU 38.5%, and the Independent institutions 17.9%. Each of the segments experienced increases in biology degrees granted. As shown in Figure 7.5, CSU experienced a slight decline in overall S&E

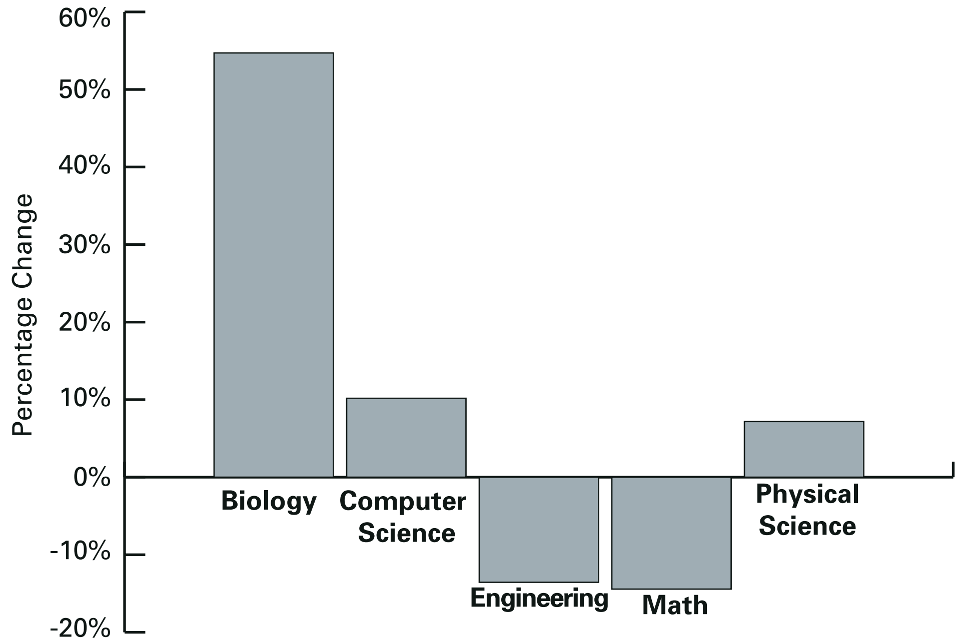


Figure 7.4: Delta change in S&E degrees, 1990-2000
Source: CPEC, December 2001.

degrees, with especially pronounced declines in engineering and physical sciences. These trends suggest the need for particular attention, at the policy level, to strategies for expanding S&E enrollments and degrees in the state's largest public university system. The growth in S&E degrees is mainly due to increases at the UC (Figure 7.6), largely in life sciences, and the Independents (Figure 7.7), although biology saw a decline at the Independents in 2000.

At CSU, only one in three students who start their studies in science, mathematics, engineering or other technical fields actually complete a degree in those fields.

Attrition in S&E disciplines is significant, though difficult to document with precision. Within the CSU, only about one in three students who start their studies in science, mathematics, engineering, or other technical fields actually complete a degree in those fields.

Enrollment trends in S&E disciplines have been generally positive in the 1990s, with the exception of engineering, mathematics, and physical science. The number of students who enrolled in California colleges and universities increased by approximately 14% from 1990 to 1999. From fall 1990 to 1999, the number of students enrolled in science and engineering disciplines rose by 17%. While these positive enrollment trends will lead to increases in degrees, the limited magnitude of these increases is not likely to address the state's workforce gap.

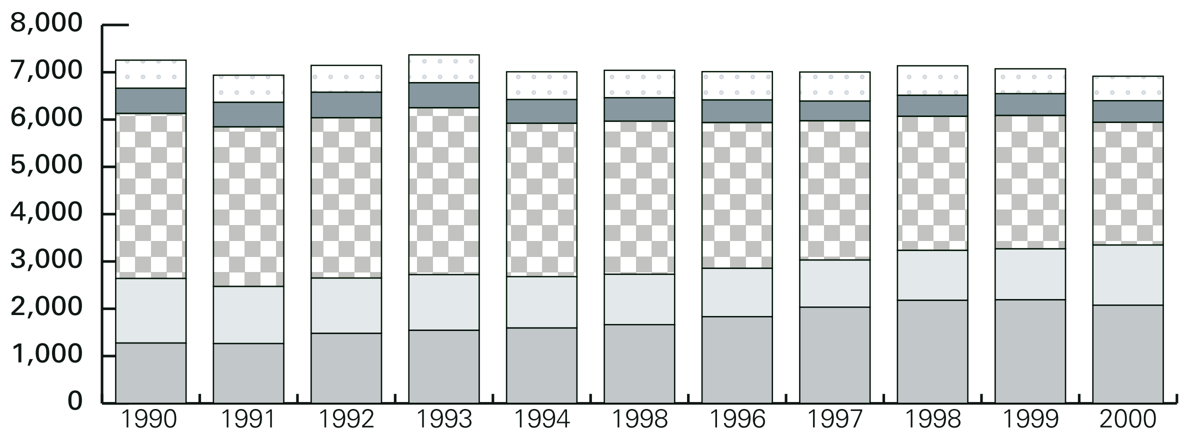


Figure 7.5: Trend of CSU baccalaureate degrees, 1990-2000

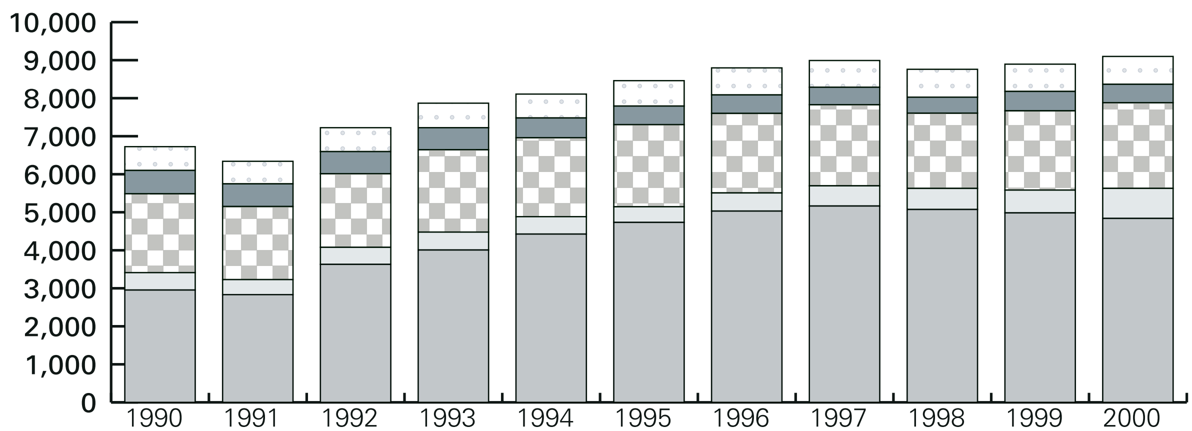


Figure 7.6: Trend of UC baccalaureate degrees, 1990-2000

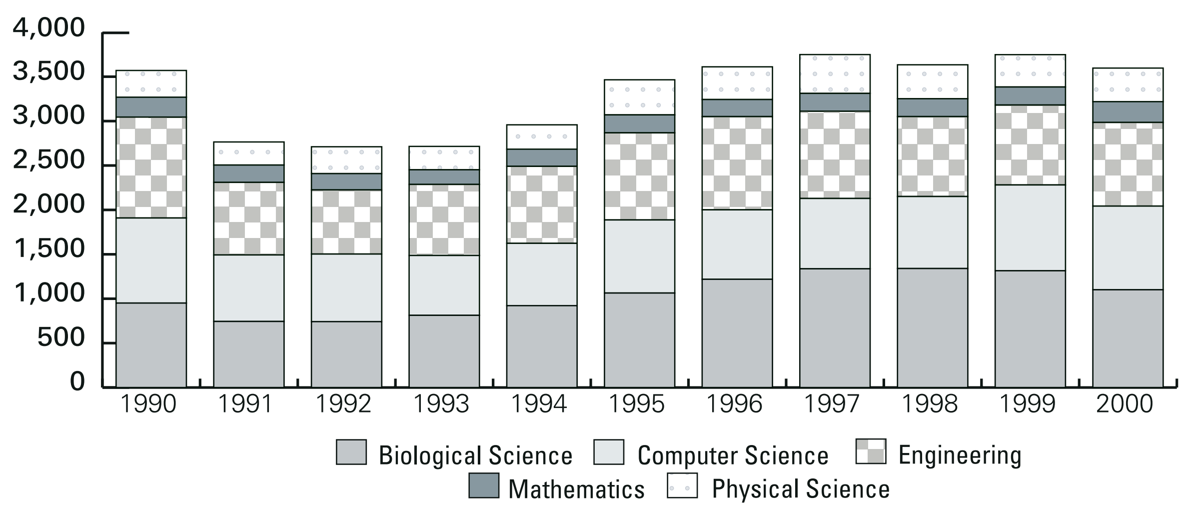


Figure 7.7: Trend of Independent institution baccalaureate degrees, 1990-2000

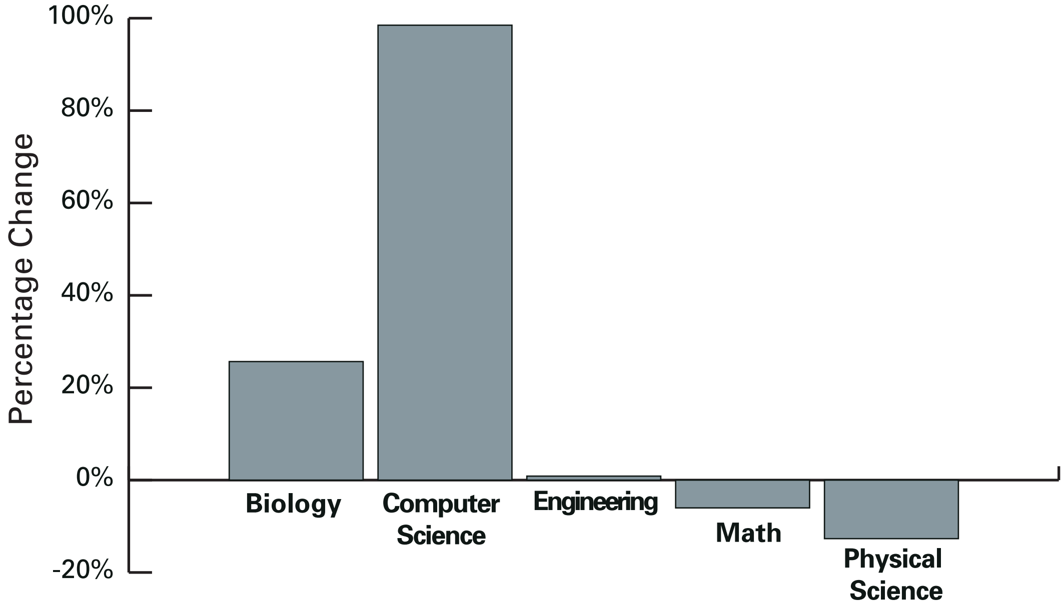


Figure 7.8: Delta change S&E baccalaureate enrollment, 1990-2000

Projections of degrees in S&E fields suggest that the positive trends in enrollments (Figure 7.8) will have the most impact on the number of degrees produced in computer science, which has seen a dramatic increase (nearly 100%) in enrollment since 1997 that has not yet fully registered in degrees granted. However, it is possible that significant attrition due to students entering the workforce directly in this high-demand sector will mitigate the number of degrees actually produced.

There have also been some hopeful trends in S&E enrollments by gender and ethnicity, though the record here is mixed. Female enrollment as a percentage of overall S&E enrollment rose by 6% between 1990 and 2000 (Figure 7.9), with a corresponding rise in females earning S&E degrees. However most of the increase in female S&E enrollment has been in life sciences (e.g. biology), which saw a 50% increase from 1990 to 1999, mostly at UC and the Independents. Non-life sciences S&E degrees earned by females at CSU have actually declined over the past decade.

Among ethnic groups during the 1990s, white students declined as a percentage of the total student population and as a percentage of all degree recipients, while increases were noted among Latinos and Asians. These overall enrollment and degree trends were mirrored by S&E enrollment and degree trends, as documented by Figure 7.10.

The percentage of non-resident aliens enrolled in S&E California baccalaureate programs has remained constant at approximately 7.5% from 1990 through 2000.

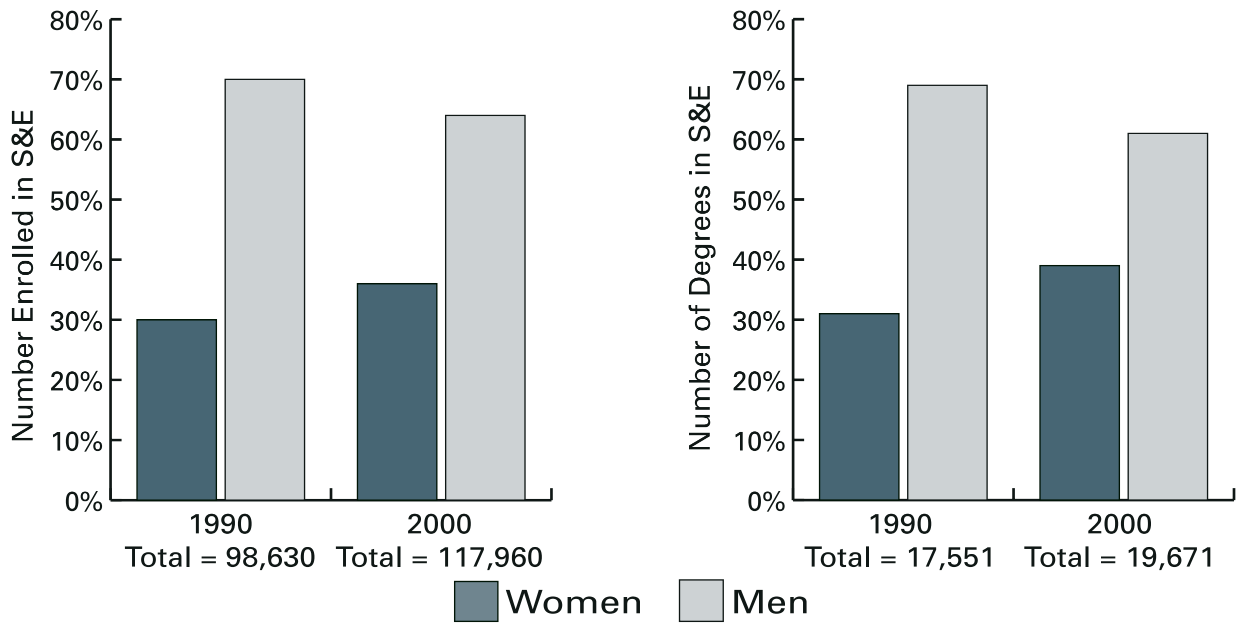


Figure 7.9: Undergraduate enrollment and degrees by gender, 1990 & 2000, overall and S&E
Source: CPEC

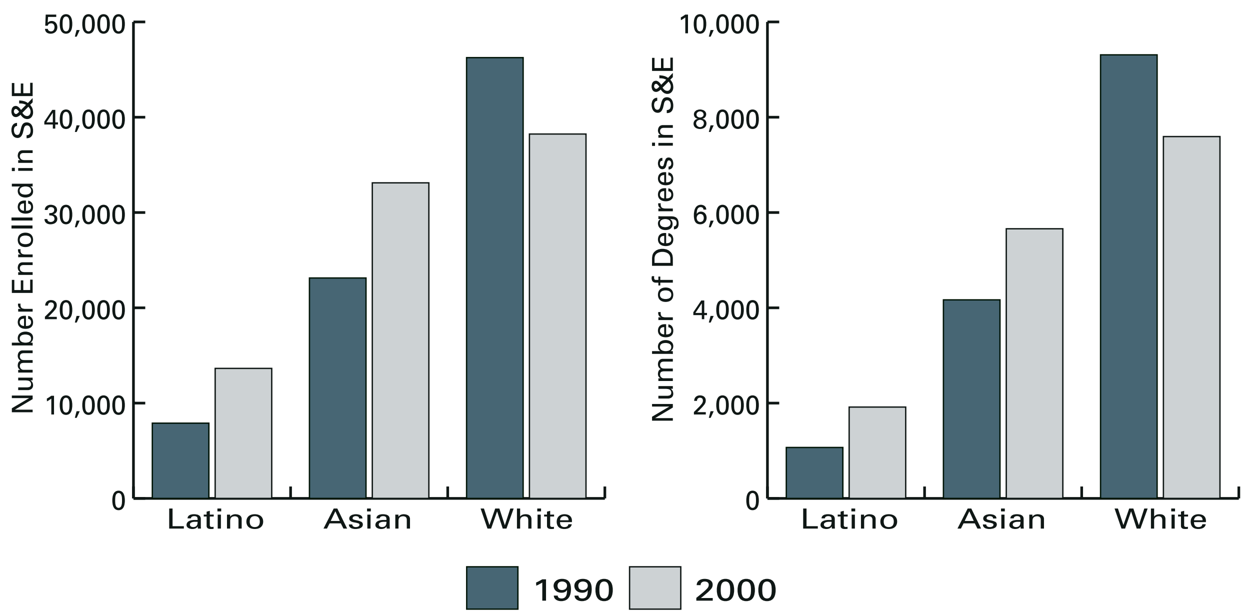


Figure 7.10: Undergraduate enrollment and degrees by ethnicity in S&E, 1990 & 2000
Source: CPEC

7.3 Quality

There is no doubt that the education a student receives in the CSU, UC, or California's Independent colleges and universities is of high quality. However, there is increasing concern whether students can succeed in a system that they are ill prepared to enter.

Nationwide, overall retention to graduation in baccalaureate programs in all fields is just under 80%, while less than 50% of students enrolled as S&E majors actually complete their degrees in 5 years or less. This number drops to 25% for underrepresented minorities, including Blacks and Latinos.[66] California is doing no better. In 2000, over 45% of CSU freshmen, although qualifying for admission, failed the entrance test in mathematics and English.

S&E students have a high attrition rate compared to other disciplines (as high as 66% at CSU). Several UC campuses report that high attrition rates in S&E are due to the poor preparation, which many freshmen have in mathematics and science, leaving them unable to master the subject material. Many have difficulty with the entry-level core courses in S&E, and because of limited class availability, it is hard to make up for lost time when a student fails a class or requires additional remediation.

The overall percentage of S&E graduates who continue into graduate school (about 40%) remains slightly behind that of Massachusetts and New York.

7.4 Resources

Growing resource adequacy problems exist related to the maintenance and expansion of higher cost public college and university science and engineering programs. For example, for the UC and CSU, state funds are not presently provided to address the non-salary, research-related start-up costs (for laboratories, etc.) associated with the hiring of new and replacement science and engineering faculty. Recruitment of new faculty in science and engineering is intense. The realities of the needs for doing research and the highly competitive market both necessitate very substantial financial packages for recruitment and start-up, typically used for specialized research equipment and facilities and for technical/technician support during the period before proposals developed by new faculty members can be funded from external sources. As things stand, the state provides few resources designated for such purposes, and that fact has negatively affected the abilities of California's public universities to compete for new faculty in S&E areas.

Moreover, the methods by which CSU and California Community College S&E instructional programs are funded do not address the real cost of hiring additional faculty and supporting their instruction. These S&E programs incur

[66] *National Science Board, Science & Engineering Indicators – 2000*, Figure 4.26.

extraordinary costs related to the hiring of new faculty; starting salaries are higher than the average, due in part to competition from industry and other universities.[67] The instruction conducted by new S&E faculty must also be supported by technical staff, equipment and specialized facilities, adding further to the cost of instruction. Present inadequate funding has created decided disincentives for the CSU and the California Community Colleges to invest in the expansion of higher cost science and engineering instructional programs. The steady erosion of undergraduate enrollments and degrees in science and engineering disciplines (other than biology) over the past decade is, in part at least, a logical and inevitable consequence of this inadequate funding. To help reverse the decline in enrollments and degrees in CSU and California Community College S&E programs and position them for future growth, present funding mechanisms must be re-examined.

7.5 Discussion

California is not producing sufficient numbers of students to meet the workforce demand. One estimate is that there are approximately 15,000 job vacancies for graduates with an S&E degree.[68] A rise in biology degrees over the past decade has been offset by slow growth or declines in engineering, computer science, mathematics, and physical science degrees.

Various factors account for this decline including:

- Inadequate preparation in high school and consequent need for remediation;
- Inadequate teacher workforce in K-12 in mathematics and science, particularly in low income and predominantly minority schools;
- Low transfer numbers from the community college system in S&E;
- Student difficulty in core S&E courses, experienced early on, causing them to become discouraged;
- The persistent lag in female and minority enrollment in S&E may be a result of a lack of faculty mentors and role models of the same gender and/or ethnicity. Further study of this factor may be needed;[69]
- As a result of the rationing of scarce resources, many core courses in S&E are offered only once a year and any failure in these courses can mean a significant setback (this may provide a significant target of opportunity for high-quality distance learning courses);

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[67] For example, the current CSU marginal cost methodology provides about $45,000 for recruitment of new CSU faculty, but the average salary paid to new CSU assistant professors in all disciplines in fall 2000 was $48,763. Average salaries for new CSU assistant professors in S&T fields were as follows: agriculture, $49,279; architecture, $51,360; engineering, $56,636; health sciences, $49,592; mathematics and computer science, $53,270; natural sciences, $48,740 ("Report on Faculty Recruitment Survey, 2000", CSU 2001).

[68] Source: Author's calculations using http://www.calmis.cahwnet.gov/file/indhist/cal$haw.xls and OES data on occupational employment by industry for California

[69] Zucker & Darby, p.6.

- Support services such as tutoring do not always reach the students who need them the most in a timely way and supply of these services often lags behind demand;
- Funding distribution is not based on retention, only enrollment.

CRITICAL PATH OF BACCALAUREATE SYSTEM

- **California is not producing enough baccalaureates in S&E.**
- **There is a gap between degree production and workforce demand.**
- **California lags behind other states (NY, MA) in per capita production of S&E degrees and rate at which B.S. recipients pursue graduate degrees.**
- **The recent efforts to increase the number of S&E degrees are insufficient.**
- **Students are not often adequately prepared to pursue S&E baccalaureate degrees. They also have low interest in S&E. Both problems stem from inadequate exposure to S&E in K-12 and poorly qualified high school mathematics and science teachers, particularly in low-income and minority schools.**
- **The attrition rate in S&E at CSU is too high (close to two thirds).**
- **Unlike UC, CSU does not have a differential salary scale for S&E disciplines, despite the significant difference in earning potential in these disciplines.**
- **A rise in biology degrees in the past 10 years has masked declines or stagnation in engineering, computer science, mathematics, and physical science degrees.**

Recently, at the state level, there has been some recognition of the importance of increasing S&E enrollments and degrees at California's universities. To date, efforts to address the situation have been on varying scales and include:

- Four years ago, the UC system initiated a program to increase the number of S&E graduates. According to the 2001-02 budget, UC plans to target growth of about 1,000 students in engineering and computer science, for a total of about 20,000 overall. This would be the fourth year of an eight-year plan to increase enrollment in these fields to about 24,000 by 2005-06; UC has met or exceeded its goals during each of the first three years. This initiative represents a substantial enrollment increase for these two fields and appears to be the most successful such initiative to date.
- The CSU, through its Strategic Academic Programs initiative, proposed directing a total of $30 million in new funds toward S&E programs over the next several years, permitting campuses to begin to more adequately budget funds for the lower student/faculty ratios required in S&E disciplines and for the higher instructional costs associated with the laboratory and equipment intensive instruction in these fields. While developed to

help position CSU S&E programs for enrollment and degree growth, the Strategic Academic Programs initiative has not set explicit targets for either enrollments or degrees.

- Both public and private universities throughout the state have expanded K-12 pipeline initiatives, including: university early awareness and recruitment initiatives; teacher education and professional development initiatives; and other initiatives to help strengthen and expand participation by K-12 students in college preparatory courses of study, including those leading to S&E fields of study.

7.6 Policy Options

In order to achieve expanded access for California students to further study in S&E fields, and in order to better meet the growing private- and public-sector demand for S&E baccalaureate graduates, a comprehensive, statewide strategy is needed. In particular, the resource adequacy problems related to the maintenance and expansion of higher cost public college and university science and engineering programs need to be overcome. Toward this end it is necessary to develop appropriate funding and budget allocation strategies in the CSU and the Community Colleges to attract and retain the faculty necessary for instruction in S&E programs, to equip and maintain the instructional laboratories, and provide the necessary instructional technical support staff. In developing these funding and budget allocation strategies, recognize the differing programmatic/disciplinary mixes of campuses.

Moreover, in order to be competitive in attracting and retaining faculty in science and engineering in both the CSU and UC Systems, it is important to provide the research-related start-up costs (for laboratories, etc.) associated with hiring of new and replacement faculty. No funding currently exists to achieve this.

In addition, consideration should be given to including the following elements in any overall strategy to expand access to S&E degrees:

1. **Achieve targeted increases in the number of S&E degrees.**

    - Address the significant attrition rate in S&E enrollments, particularly at CSU.
    - Increasing enrollment, lowering attrition and increasing degree completion should be a greater priority in the allocation of incremental new state operating and capital budget funds and in the universities' strategic plans.
    - Strengthen diagnostic testing and expand the role of community colleges to include offering remedial instruction to students when needed, especially in the CSU system.

- More scholarships should be considered to achieve specific increases in the number of students statewide who receive undergraduate degrees in engineering, computer science, mathematics, and the physical sciences.

2. **Develop more appropriate funding and budget allocation strategies for the S&E programs in the CSU and the community colleges.**

    - This will help attract and retain the faculty necessary for instruction in S&E programs, equip and maintain the instructional laboratories and provide the necessary instructional technical support staff.
    - In developing these funding and budget allocation strategies, recognize the differing programmatic/disciplinary mixes of campuses.

[70] Pell Grants are a form of federal financial aid available to undergraduates; they are awarded based on financial need (http://www.pellgrantsonline.ed.gov/ accessed 3/5/02). Cal Grants are a form of state financial aid available to undergraduates awarded based on financial need and academic performance (http://www.csac.ca.gov accessed 3/5/02).

CHAPTER 8 - MASTER'S DEGREE PRODUCTION

After completing a baccalaureate degree, graduates may pursue any of a number of graduate degree programs. In natural science disciplines, the Ph.D. is considered the main object of graduate school, while in engineering and computer science the master's degree is increasingly seen as the objective for students intending to work in industry. The latter is in fact somewhat underestimated as a valuable degree and needs to be considered as more than a 'way station' towards achieving a doctorate.

The California Master Plan for Higher Education designates different graduate school functions for the UC and CSU systems. The UC system is designated as the exclusive state school organization empowered to grant Ph.D.'s. CSU specializes in terminal master's degree programs; in rare instances, CSU grants doctorates jointly with other institutions. Independent institutions play an important role at the master's level in S&E. They issued 45% of all California S&E master's degrees in 2000– more than either UC or CSU.

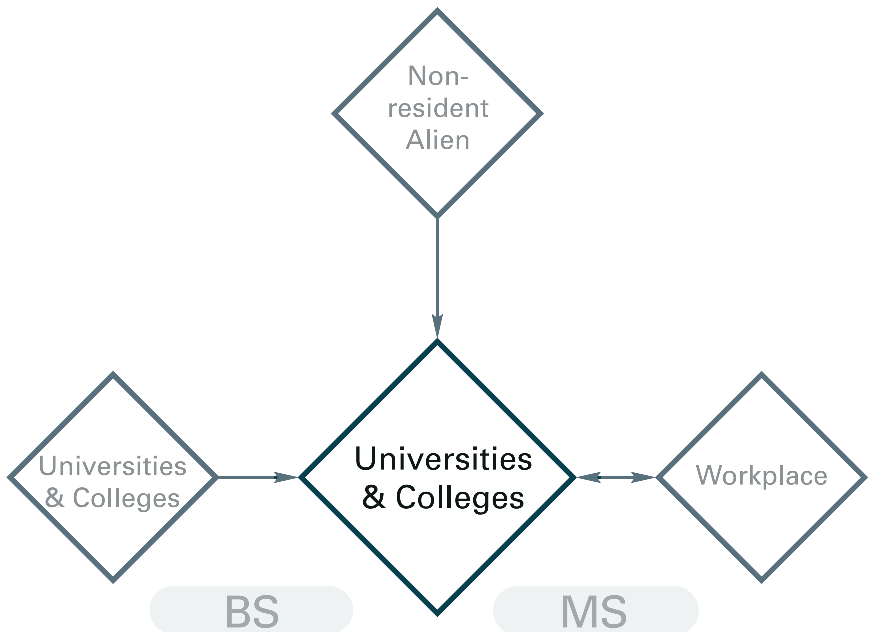

Figure 8.1: Baccalaureate to master's degree higher education flow diagram

The master's degree is the point at which S&E graduates are often considered professionals in their respective fields. Evidence suggests that this is where the workforce gap is most significant. A small survey was conducted of H-1B visa recipients employed by a technology consulting and personnel supply firm based in Northern California.[71] Of the 27 respondents, 52% held a master's degree as highest degree earned. There is a significant need for master's recipients in the workforce and there are not enough Californian citizens earning these degrees. This is evidenced by the number of non-resident aliens who enroll in M.S. pro-

[71] Conrad, p. 8.

grams. Figure 8.1 documents the flow of students through graduate school at the master's level.

8.1 Relationships

8.2 Quantity

In 2000, California graduated 42,118 students with master's degrees; 6,153 of these were in S&E. The total number of master's degrees has risen by nearly 15% since 1990, but the number of S&E degrees has remained virtually unchanged for ten years (Figure 8.2). Consequently the percentage of S&E degrees relative to the total has dropped from 16.8% to 14.5%.

Latinos remain strikingly underrepresented at the master's level in S&E, with just 4% of the total in 2000.

Moreover, fewer master's degrees are being received by students graduating from the California education system. This is evidenced by a significant influx of non-resident aliens at the master's level. As seen in Figure 8.3, overall S&E master's degree production in California remained essentially unchanged from 1990-2000. However, non-resident aliens received 36% of S&E master's degrees in California in 2000, up from 27% in 1990. This means that even though the total number of S&E master's degrees has not varied much during the past decade, non-resident aliens have been making up an increasingly large proportion of the total. It must be remembered that the number of non-resident aliens receiving California baccalaureates remains at only 7.5%; the increase has been exclusively at the graduate level.

In contrast to undergraduate enrollment numbers, Independent institutions (Figure 8.6) grant a larger number of master's degrees than either CSU or UC in S&E (Figures 8.4 and 8.5.) In fact, in 2000 Independent institutions granted more master's degrees in S&E than at any point since 1990 (2,814), an increase spurred on largely by a sharp rise in computer science degrees. This trend does not continue into the production of Ph.D.'s.

Whites remained the dominant ethnic group receiving master's degrees, although declining from 74% to 61% during the past decade (Figure 8.7). The percentage of female degree recipients has risen by 5% during this period, with 80% of the increase due to Asian women. Despite a 75% increase in percentage of degrees from 1990-1999, Latinos remain strikingly underrepresented at the master's level, with just 4% of the total in 2000. Zucker and Darby detail adhesion rates of students from the baccalaureate to master's by ethnicity and gender up through 1996.[72]

[72] Zucker & Darby, pp. 56-60.

In addition, the number of transfer students from the community college system who go on to a master's degree after receiving their baccalaureate is very small.

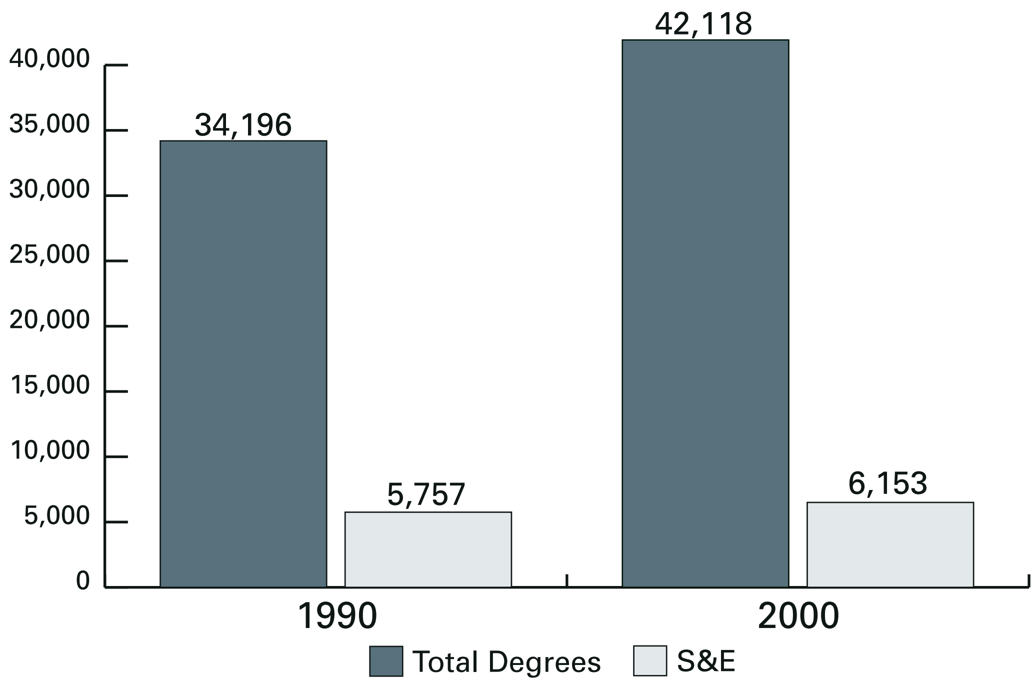

Figure 8.2: Master's degrees, overall and S&E, 1990 & 2000

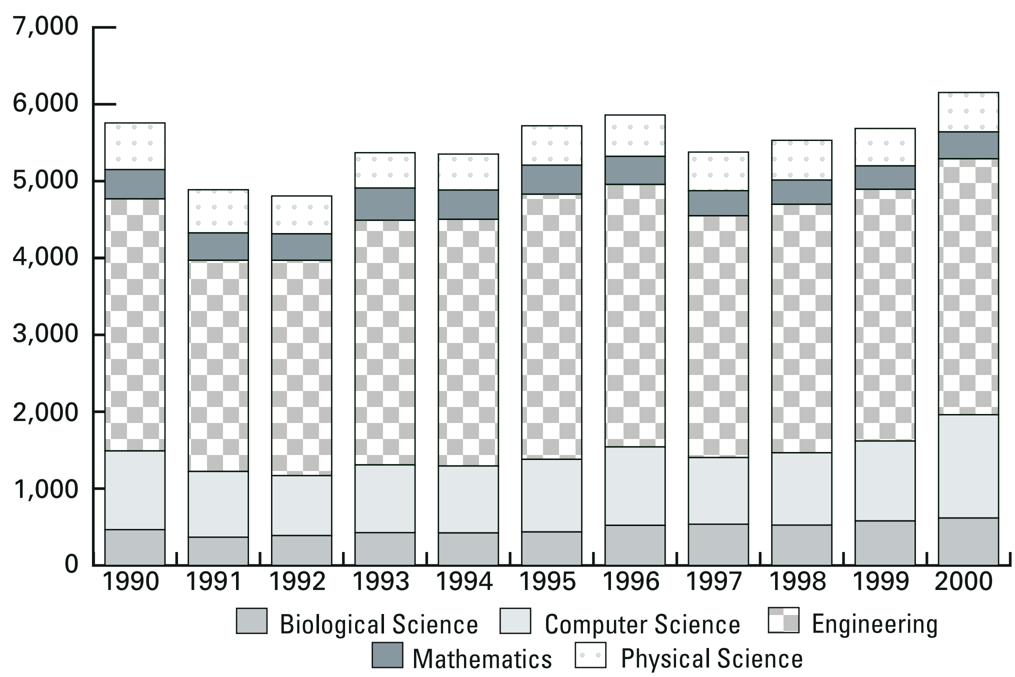

Figure 8.3: Total S&E master's degrees, 1990 & 2000

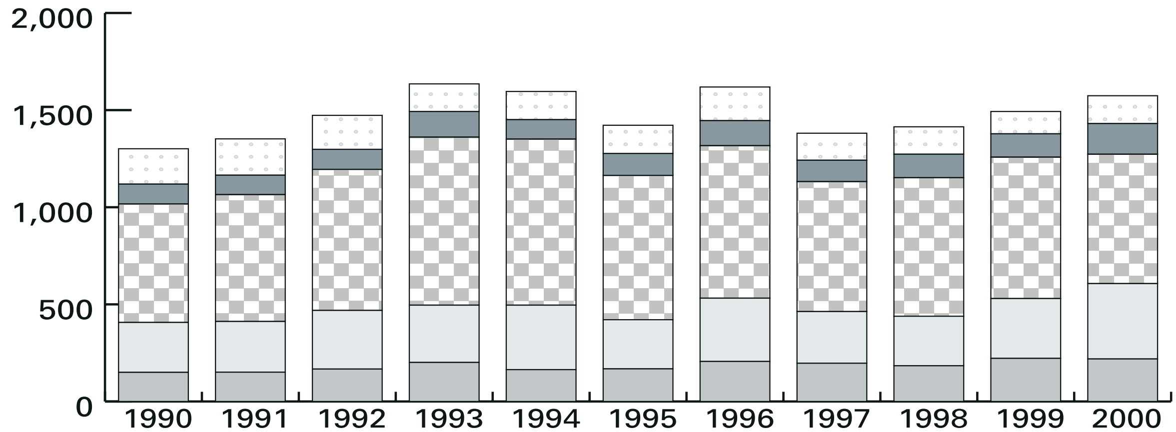

Figure 8.4: Trend of CSU S&E master's degrees, 1990 - 2000

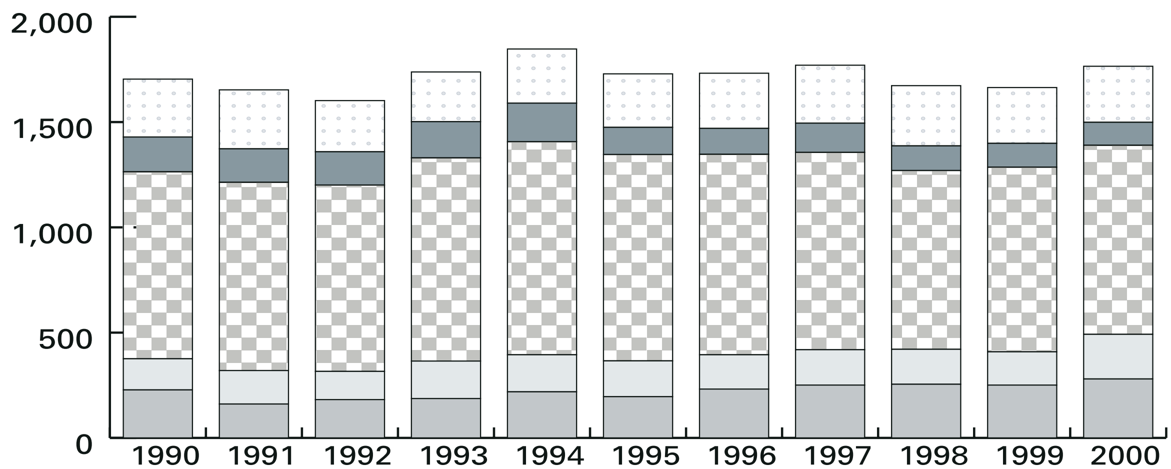

Figure 8.5: Trend of UC S&E master's degrees, 1990 - 2000

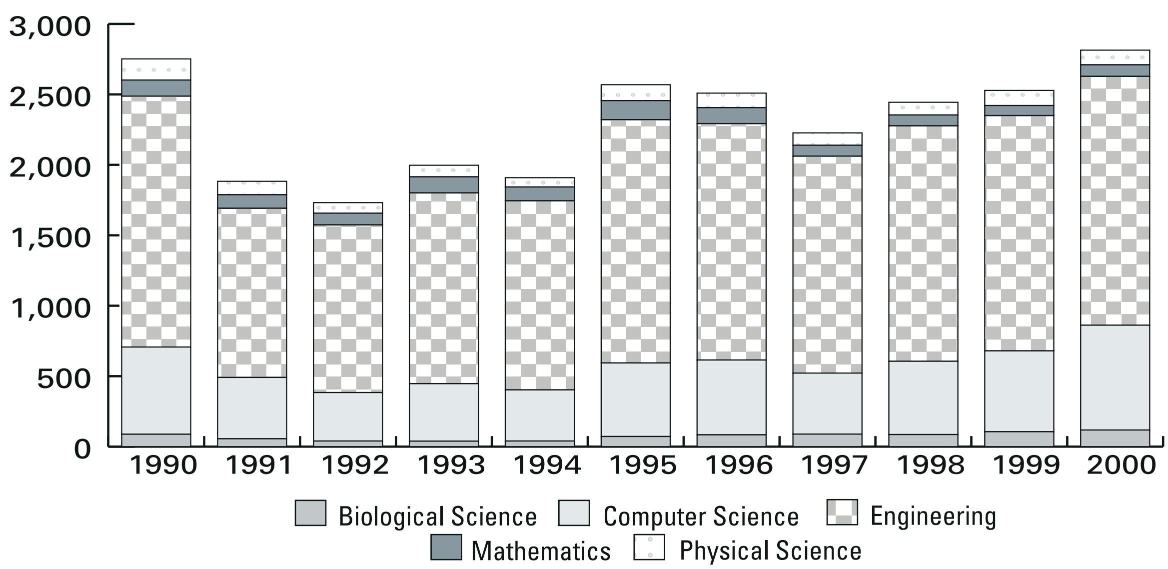

Figure 8.6: Trend of Independent institution S&E master's degrees, 1990 - 2000

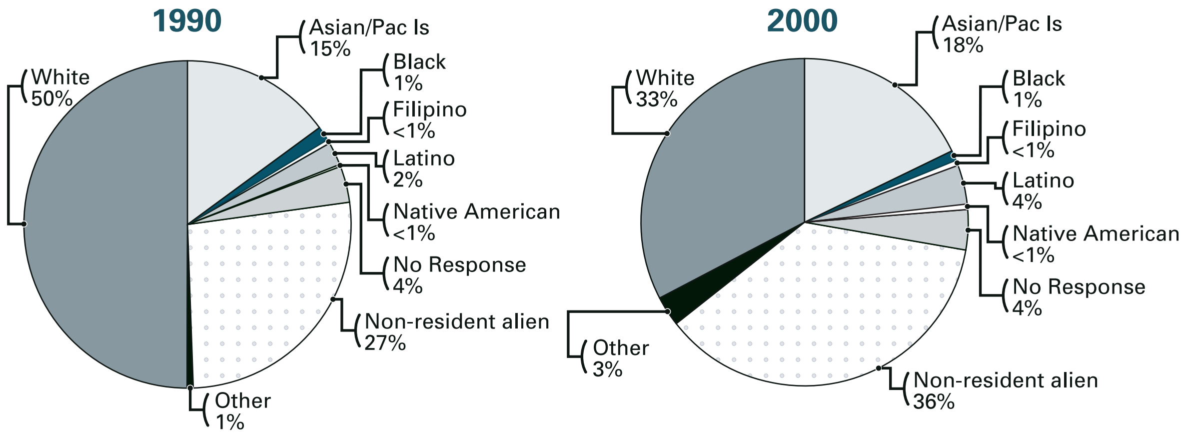

Figure 8.7: Master's degrees by ethnicity, 1990 & 2000

8.4 Resources

Most graduate students receive funding through research assistantships and/or teaching assistantships. Through the 1990s, both of these have declined and the number of graduate students reporting self-support rose by approximately five percent.[73]

In September 2001, the UC Commission on the Growth and Support of Graduate Education initiated a campaign to increase financial support of graduate students by $215 million between 2001 and 2010, in order to add at least 11,000 graduate students. This represents an increase of over 50% from the 1998-99 expenditure total of $417 million.[74] In order to achieve the increased graduate enrollment, the Commission recommended tax relief for graduate students from the federal government, and increased funding from state government, industry, and private foundations.

8.5 Discussion

- The value of the master's degree is perhaps too often overlooked. For many it is the primary educational goal, rather than a stepping-stone to a doctorate. Master's degree recipients in some disciplines, such as computer science and engineering, enjoy higher median salaries than Ph.D. recipients in life sciences and social sciences.
- Production of master's degrees has remained fairly constant throughout the 1990s despite a 9% rise in the number of non-resident alien degree recipients. This means fewer Californians with baccalaureates are pursuing graduate degrees in S&E. While it is advantageous to California to import students at the master's level, there is obviously a need to increase the number of students who are California residents.

Although master's degrees are in significant demand, too few Californians are pursuing them.

[73] *National Science Board, Science & Engineering Indicators – 2000,* 6-21.

[74] UCOP Presentation to Board of Regents 308, September 5, 2001.

- Independent universities play an especially important role in S&E master's degree production, accounting for 45% of all such degrees awarded statewide in 2000.
- To increase the number of students who receive a graduate degree in S&E, they must be convinced that this kind of degree can lead to better career outcomes. The benefits of graduate school need to be clearly explained, and incentives made available. It is also possible that creating a two year post-graduate entry degree in S&E, along the lines of the MBA, would enable more students to participate in graduate S&E programs.

The percentage of female degree recipients has only risen by 5% since 1990, with 80% of the increase due to Asian Women.

- It is possible that differences in continuation rate from baccalaureate to master's degrees (and beyond) are partly due to a lack of female and minority role models at the highest levels of university faculty. Men dominate the ranks of full and associate professors in California as well as New York and Massachusetts.[75]
- The rise in biology degrees does not reflect the demand: nationally, people holding master's degrees in life sciences have higher unemployment rates and lower median salaries than recipients of degrees in other S&E disciplines.[76]

CRITICAL PATH OF GRADUATE SCHOOLS – MASTER'S LEVEL

- **Master's degrees are in significant demand as shown by the numbers of H-1B workers who hold them.**
- **Growth in S&E master's degrees is largely driven by the increasing participation of women in the health and life sciences.**
- **A significant percentage (over 35%) of master's degrees are awarded to non-resident aliens. Many, perhaps most, of these students are not products of the California education system.**

[75] Zucker & Darby, p.6.

[76] *National Science Board, Science & Engineering Indicators – 2000*, Figures 3-4 and 3-5.

8.6 Master's Policy Options

1. **Encourage more California students to pursue graduate education to the master's level.**

    - Initiate a Cal Grant type of program for students pursuing a master's degree in science or engineering.
    - Explore a two year post-graduate entry degree in S&E along the lines of the MBA.

2. **Increase graduate enrollment rates for students who entered university as community college transfers.**

    - Develop more support for those who continue their education beyond the baccalaureate in S&E fields.

3. **Expand terminal/professional master's degree options within UC and CSU, and encourage same in the Independent institutions.**

4. **Encourage closer connection to industry in graduate training programs.**

    - Create graduate training programs in areas such as bio-informatics and manufacturing engineering, where private sector demand for graduates is high, or programs that involve new types of training, such as internships in private firms.

CHAPTER 9 - DOCTORAL DEGREE PRODUCTION

Completion of a doctorate is primarily required to enter the ranks of university faculty, or to conduct original R&D. In California, the Master Plan for Higher Education specifies that doctorates are awarded only by the UC system and Independent institutions; CSU occasionally offers doctorates in conjunction with UC and some Independent institutions in a limited range of disciplines, such as education and agricultural science, but the total number of degrees (less than a dozen per year) is statistically insignificant.

Earning a Ph.D. requires a student to demonstrate original work at a professional level, and can take three to five years to complete after completion of a master's degree. In many disciplines, the doctoral degree is actually closer to a mid-course transition in advanced training than a 'terminal' degree; an increasing number of graduates move into postdoctoral appointments upon completing their degree, temporary low-paying positions which offer additional training in research.

Although Ph.D. recipients comprise a relatively small number, they play a key role in economic development, especially in California. California leads in top quality programs as defined by the National Research Council[77] and top people at these institutions have a major impact on the growth of local industry. Figure 9.1 shows the flow of students through the doctoral programs.

9.1 Relationships

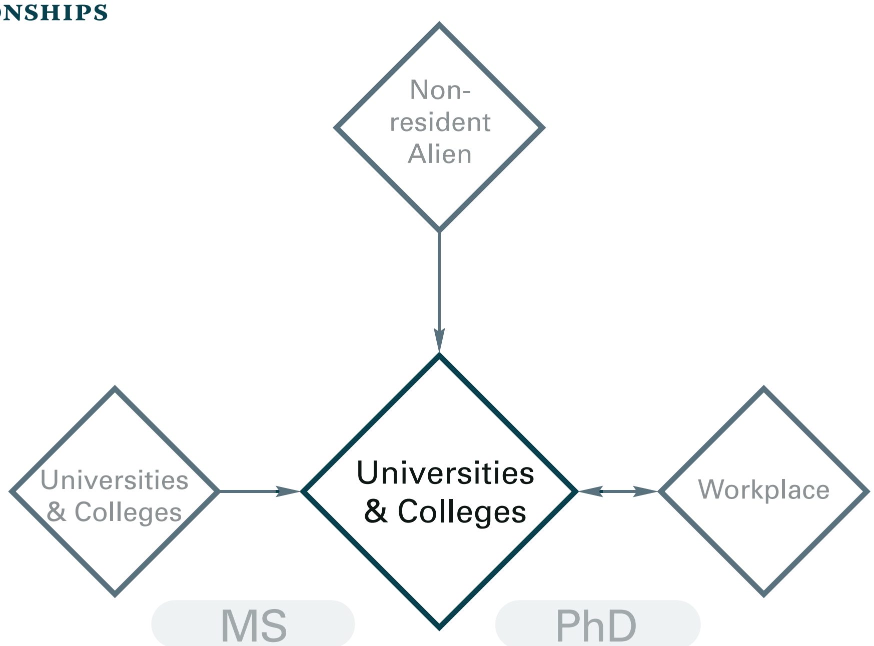

Figure 9.1: Master's to doctoral degree higher education flow diagram

[77] Zucker & Darby, Table A.1.

9.2 Quantity

California produces approximately 2,100 doctoral degrees in S&E per year; UC produces approximately two thirds of these, and the Independent institutions produce the balance (Figures 9.4 and 9.5). There was a 5% rise in the number of S&E doctorates from 1990 to 2000 (Figure 9.3), roughly comparable to other high-tech states such as New York and Massachusetts; but this increase did not kept pace with the overall rise in doctorates (up 22% in the same period). As a result, the overall percentage of Ph.D.'s granted in S&E in California declined from 44% in 1990 to 38% in 2000 (Figure 9.2). In 2000 California awarded nearly 15% of all engineering doctoral degrees granted in the U.S., more than any other state.

Ph.D. recipients play a key role in economic development despite their small numbers.

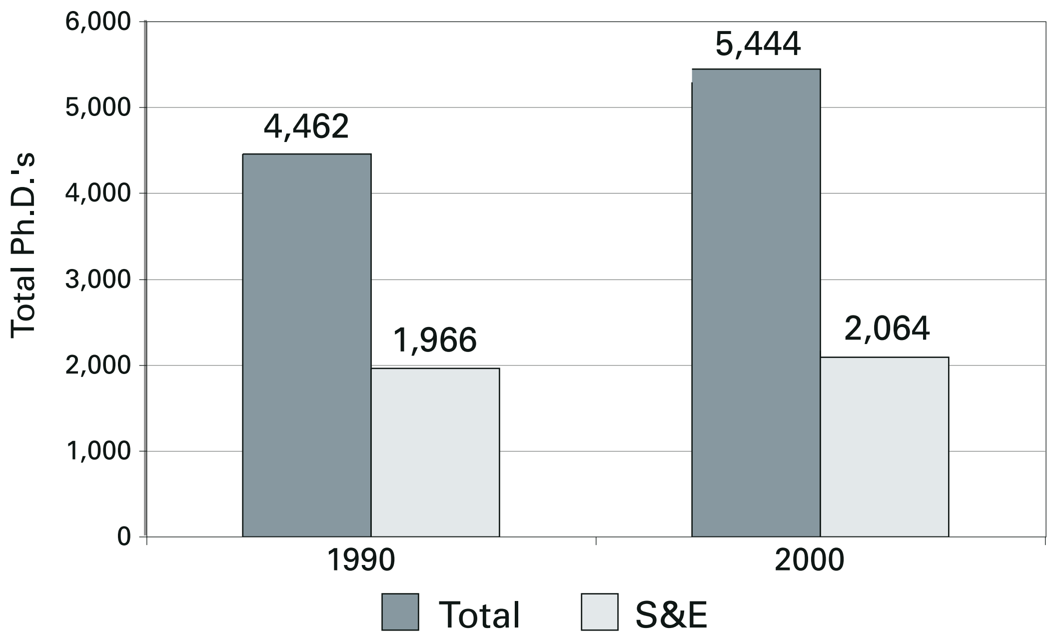

Figure 9.2: Ph.D.'s awarded, overall and in S&E, 1990 & 2000

The number of non-resident aliens declined as a percentage both of total doctorates (22% to 18%) and S&E doctorates (33% to 30%) from 1990 to 2000. However, the percentage of non-resident aliens receiving S&E doctorates remains higher than the overall percentage of non-resident aliens receiving doctorates. This is also reflected in the percentage of Ph.D.'s in the workforce: in 1993, 40% of the people in the United States who had a doctorate in engineering were foreign-born, compared to only 13% in the social sciences.

By discipline, the largest individual percentage gains were in biology and mathematics (more than 25% each, Figure 9.3). However, relative to the total number

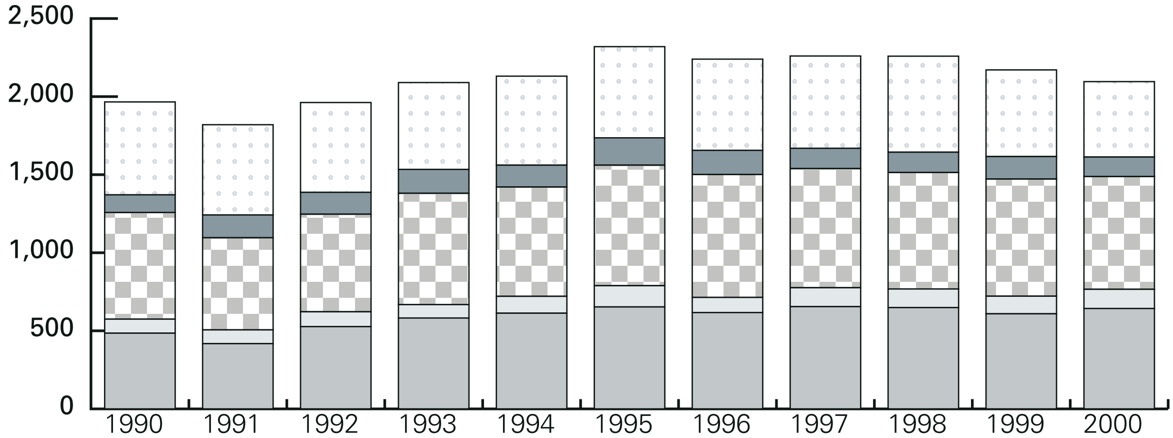

Figure 9.3: Total S&E doctorates, 1990-2000

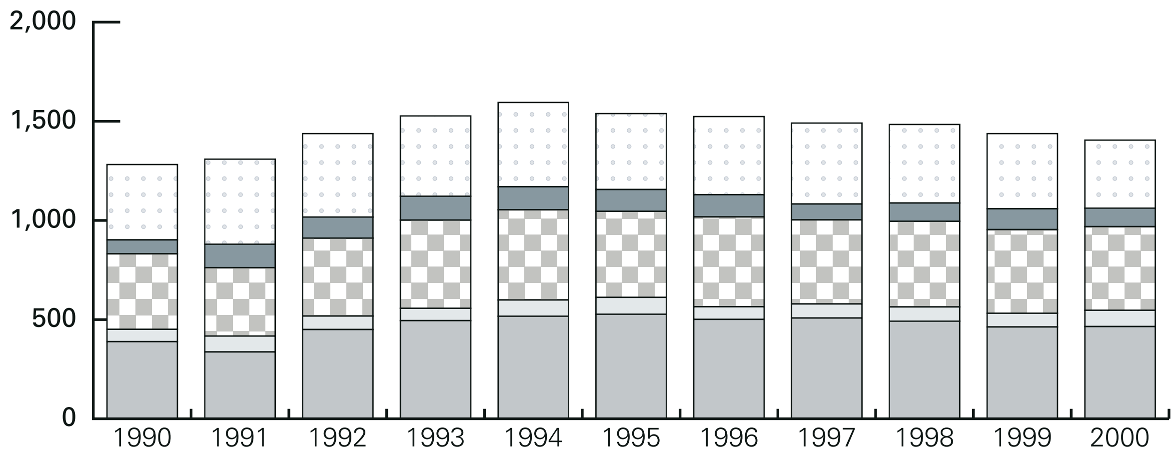

Figure 9.4: Trend of UC S&E doctorates, 1990-2000

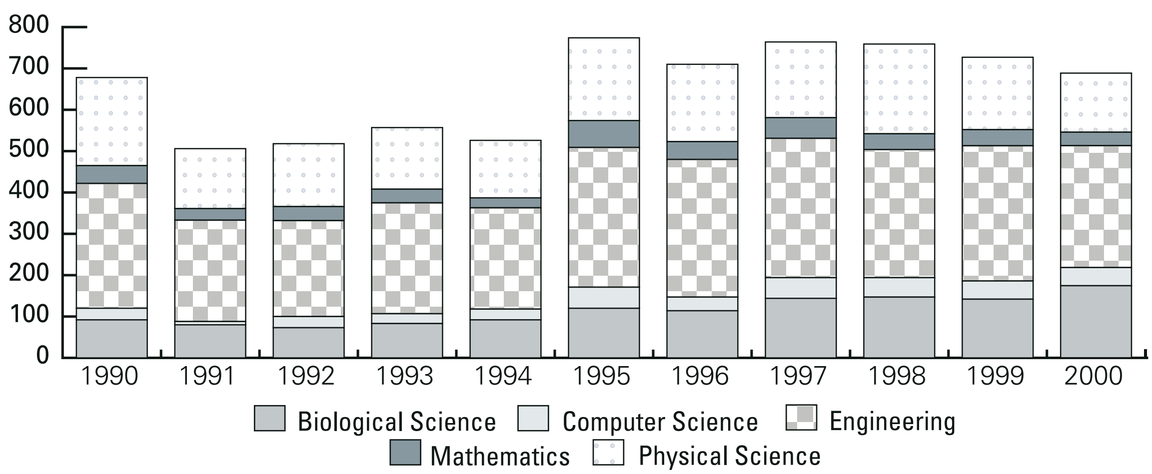

Figure 9.5: Trend of Independent institution S&E doctorates, 1990-2000

Figure 9.6: S&E doctorates by gender, 1990 & 2000

of degrees granted, biology was the only discipline to increase its percentage of the total during this period of time (more than 3%).

Figure 9.6 shows the increase in female doctoral recipients from 1990 to 2000. Again, this is mostly in the life sciences.

The practice of postdoctoral fellowships is growing rapidly in the United States: for all sciences and engineering there were 29,920 postdoctoral fellows in 1991 and 38,506 in 1998. Like S&E doctorates, most postdoctoral fellows are men. Post-docs in non-faculty (research) appointments comprise virtually the entire increase in numbers of Ph.D.'s employed by academic institutions between the early 1980s and the mid 1990s.[78]

There were 7,075 postdoctoral fellows in all areas of science in engineering in California's top research universities in 1998. There are now nearly three post-doctoral fellows per S&E doctoral degree granted by these universities.

9.3 Quality

According to the Institute of Scientific Information, U.S. University Science Indicators, California has 12 institutions ranked among the top 100 research universities in the country, 20% more than New York and 50% more than Massachusetts. In addition to having the nation's finest public university system, California is the only state with three Independent universities in the highly prestigious American Association of Universities.

[78] Paul M. Romer, *Should the Government Subsidize Supply or Demand in the Market for Scientists and Engineers?* National Bureau of Economic Research: Cambridge, MA, June 2000, p. 34.

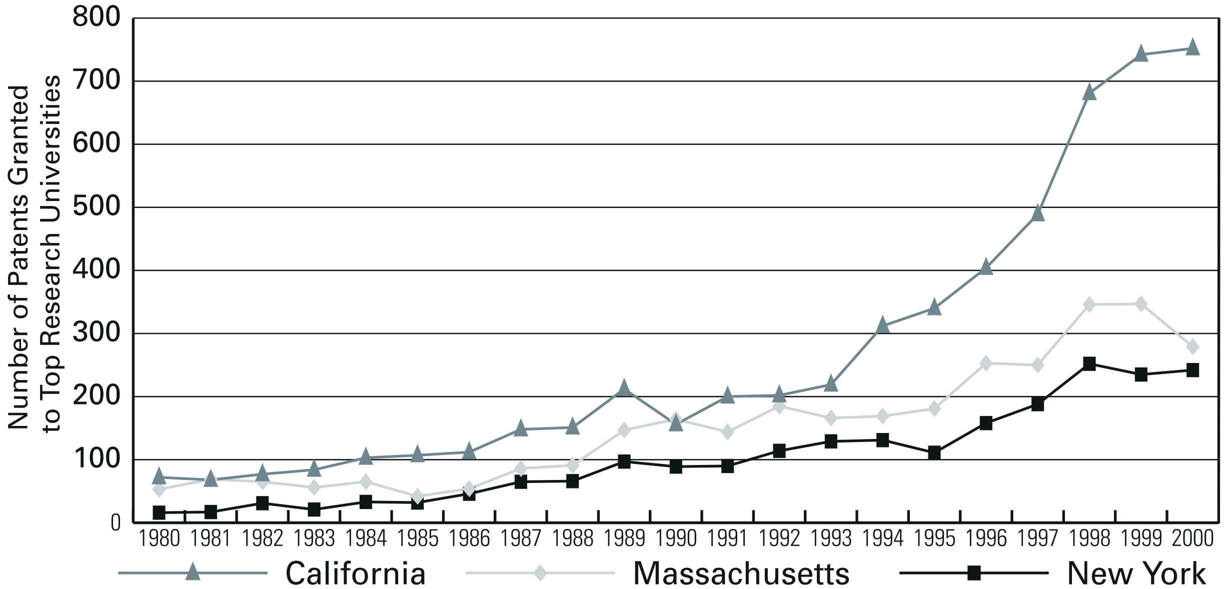

Figure 9.7: Patents granted to top research universities, 1980-2000, CA, MA and NY

Patents provide a good measure of the creation of new technologies and of the perceived and actual quality of top research universities. Nationally, university patents have increased ten-fold during the last 20 years, compared with a six-fold increase in industry patents. Patents earned by California universities indicate that they remain among the country's best with regard to research.[79]

As for employment prospects, overall Ph.D. unemployment rates are low. Surprisingly, however, Ph.D.'s have a higher unemployment rate (1.6%) than master's recipients in computer science (1%). Ph.D.'s in biology have the highest unemployment rate of any S&E discipline (2.1%), and the expected further increase in biology Ph.D.'s will not help this situation.

9.4 Resources

The majority (53%) of students attending public universities rely on research assistantships or teaching assistantships.[80] This compares to 42% of students in Independent institutions.

A UC Graduate Student Support Survey (2001) indicated that UC is losing good students who are getting better offers elsewhere. To meet the financial shortfall, UC asserts that it will need to increase spending an additional $215 million annually by 2010 to adequately support its graduate students. Private doctoral-granting universities face similar concerns.

[79] Zucker & Darby, p. 72.

[80] *National Science Board, Science & Engineering Indicators – 2000*, p. 6-30.

9.5 Discussion

Understanding the behavior of the market for Ph.D.'s is critical to the formulation of policy concerning the supply of scientist and engineers. Master's degree recipients in computer sciences, mathematics, and life sciences are sometimes more employable than doctoral degree recipients in the same disciplines, as evidenced by the differences in unemployment rates. Despite the fact that Ph.D.'s are the prime movers for creating new science and technology graduate students are often turned off from pursuing a doctorate because of a perception that there are already too many in the job market. However, the perceived "Ph.D. glut" fails to take into account disciplinary differences and the difference between people who are educated exclusively for employment in research universities and people who can work in research and development in the private sector, the K-12 or undergraduate sector. The issue here is that the Ph.D. in some academic science disciplines (e.g., life sciences and physical sciences) can be too narrowly focused. However, this is not true for engineering, where there is no "Ph.D. glut".

A fundamental problem is that the current funding and training system, one that puts graduate students in the position of apprentices to established scientists and that does not prepare students for careers outside of academic science, is crucial, in part, to the maintenance of the institutions of science. It is important to explain how the existing system of graduate education could be improved in training people for employment outside of academic science, particularly in disciplines such as engineering and computer science.

Ph.D. students should be better prepared to take up careers outside of academic research.

Some disciplines have undertaken steps to address the inappropriate distribution of Ph.D. graduates in certain disciplines. For instance, some policymakers have recently concluded that the rate of growth of graduate students in the life sciences should be restrained and that graduate education in the life sciences be reshaped along lines that are closer to those followed by professional schools and be given training that prepares them for employment in jobs outside of university-based research.

Postdoctoral fellows provide the highest skilled employees for existing high-technology firms and are frequently the initiators of links between those professors and their firms. Those links are key to the growth and success of the firms.

While some recent Ph.D.'s take postdoctoral positions for additional training, a recent NSF survey found that nearly 24% did so mainly because doing so was expected in their field, and 17% said that other employment was not available.[81]

[81] *National Science Board, Science & Engineering Indicators – 2000*, Text Table 3-14.

CRITICAL PATH OF GRADUATE SCHOOLS – DOCTORAL LEVEL

- **Ph.D.'s are very important to economic growth.**
- **A small number of top schools in California are responsible for the majority of innovation.**
- **Although California has many top research schools in the UC system and Independent sector, comparatively low levels of financial support for graduate students increase the difficulty of recruiting the best.**
- **Non-resident aliens earn over 30% of S&E doctorates.**
- **There is an increasing number of Ph.D.'s in relatively low paying postdoctoral positions in some disciplines (biology and physics), partially because their skills are directed more towards academe than industry.**

9.6 Doctoral Policy Options

1. **Encourage more California students to pursue graduate education to the Ph.D. level.**

   - Support the adoption of the six key recommendations from the recent UC Commission on Graduate Education and Support.[81] These include increasing the annual level of fellowship stipends; creating a program of repayable fellowships; incentive grants; industry-university internships; and more funding for non-resident graduate students. The Commission also recommends fundraising for a new graduate fellowships endowment.
   - Initiate a Cal Grant type of program to provide funding for students pursuing a doctoral degree in science or engineering.

2. **Improve doctoral completion rates for underrepresented populations.**

   - The demographic shift increasing the percentage of Latinos and other underrepresented students in the state has not been reflected in the number of Ph.D.'s awarded.

3. **Improve preparation for Ph.D.'s to enter industry in fields such as biological sciences and physics, for example, through programs involving industrial internships.**

[82] University of California Office of the President, Committee on Educational Policy Discussion Item 308, *Report of the Commission on the Growth and Support of Graduate Education*, September 13, 2001, p. 1.

CHAPTER 10 - CONTINUING EDUCATION

Continuing education programs are important to understand because they play a vital role in qualifying generally educated students with industry specific skills and competencies (e.g. a biology graduate with skills in clinical trials management, a literature graduate with technical writing skills, or a sociology graduate with project management skills). These programs also reflect industry trends and priorities at the regional level because they evolve out of regional needs for competencies.

Continuing education programs relate to immediate employment opportunities and are often subsidized or reimbursed by employers.

10.1 Relationships

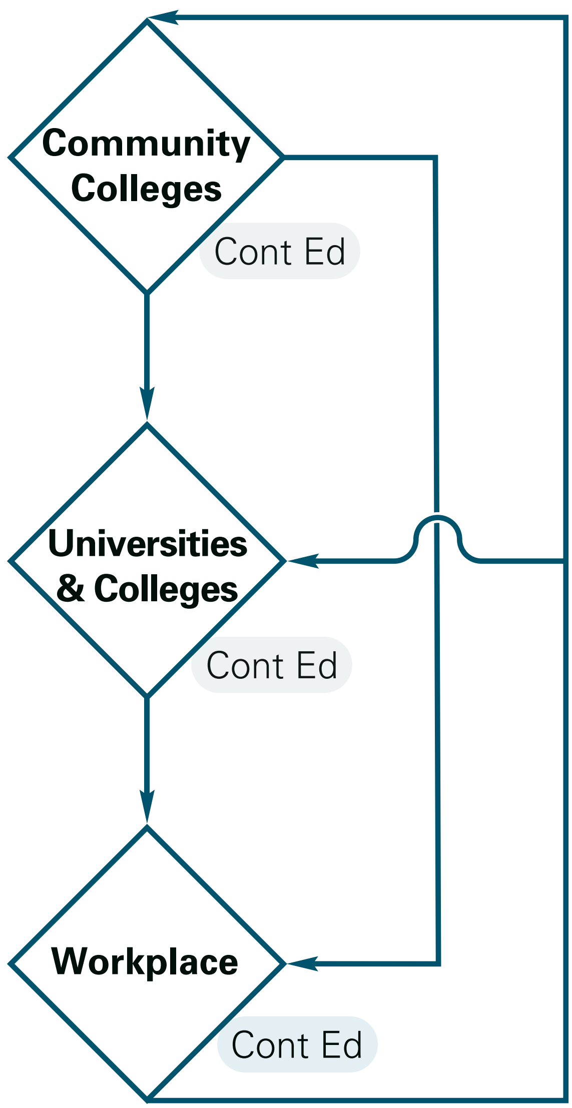

Figure 10.1: Continuing education flow diagram

10.2 Quantity and Quality

There are many institutions involved in continuing education in California. Conrad found that non-credit, post-secondary education and especially non-credit post-baccalaureate education represent a critical and underreported element of California's science and technology workforce development capabilities.[83] There are large annual enrollments in UC Extension and CSU Extended Studies courses. California Community Colleges also contribute significantly to California's post-secondary enrollments, although it is not possible to separate 'continuing education' students from the regular student body with existing data. In addition, hundreds of thousands of California's citizens participate in non-state-funded science and technology education and technology education and training programs. There are also many corporations, such as Motorola and IBM, with their own "corporate universities," which primarily exist to serve their own employees. We recognize the wide range of continuing education opportunities across the state and the important role of the Independent institutions and for-profit continuing education sector; however, due to the relatively limited scale of this study and limited availability of data, we have focused our inquiry on continuing education in UC and CSU.

The total number of adult learners participating in UC Extension programs is at least on the same order of magnitude as the total number of full-time UC students, and may be considerably higher.

Enrollments in UC and CSU continuing education programs can dwarf regular full-time enrollments on the same campus. Unduplicated head counts for Extension/Continuing Education programs are unavailable due to technical reporting difficulties at the campus level. Nevertheless, the number of working adults participating in Extension/Continuing Education training programs on an annual basis is enormous. In 1999-2000, combined degree enrollments at UC and CSU exceeded 520,000 while their combined Extension enrollments exceeded 700,000. UC Extension enrollments are four times larger than regular UC full-time enrollments. If we deflate these duplicate enrollments several-fold (a very conservative guess to adjust for the unknown duplication in headcounts), the total number of adult learners participating in UC Extension programs is at least on the same order as the total number of full-time UC students, and may be considerably higher. Furthermore, the student turnover rate is substantially higher in Extension programs compared to regular enrollments. In terms of workforce training, this means that Extension programs impact a large number of workers in a region over a very short period of time.

[83] Conrad, p. 2.

There is little data available on the role of continuing education programs at Independent institutions. Member institutions of the Association of Independent California Colleges reported granting over 16,300 degrees and certificates in 1999, only 14% of the total. However reporting is not consistent and it is almost certain that this number is too low.

A survey of students in two diverse regions in California show that most extension students are working adults since over 80% of the students are fully employed. The majority of these employed students are college graduates who have worked less than five years at their present employer. More than 50% work for mid-sized to large firms while less than 20% work for small firms. Over 90% indicate that course-taking activities are career related.

10.3 Resources

In the state of California, University Extension (or Continuing Education) programs are largely self-supporting. For example, at the University of California, over 90% of the program funding derives from student fees, with the rest coming from local, state and federal grants.

In a high-tech region more companies are prepared to pay for employees' continuing education.

In the San Diego region (a "high-tech" economy), approximately two-thirds of UCSD Extension students report receiving an employer subsidy. Over half report their employer paid 100% of the course costs including tuition and books. By comparison, in the Riverside region (a "low-tech" economy), approximately half of UCR students paid for their course(s) themselves. Of the students reporting employer subsidies, over 50% report working at a large firm (more than 500 employees). Only 10% report working for small firms (0-50 employees). Among the subset reporting no employer subsidy, fully one quarter of these students worked for small firms.

10.4 Discussion

In today's fast moving economy, job knowledge and skill requirements are changing so rapidly that workers at all levels require continuous re-education and training. The rise and fall of specific industries typically translate into an undersupply of highly skilled workers with specialized knowledge bases. Instead of viewing workforce training and investment as primarily an investment in training for specialized skills at many skill levels in specific industries, we must change our thinking to accommodate continuous upgrading of skills lifelong and "move up" strategies for all California workers.

Many high demand technical positions do not require four-year college degrees. Training for many of these positions may require only a modest cost, in terms of time and money – typically less than two years (several months in some cases) at a cost of less than $1,000. Continuing education programs, at the university or community college level can provide this type of technical training for college graduates from the liberal arts as well as highly motivated high school graduates.

There is little to no systematic data collected on:

- Workplace training by corporate education centers;
- Fee-based, practice-oriented courses offered by professional societies;
- Continuing education in law and medicine offered by the appropriate professional schools; and
- Continuing education certificates and other credential granting programs offered by every community college and publicly funded university in the state.

CONTINUING EDUCATION PROVIDES AN EFFECTIVE MEANS OF PRODUCING A SKILLED REGIONAL WORKFORCE, BUT IS POORLY MONITORED AT THE STATE LEVEL.

Non-credit, post-secondary education and especially non-credit post-baccalaureate education represent a critical and underreported element of California's science and technology workforce development capabilities. The data reveals large, annual enrollments in UC Extension, CSU Extended Studies and California Community College courses. A significant fraction of these students are taking courses or completing certificate programs that are directly relevant to science and technology fields and competencies.

The significance of these non-degree oriented post-secondary and post-baccalaureate continuing and professional education programs increases as the rate of technological change increases. Traditional degree programs may be too inflexible in format or have too many course requirements to meet the workforce training needs of regional industry.

CRITICAL PATH OF CONTINUING EDUCATION SYSTEM

- **Continuing education providers play a vital and often unrecognized role in qualifying generally educated students with industry specific skills.**
- **Typically these programs reflect local industry workforce needs but are not tracked sufficiently at the state level.**
- **State programs do not sufficiently support continuing education.**
- **There is a significant lack of regional demographic data on the effects of continuing education on the science and technology workforce.**

10.5 Policy Options

1. **Assign a state entity to comprehensively analyze the continuing education system.**

    - Centralize responsibility for gathering data on the varieties of institutions and programs addressing the science and technology continuing education and training needs of the state to an entity within the state of California.

2. **Reassess the state's role in continuing education.**

    - Direct the state to address such issues as what role it should play in providing access to these programs. Document the results and ensure that these programs adequately meet the training needs of the state's high-tech workforce.

3. **Encourage industry to expand support for employee participation in continuing education.**

CHAPTER 11 - WORKFORCE IMMIGRATION

Immigration is clearly responsive to demand conditions and is an alternative source of supply for the labor market in the United States.[84] Data from the Census 2000 Supplemental Survey with details about migration indicates that for California, out of a population of over 33 million, 16.7 million were born in California; 7.4 million were born in a different state; and 8.6 million were born in a different country. Of the foreign born, 3.3 million entered the U.S. between 1990 and 2000. Of the population above one year old, approximately 500,000 lived in a different state one year ago and 400,000 lived in a different country one year ago.

California is a net importer of technical talent.

Evidence suggests that this influx of immigrants, both from abroad and elsewhere in the country, has been crucial in filling high-tech jobs in California and that California is a net importer of technical talent. Despite the fact that the state has over 16% of the nation's high-tech jobs,[85] California grants no more than 9% of the nation's graduate degrees in science and technology. Moreover, at least 40% of S&E graduate degrees in California are awarded to foreign students who cannot enter the workforce directly. Betts estimates that between 1970 and 1990, California's universities produced only 53% of its net growth in college-educated adults during this period.[86] In other words, 47% of the increase in California's college-educated adults earned their degrees in other states or countries.

Twenty percent of job openings for computer and mathematics scientists are being filled by foreign-born workers.

One tangible indicator of the demand in the science and technology sector is the popularity of the H-1B visa program. The H-1B visa program allows a skilled foreign person to work for a maximum of six years in the United States. The H-1B visa holder must be in a "specialty occupation" – one that requires both the theoretical and practical application of a body of highly specialized knowledge and attainment of a baccalaureate's degree or higher in the specialized field. Although the H-1B visa program is not the only means of entry for skilled immigrants, backlogs in the processing of permanent visa applications have increased the attractiveness of the program.

11.1 Quantity

Before 1999, the upper limit on H-1B visas was 65,000 workers a year. In 1999 and 2000, the limit was raised to 115,000 workers a year and in 2001 the limit was again raised to 195,000 (Table 11.1). Approximately 163,200 workers were

[84] Romer, pp.29-30.

[85] Conrad, Table 2.1.

[86] Betts, p.1.

approved for H-1B visa status in fiscal year 2001.[87] Approximately 60% of approved petitions were for workers in computer-related and engineering occupations. Estimates are that the number of H-1B visa holders in 2001 is approximately 460,000.[88] If 60% are in science and engineering occupations (276,000), H-1B visa holders would only represent less than one percent of total employment in this sector. Estimates suggest that 20% of job openings for computer and mathematics scientists are being filled by foreign-born workers.

One source of information on immigrant labor is the U.S. Current Population Survey, which is a monthly survey of a national sample of households. It has information on citizenship status and year of arrival in the United States, but not on visa status. Nevertheless, it is possible to draw some inferences about H-1B visa holders by examining recent immigrants in skilled occupations. These data indicate that non-citizens are slightly better educated than citizens. The most recent immigrants are more likely than any other group to have a doctorate degree.

The report commissioned for this study from Cecilia Conrad describes the demographic characteristics of California's engineers, computer and mathematics scientists, natural scientists, and engineering and science technicians by citizenship status and year of arrival in the U.S. since 1994. Conrad also describes the composition of these occupations by immigrant status.[89] Sixteen and one-half percent of engineers are non-citizens and nine percent are potentially H-1B visa holders; 21.6% of computer and mathematics scientists are non-citizens and 14.7% are potentially H-1B visa holders. Among industries, computer manufacturing hosts the largest percentage of recent immigrants.

The H-1B visa system cannot substitute for the long-term development of California's own people resources.

The Immigration and Naturalization Service (INS) initiated a sample survey of H-1B visa petitions just three years ago, but the data collected is limited and as a result it is not currently possible to sort H-1B visa holders by geographic location.[90]

[87] Source: Immigration and Naturalization Service Statement, November 5, 2001, www.ins.gov/graphics/publicaffairs/statements/h1bfy2001rel.htm, accessed 4/3/02.

[88] B. Lindsay Lowell, *H-1B Temporary Workers: Estimating the Population, A Report for the Institute of Electrical and Electronic Engineers*, April 28, 2000, p. 2.

[89] Conrad, Table 3.5, p. 17.

[90] The INS does publish a list of employers with more than 50 H-1B visa petitions, but employers on this list may have locations in multiple states. In addition, a nontrivial percentage of H-1B visa holders are employed through intermediaries, personnel supply firms; e.g., the employer may be based in California, but the worker in Virginia.

Table 11.1: H-1B caps, 1998-2004

H-1B Caps
FY 1998: 65,000
FY 1999: 115,000+
FY 2000: 115,000+
FY 2001: 195,000
FY 2002: 195,000
FY 2003: 195,000
FY 2004: 65,000

Source: U.S. INS, 2000

11.2 Quality

As would be expected given the rules of the program, the H-1B visa holders tend to be better educated than the science and technology workforce as a whole. In a five-month sample of H-1B visas approved, 41% had a graduate degree (Figure 11.1). In addition to these high proportions, a recent survey found that most respondents reported facility in two or more software languages or systems.

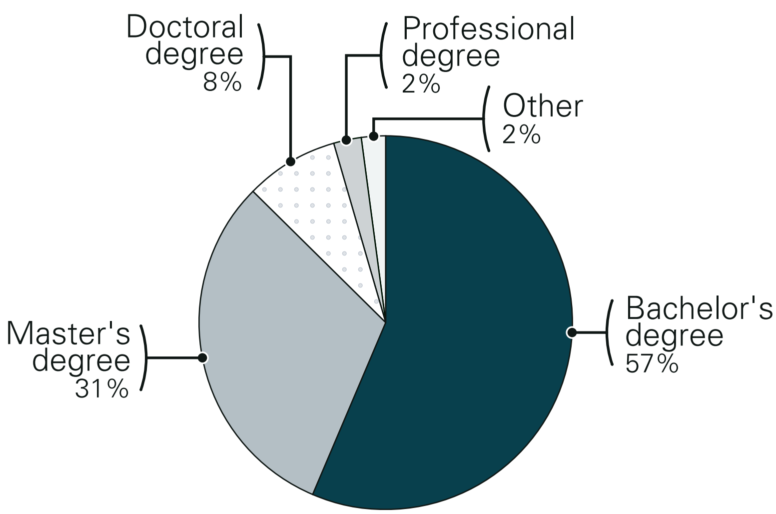

Figure 11.1: H-1B visas granted by degree, October 1999 - February 2000

11.3 Discussion

Employers are using the H-1B program to hire workers with slightly higher levels of educational attainment than their domestic workforce; they are using the program to hire workers with knowledge of specific software and programming languages; and they are using the program to hire workers with degrees in computer science or other technical fields.

The flow of H-1B immigrants helped to mitigate the tightness in the science and technology labor market over the past five years. As demand slackens in this labor market, the fate of this pool of skilled labor becomes uncertain.

Under the terms of the visa program, the H-1B visa is specific to the employer. An H-1B visa holder who is laid off has a limited time to either locate a new employer and obtain approval for a new visa or to return to his/her home country. The immigrant is not allowed to work during this time period. These rules have two potential implications for labor force dynamics. First, a slackening in demand for workers in the science and technology sector may not show up as an increase in unemployment rates. Second, a temporary decrease in demand (2-4 months) could lead to a contraction of longer-term supply (6-12 months) through the repatriation of this skilled workforce.

A survey found 41% of H-1B visa recipients had a graduate degree. Most also knew two or more software languages.

The H-1B visa system is a benefit to California since it provides elasticity of supply. However, it does not substitute for the long-term development of education and training programs for Californians. The program is also costly for employers; in addition to fees paid to the government, there are legal costs associated with making the case for a visa. Moreover, it must be asked how a society can justify bringing in non-resident aliens while ignoring the education of its own citizens who could be educated to fill these jobs. Finally, the national political consensus in support of continuing or expanding the H-1B visa program for skilled foreign workers may not last, particularly in economic hard times.

CRITICAL PATH OF WORKFORCE IMMIGRATION

- **California employers hire foreign-born workers as a solution to shortages of skilled domestic workers.**
- **Individuals with graduate degrees receive a high percentage (41%) of H-1B visas, and the balance hold a B.S. or its equivalent.**
- **The rise in the use of foreign-born workers underscores the inability of the California education system to produce enough skilled labor.**

11.5 Policy Options

A system of data collection is needed so that state policy makers can analyze the supply and demand of workers to track necessary changes in skill sets and provide feedback to the California educational system.

CHAPTER 12 - DIGITAL DIVIDE EFFECT ON CALIFORNIA

A complete picture of the ability of the state to produce a technically trained workforce is not complete without analyzing an individual's ability to access and use, in a meaningful way, computer and Internet related technologies. Therefore, this section is included in this report to examine the nature and magnitude of the digital divide in California. The digital divide refers to differences in the use of advanced information technology (computers and the Internet) among various socioeconomic and demographic groups. For the purposes of this discussion, we will look at the effects of the digital divide in California schools.

12.1 Quantity

There has been exceptionally rapid adoption of Internet access in K-12 schools.

After many years of a slowly shrinking ratio of students per computer in American schools, there has been exceptionally rapid adoption of Internet access in K-12 schools. Data from the U.S. National Center for Educational Statistics (NCES) reveal that from 1994 to 1999, the percentage of schools with Internet access in public schools grew from 35% to 95%; the percentage of instructional rooms that are connected to the Internet increased from 3% to 63%. Furthermore, by 1999, Internet connectivity methods had developed considerably beyond the assumption of slow dial-up modem connections—fully 64% of schools in 1999 had dedicated wide area networks (WAN) lines, with only 14% using dial-up.[91] And the classroom computers are not isolated from one another within these schools, as 84% of public schools reported use of local area networks (LANs) in 1999 (unfortunately not reporting what proportion of their classroom computers are connected to their LANs). California has continued to increase the number of schools with Internet access, expanding the total by 10% between 2000 and 2001. However, despite such advances, California ranked last in the country in students per computer with internet access in 2001.[92]

NCES data released in its February 2000 report demonstrated a significant digital divide in schools serving lower-income communities. Schools with the highest concentration of poverty had 16 students per instructional computer with Internet access, compared to seven among schools with the lowest concentration of poverty. And beyond such socio-economic status effects, there were important results for geographical region and for school size. Rural schools and smaller schools are ahead of city schools and larger schools in their provision of instructional computers with Internet access. In rural schools, there are seven students per computer but in city schools, 11 students per computer. In smaller

[91] *The Digital Divide*, ed. Roger G. Noll, CCST, March 2001, p. 44.

[92] American Electronics Association, *Cybereducation 2002*, January 2002, Appendix A, p. 100.

schools, there are six students per computer, but 10 students per computer in large schools.

12.2 Quality

It is not enough to simply place a computer in a classroom. Their effectiveness, as with any other educational resource, depends in large part upon the qualification of the teacher.

It is not enough to simply put a computer in a classroom. Its effectiveness depends on the teacher.

Most studies demonstrating improvements in student performance are extremely limited and do not take into account other factors which could account for changes in student performance or the actual manner in which computers are used. The more other factors affecting computer use are controlled for, the less impressive the gains. Wenglinsky analyzes data on computer use and test scores from the 1996 National Assessment of Educational Progress. The paper relates mathematics scores to four measures of computer use: "frequency of school use for mathematical tasks, access to home computers/frequency of home computer use, professional development of mathematics teachers in technology use, [and] higher order and lower-order uses of computers by mathematics teachers and their students."[93] Even after taking into account measures of family and school characteristics, several interesting correlations remain. The frequency of computer use at school and at home is related to lower outcomes for fourth graders. Home use is positively related to mathematics scores for eighth graders, and having a teacher trained with computers is related to higher scores for both grade levels. The use of computers for high-level skill instruction is also related to higher scores, while use of drills as the primary application is negatively related to outcomes. These findings suggest that in some cases increasing raw access to computers can actually depress student achievement.

This only implies, however, that there is more of a training issue than a resource issue. Access to computers is not the same as appropriately guided instruction; few would expect student performance to improve by dropping a pile of books into a classroom with no further instruction, yet this is essentially what has happened at local schools when computers are plugged in. Computer and Internet use is increasingly becoming an important life skill, with an ever-expanding list of civil services and resources available online – sometimes exclusively. Those without the skills to use the Internet effectively run the risk of becoming a new underclass, without the practical ability to access and/or use many of our society's online resources.

[93] Harold Wenglinsky, *Does it Compute? The Relationship Between Educational Technology and Student Achievement in Mathematics*, Policy Information Center at the Educational Testing Service Network, September 1998, p.25.

12.3 Discussion

Well-trained teachers and targeted applications with measurable outcomes are required to make computer use productive.

- There are still disparities in teacher training levels, the ways in which computers are used by students, home access to computers, and parental skills.
- Even if optimally implemented programs are cost-effective, current research shows little evidence that typical usage has significant benefits.
- Given the trends in high-poverty and digital access for home Internet use and school Internet use, we may conjecture that high-poverty level schools will not only have more under-qualified teachers, but less digital inclusion. [94] "Digital inclusion" for social mobility requires skills and knowledge ranging from basic literacy to new technical fluencies for participation—with different strategies for home, school, community, and work. There are skills and fluencies that Internet users will need to have available or to achieve in order to take real advantage of the Internet's resources for the diverse purposes of lifelong learning and living.

CRITICAL PATH OF THE DIGITAL DIVIDE

- **Use of computers and the Internet is becoming a critical life skill.**
- **The digital divide is not just an issue of resources; it is also an issue of training.**
- **California's high number of under-qualified teachers, especially in low-performing schools, severely impacts the effectiveness of placing computers in the classroom.**

12.4 Policy Options

- At least as much needs to be spent on software and teacher professional development as on hardware and Internet access for computers to have a positive effect on educational performance.
- Far more attention needs to be given to experimenting with the use of information technology and carefully monitoring the results.
- Targeting schools is a necessary but not sufficient condition for addressing the digital divide. Computer use in the home and in the public environment, such as community technology centers, is also important.

[94] *The Digital Divide*, p. 47.

Chapter 13 - Conclusions and Policy Recommendations

California is faced with a critical public policy challenge. Our own citizens are not being prepared in adequate numbers for important, challenging – and well-paid – science and technology jobs in the state's new economy. In the long run, this threatens to put at risk California's ability to compete in the global economy. Given the state's leading role in the technology sector, it will also jeopardize our national prosperity and security. Our continued way of life as a free, democratic society may well depend on how well we address this critical challenge. As the U.S. Commission on National Security concluded in 2001:

"Education is the foundation of America's future. Quality education in the humanities and social sciences is essential in a world made increasingly "smaller" by advances in communication and in global commerce. But education in science, mathematics, and engineering has special relevance for the future of U.S. national security, for America's ability to lead depends particularly on the depth and breadth of its scientific and technical communities." [95]

The challenge to the state is heightened by the fact that the state's emerging new majority (Latino, African American and Native American) is traditionally underrepresented in its colleges and universities and especially in S&E fields of study (and related careers). Absent concerted and collaborative effort by the segments of the state's educational system (K-Doctoral), with the support of the state government, the numbers of students who participate in S&E programs is likely to continue to decline.

Factors that affect the workforce gap include:

- Changing state demographics and challenge of making science and engineering study accessible to diverse populations lacking a tradition of college attendance and involvement in science and mathematics;
- Lack of mathematics and science preparation in middle and high schools;
- Lack of qualified mathematics and science teachers;
- Lack of understanding of science and engineering career opportunities and lack of motivation or interest to enter college level science and engineering programs;
- Lack of necessary mathematics and science background in students desiring entrance to science and engineering programs;
- Decrease of an already inadequate number of community college transfers into four-year science and engineering programs;
- Lack of S&E-specific educational transitions; and

[95] *The United States Commission on National Security for the 21st Century 2001*, p.39.

- Insufficient access to science and engineering baccalaureate classes, support services, facilities and other learning resources has caused a decline in perceived program quality by prospective students, parents and employers, contributing to the decline in enrollments and high program attrition rates.

13.1 Workforce Demand

California's science and technology sector continues to represent a large share of the California economy. The geographic distribution of science and technology employment in California is uneven. Hence, demand and skills needs may vary across the state.

High-tech jobs are high paying. Between 1997 and 2000, both employment and average annual payroll grew dramatically in computer related industries. Even though employment growth slowed in 2001, the longer-term projections are for continued job growth.

The science and technology sector requires a highly skilled labor force. Nearly 30% of jobs in this sector require a baccalaureate degree. Over 40% of jobs require some post-secondary education. Jobs require basic skills in mathematics as well as knowledge of specific operating systems and programming skills.

Ninety-six percent of the thousand largest employers say employees must have good writing skills to get ahead. By the new millennium, the student unpreparedness rate in writing at CSU had increased more than one-fifth – to 46%. The unpreparedness rate for mathematics is 42% in mathematics (down from 54% in 1988). At UC, at least a third of entering freshmen in 2000 were unprepared for college-level writing.

13.2 Supply

Problems in California's public schools appear to represent an important bottleneck in the state's efforts to increase the number of young people who go on to graduate from college. The majority of college educated adults living in California came from other states or abroad; California natives comprise less than a third of college graduates living in the state.[96]

Women of all races, African American men and Latino men represent underutilized pools of potential labor in the science and technology sector. Differences in educational attainment and in choice of major (by women) contribute to their under-representation in science and technology occupa-

[96] Betts, Figure 1.1, p. 2.

tions and industries, but are not sufficient to explain differential rates of employment.

Students from ethnicities that are traditionally underrepresented at the state's public universities, Latinos, African Americans, and Native Americans, also tend to receive fewer resources than do students who are white or Asian. However, inequality in resources appears to be somewhat more strongly related to student poverty than to student race.

Employers have used the H-1B visa program to hire workers who have higher levels of educational attainment than domestic workers performing the same jobs. At the end of the 1990s, this program probably eased the tight labor market conditions, but there is uncertainty surrounding the fate of H-1B workers during periods of slack demand.

Continuing education "move up" strategies view workforce training as providing continuous skills improvement for a wide spectrum of workers so that all workers progress steadily up the ladder to fill jobs requiring higher skill sets than they presently possess. If the high-demand, high-skill jobs could be filled with strategic education and training programs aimed at general baccalaureate level workers, then more middle level positions (i.e. "less highly skilled, less in demand" positions) could open up for high school and community college graduates with appropriate education and training. In turn, those semi-skilled jobs currently held by high school and community college graduates could then be open to currently unemployed or underemployed citizens, with proper training. In order to account for the interdependencies between the myriad systems of education and training across a diverse range of industries and skills, policymakers must pursue monitoring, planning and funding for a wide continuum of workforce education and training programs.

Alternative policy programs could be used to fill the gap created by an exclusive reliance on demand-side subsidies, one that works directly to increase the supply of scientific and engineering talent. Goals should be conservative and should represent objectives that are neither risky nor radical and for which there is a broad base of intellectual and political support. They should also include metrics for measuring success.

In this report, the shortcomings of the K-12 system are outlined, particularly the issues of teacher quality and the high dropout rate. The community college system is identified as having a pivotal role for many first time college goers and serves as a key resource for remediation when necessary. Problems at the baccalaureate level include the low college-going rate and inadequate support for expensive S&E programs. At the graduate level, there is excessive reliance on students from abroad. The continuing education system is identified as an essential ingredient for lifelong learning, but its use is very poorly documented.

13.3 Policy Strategy

Policies must be developed to support a comprehensive state education strategy to significantly increase participation by Californians in the S&E workforce, through pursuit of the following overarching goals:

GOAL 1 Increase student participation and success in mathematics, science, and technology subjects at all levels from kindergarten through the doctoral level. To achieve this goal, priority should be given to: (a) expanding student awareness of S&T career opportunities available through the study of science, mathematics, and technology; (b) educating a new generation of science, mathematics, and technology teachers and faculty and ensuring that all schools and institutions of higher education are staffed by qualified teachers and faculty; and (c) propagating effective pedagogical models, with the ability to excite and engage students in the study of science, mathematics, and technology.

GOAL 2 Achieve targeted increases in college and university S&E program enrollments, degrees, and quality indicators, at the associate, baccalaureate, master's, and doctoral levels, through comprehensive, collaborative, focused and sustained efforts by the community colleges, UC, CSU, and Independent university sectors to plan for, implement, and evaluate S&E programs. This includes leveraging federal and private support for public and private institutions as well as state support, and encouraging industry sector-specific initiatives that seek to vertically integrate public-private investments in education with the workforce needs of industry.

GOAL 3 Overcome the resource adequacy problems related to the maintenance and expansion of higher cost college and university science and engineering programs in public institutions.

GOAL 4 Expand the state's capacity to gather data on and plan for the variety of institutions and programs addressing California's S&E continuing education and training needs.

California needs to undertake a comprehensive strategy to address these goals. We need a "systems approach", as piecemeal reform efforts cannot address the full scope of the problem. However this strategy should be undertaken in concrete steps by prioritizing the most effective methods first. The state needs to focus on measurable metrics and then specify a number of different strategies with their accompanying costs and conjectured contributions to these objectives. The policy options detailed in the previous chapters comprise what we believe to be the most important, feasible and effective steps needed to achieve these objectives. Implementation of some or all of these policy options should however represent only the beginning of California's "systems approach" to S&E education.

In addition to the aforementioned segment-specific policy options, state leaders could develop further resources to enhance the success of California's S&E education system, such as:

1. State-produced marketing materials that highlight pathways from undergraduate degree majors in S&E to career tracks, which underscore average annual income differentials from other majors and likely lifetime earnings;
2. Robust state-developed/funded e-learning programs for the core mathematics – that is demonstrably a bottleneck to mathematics and science courses taking in the 8th grade and beyond, which limits the possibility of students feeling proficient enough to become a major in S&E disciplines; and
3. An S&E career development pathway website that would be made broadly useful for high school counselors and parents, for "steering" students on a S&E course-taking highway so they keep their eyes on the prize, get reminders (email, mail) if they are not making their way to the a-g requirements, and so on.

Other steps could include the introduction of training grants to universities that could be used to increase the fraction of undergraduates who receive degrees in natural science and engineering; a system of exams that gives objective measures of undergraduate achievement in natural science and engineering; and a type of fellowship, backed by a substantial increase in funding, for students who continue their studies in graduate school. In addition, we recommend additional use of training grants, such as the NASA & NDEA training grant programs. For all measures undertaken, it is important to understand that long-term intervention is needed.

Finally, the earning potential of S&E graduates in the labor market must be recognized when developing hiring strategies for S&E teachers at all levels. It is very difficult, if not unrealistic, to expect that the state will be able to attract sufficient numbers of qualified S&E degree holders to teach in the K-12 system, community college system, and CSU, when none of these segments is able to offer differential salary scales.

California remains, for the moment, the nation's leading science and technology state. It seems clear, however, that the state's educational system has steadily fallen behind in the production of science and engineering graduates over the past two decades. California's educational institutions, industry, and government will need to cooperate on an unprecedented scale, building new relationships and working together towards mutually defined goals, if the state is to sustain its position as a global leader in high-technology. It is our hope that the Critical Path Analysis presented in this report can be used to facilitate this process.

APPENDICES

APPENDIX A: List of Principal Investigators

Julian Betts

Professor, Department of Economics
University of California, San Diego

Julian Betts is a Professor with the Department of Economics at the University of California, San Diego. He is also a Senior Fellow with the Public Policy Institute of California and an Adjunct Professor in the Graduate School of International Relations and Pacific Studies at the University of California, San Diego.

He received his Ph.D. in economics at Queen's University, Kingston, Ontario in 1990 and a M.Phil. degree in economics at the University of Oxford in 1986. Dr. Bett's research interests include labor economics, economics of education, applied econometrics, and applied microeconomics. Dr. Betts is one of five members of the national nominating committee of the Association for Public Policy Analysis and Management and a member of the board of directors of the Preuss School at UCSD.

Cecilia A. Conrad

Associate Professor of Economics
Pomona College

Cecilia A. Conrad is an Associate Professor of Economics at Pomona College. Dr. Conrad received her master's and doctorate in economics from Stanford University and her bachelor's degree from Wellesley College. Prior to joining the faculty at Pomona, Professor Conrad taught at Duke University and at Barnard College, Columbia University. Her research focuses on the economics of inequality and the economics of the family. She is a member of the board of economists of Black Enterprise Magazine and of the American Economic Association's Committee on Economic Education. Professor Conrad is director of the American Economics Association's pipeline project to increase the number of minority doctorate holders in economics. She is a past president of the National Economic Association, and a past board member of the Committee on the Status of Women in the Economics Profession.

Michael R. Darby

Warren C. Cordner Professor of Money and Financial Markets
John E. Anderson Graduate School of Management
University of California, Los Angeles

Michael R. Darby is the Warren C. Cordner Professor of Money and Financial Markets in the John E. Anderson Graduate School of Management in the Departments of Economics and Policy Studies at the University of California, Los Angeles, and is Director of the John M. Olin Center for Policy in the Anderson School. Concurrently, he holds appointments as Chairman of The Dumbarton Group, Research Associate with the National Bureau of Economic Research, Consulting Economist with City National Bank, and Adjunct Scholar with the American Enterprise Institute. He also serves as Associate Director for both the Center for International Science, Technology, and Cultural Policy in the School of Public Policy & Social Research and the Organizational Research Program of the Institute of Social Science Research at UCLA.

Dr. Darby received his A.B. summa cum laude from Dartmouth College, and his M.A. in 1968 and Ph.D. in 1970 from the University of Chicago.

Carolyn Lee

Coordinator of Public Programs, Extended Studies and Public Programs
University of California, San Diego

Carolyn Lee is the Coordinator of Public Programs with the Extended Studies and Public Programs at the University of California, San Diego. Dr. Lee is the former Director of Research for UCSD CONNECT. She is working with Vice Chancellor Mary Walshok on projects to identify the emergence of social networks among San Diego's high-tech companies and research institutions. She is attempting to document and quantify the extensive linkages between San Diego's research institutions and their spin-off companies. Dr. Lee has an extensive background in technology transfer from UCSD, UCI and UCLA. She holds a Ph.D. in chemistry from MIT and an M.A. in public policy from UCSD's Graduate School of International Relations and Pacific Studies.

Mary Lindenstein Walshok

Associate Vice Chancellor for Public Programs
University of California, San Diego

Mary Lindenstein Walshok is Associate Vice Chancellor for Public Programs, Dean of University Extension and Adjunct Professor in the Department of Sociology at the University of California, San Diego. In this capacity, she is responsible for the University's self-funded continuing education and outreach programs with an annual budget of more than $27 million.

Dr. Walshok received her B.A. (1964) from Pomona College and her M.A.(1966) and Ph.D. (1969) in sociology from Indiana University. She has been associated with UCSD since 1972 and has remained active as an industrial sociologist, authoring numerous book chapters and articles on education, the world of work, the role of research institutions in the "new economy," and the education and training challenges of knowledge-based companies.

Lynne G. Zucker

Professor of Sociology and Policy Studies
University of California, Los Angeles

Lynne G. Zucker currently serves as Professor of Sociology (1989-present) and Policy Studies (1996-present), Director (1986-present) of the Organizational Research Program at the Institute for Social Science Research and Director (1996-present) of the Center for International Science, Technology, and Cultural Policy in the School of Public Policy & Social Research at the University of California, Los Angeles. Concurrently, she holds appointments as Research Associate with the National Bureau of Economic Research, as Consulting Sociologist with the American Institute of Physics, and is a member of the affiliated faculty of the UCLA School of Education.

Professor Zucker received her A.B. with Distinction in sociology and psychology from Wells College in 1966. She took her M.A. in 1969 and Ph.D. in 1974 from the Sociology Department of Stanford University.

APPENDIX B: Critical Path Analysis Committee

Warren J. Baker

President
California Polytechnic State University, San Luis Obispo

Warren J. Baker, a registered civil engineer in four states, has been President of Cal Poly San Luis Obispo since 1979. Prior to his appointment, Dr. Baker served as Chief Academic Officer and Vice President at the University of Detroit and was Chrysler Professor and Dean of the College of Engineering.

President Baker was educated in civil engineering with Bachelor of Science and Master of Science degrees from the University of Notre Dame in civil engineering. His Ph.D. is in geotechnical engineering from the University of New Mexico.

He has published more than 35 papers on technology, distance learning, geotechnical engineering, risk analysis, and engineering education.

Susan Hackwood

Executive Director
California Council on Science and Technology

Susan Hackwood is currently Executive Director of the California Council on Science and Technology and Professor of Electrical Engineering at the University of California, Riverside.

Dr. Hackwood received a Ph.D. in solid state ionics in 1979 from DeMontfort University, UK. Before joining academia, she was Department Head of Device Robotics Technology Research at AT&T Bell Labs. In 1984 she joined the University of California, Santa Barbara as Professor of Electrical and Computer Engineering and was founder and Director of the National Science Foundation Engineering Research Center for Robotic Systems in Microelectronics.

In 1990, Dr. Hackwood became the founding Dean of the Bourns College of Engineering at the University of California, Riverside. Dr. Hackwood's current research interests include science and technology policy, distributed asynchronous signal processing and cellular robot systems. She has published over 140 technical publications and holds 7 patents.

Charles F. Kennel

Director, Scripps Institution of Oceanography
University of California, San Diego

Charles F. Kennel is author or co-author of over 250 experimental and theoretical publications in his field. He has been a Fulbright and Guggenheim scholar, and a Fairchild Professor at Caltech. He is a fellow of the American Geophysical Union, the American Physical Society, and the American Association for the Advancement of Science, and a member of the International Academy of Astronautics; the National Academy of Sciences and the American Academy of Arts and Sciences. His many awards include the NASA Distinguished Service Medal; the James Clark Maxwell Prize, American Physical Society; and the Aurelio Peccei Prize for Environmental Science. He serves on advisory panels and boards including the NASA Advisory Council.

C. Judson King

Provost and Senior Vice President, Academic Affairs
University of California

C. Judson King is Provost and Senior Vice President of Academic Affairs at the University of California, and continues as Professor of Chemical Engineering on the Berkeley campus, a position he has held since 1969. Dr. King was previously the Vice Provost for Research for the UC System and was Provost, Professional Schools and Colleges; Dean of the College of Chemistry; and Chair of the Department of Chemical Engineering, all on the Berkeley campus. He is a member of the National Academy of Engineering, and was recently honored by the Executive Board of the Yale Science and Engineering Association with its award for Distinguished Service to Industry, Commerce or Education. He is a former Director of AIChE, Chair of the Council for Chemical Research, and Chair of the Chemical Engineering Division of the American Society for Engineering Education, and was founding Chair of the Separations Division of AIChE. His research interests center around separation processes, presently spray drying and the use of reversible chemical complexation for recovery of polar organics (carboxylic acids, glycols, etc.) from aqueous solution.

Dr. King graduated from Yale University in 1956 with a B.E. in chemical engineering and later received his S.M. and Sc.D. in chemical engineering from the Massachusetts Institute of Technology.

Victoria P. Morrow

Vice Chancellor, Educational Services and Economic Development
Chancellor's Office
California Community Colleges

Victoria P. Morrow has a B.A. in Spanish from Pomona College, an M.A. in Spanish from Columbia University, Teacher's College, an M.S. in sociology from Texas A&M University, and a Ph.D. in sociology from the University of Colorado. She served at Chabot College from 1974-1998 in many capacities: as an instructor of Sociology, Chair of the Curriculum Committee, Faculty Senate President, Division Chair for Social Science, Associate Dean for Natural and Applied Sciences (including the role of vocational education dean), and Vice President for Academic Services. Dr. Morrow was also President of the Chief Instructional Officers, California Community Colleges, and served on the executive board of that organization for 7 years. She has served as Vice Chancellor for Educational Services and Economic Development, California Community Colleges, since 1998, leading efforts to strengthen and expand the system's workforce and economic development programs and to develop and implement a technology plan for the system.

Lawrence T. Papay

Sector Vice President, Integrated Solutions Sector
Science Applications International Corporation (SAIC)

Lawrence T. Papay recently joined SAIC as the Sector Vice President for the Integrated Solutions Sector. Prior to joining SAIC, Dr. Papay was the Senior Vice President and General Manager of Bechtel Technology & Consulting.

Dr. Papay received a B.S. in physics (1958) from Fordham University, an M.S. in nuclear engineering (1965), and an Sc.D. in nuclear engineering (1969) from the Massachusetts Institute of Technology (MIT). He is a nationally recognized authority in engineering, science and technology. He currently serves on numerous special committees, panels, and task forces including the President's Council of Advisors on Science and Technology, and the Secretary of Energy Advisory Board. He is a member of the National Academy of Engineering, National Science Foundation, National Research Council, American Nuclear Society, and Electric Power Research Institute. He is a registered Professional Engineer (Nuclear) in California.

Roy D. Pea

Professor of Education and the Learning Sciences
Executive Director, Stanford Institute for Learning Sciences and Technologies
Stanford University

Roy D. Pea joined Stanford's School of Education in September 2001 as Professor of Education and the Learning Sciences. In addition to teaching, Dr. Pea is also the Executive Director of the new Stanford Institute for Learning Sciences and Technologies. The Institute is one of several major programs of the Stanford Center for Innovations in Learning, which Dr. Pea co-directs. He also directs the multi-institutional Center for Innovative Learning Technologies (http://cilt.org), funded by the National Science Foundation.

Prior to accepting his new position at Stanford University, Dr. Pea was Co-Director of the Center for Technology in Learning at SRI International, formerly Stanford Research Institute, in Menlo Park, California.

In 1978, he received his doctorate in developmental psychology from the University of Oxford, England, where he was a Rhodes Scholar.

Karl S. Pister

CCST Board Chair
Former Vice President-Educational Outreach, University of California, Office of the President, and Chancellor Emeritus, University of California, Santa Cruz

Karl S. Pister, Chair of the governing board of the California Council on Science and Technology, is former Vice President-Educational Outreach, of the University of California and Chancellor Emeritus of the University of California, Santa Cruz. Prior to retirement he completed five decades of service to higher education, beginning his career in higher education as Assistant Professor in the Department of Civil Engineering at UC Berkeley. He served as Chairman of the Division of Structural Engineering and Structural Mechanics before his appointment as Dean of the College of Engineering in 1980, a position he held for ten years. From 1985 to 1990 he was the first holder of the Roy W. Carlson Chair in Engineering; from 1991-1996 he served as Chancellor, University of California, Santa Cruz.

Dr. Pister received his B.S. and M.S. in civil engineering from the University of California, Berkeley, and his Ph.D. in theoretical and applied mechanics in 1952 from the University of Illinois, Urbana-Champaign.

James M. Rosser

President
California State University, Los Angeles

Since 1979, James M. Rosser has served as President of California State University, Los Angeles, a preeminent urban university that offers programs in more than fifty academic and professional fields, has an annual enrollment of approximately 22,000 students, and has granted degrees to more than 150,000 graduates. His background is in the field of health care delivery and he also holds an academic appointment as Professor of Health Care Management at the university.

Dr. Rosser earned academic degrees in health education and microbiology from Southern Illinois University at Carbondale (Ph.D. 1969, M.A. 1963, B.A. 1962).

Prior to his appointment at Cal State L.A., Dr. Rosser served for five years as Vice Chancellor of the State of New Jersey Department of Higher Education and was appointed Acting Chancellor in 1977.

AnnaLee Saxenian

Professor, Department of City and Regional Planning
University of California, Berkeley

AnnaLee Saxenian is a Professor of City and Regional Planning at the University of California at Berkeley. She is an internationally recognized expert on regional development and the information technology sector. Her current research examines how immigrant engineers are building networks linking Silicon Valley to regions in Asia.

Dr. Saxenian is currently an Affiliate of the San Francisco-based Institute for the Future (IFTF), a visiting Senior Fellow at the Stanford Institute for Economic Policy Research and an Adjunct Fellow at the Public Policy Institute of California. She has held teaching positions at the Massachusetts Institute of Technology (MIT), Harvard University, and the Chinese University of Hong Kong.

She holds a doctorate in political science from MIT, a master's degree in city and regional planning from the University of California at Berkeley, and a bachelor's degree in economics from Williams College in Massachusetts.

George M. Scalise

President
Semiconductor Industry Association (SIA)

George M. Scalise has had a long career in the semiconductor industry and is currently serving as President of the Semiconductor Industry Association (SIA). He is a leader and a spokesman for the industry before the U.S. Congress, foreign leaders and related industry leaders. Prior to joining the SIA, he was the Executive Vice President of Operations at Apple Computer. He has served and continues to be involved with numerous board and advisory commissions that include SEMATECH, the U.S. Department of Energy Advisory Board, the Leavey School of Business at the University of Santa Clara, and the Engineering Board of Councilors at the University of Southern California.

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We wish to extend our sincere appreciation to the reviewers listed below, whose expertise and diligence in reviewing the Critical Path Analysis and its associated projects have been invaluable, both in rigorously honing the accuracy and focus of the work and in ensuring that the perspectives of their respective disciplines and institutions were taken into account. Without the insightful feedback which these reviewers generously provided, the Critical Path Analysis could not have been completed.

In addition, special thanks go to Dan Howard-Greene of California Polytechnic University, San Luis Obispo, whose assiduously detailed feedback on many successive drafts of the report has been enormously helpful. His contributions not only to the review process but to the composition of the Critical Path Analysis have been instrumental in the successful completion of the report.

Finally, we would also like to acknowledge Marsha Hirano-Nakanishi, Assistant Vice Chancellor, Analytic Studies, California State University Office of the Chancellor; Sandra Smith, Assistant Vice President, Planning and Analysis, University of California, Office of the President; and Carol Copperud, Special Assistant, Planning and Analysis, University of California, Office of the President, for their generous assistance in providing detailed and crucial data from their respective offices, as well as Marjorie Suckow of the California Postsecondary Education Commission (CPEC), who has valiantly striven to accommodate our numerous (and always urgent) requests for data above and beyond what is publicly available on the online CPEC databases.

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