

Scientists and Engineers for the New Millennium: Renewing the Human Resource

*A Collection of the
Commission on Professionals in
Science and Technology*

*Sponsored by
The Alfred P. Sloan Foundation*

March 2001

*Daryl E. Chubin
Willie Pearson, Jr.
editors*

The views expressed in this document are the editors' and authors' alone. They do not necessarily reflect the institutions for which they work.

Dedicated To:

Sharlene Krantz, wife, and Avram Fechter, son of
Alan Fechter

and

Richard C. Vetter, husband of
Betty M. Vetter

The memory of Alan and Betty continue to inspire us . . .

Table of Contents (cont.)

Part III. What Can We Do?	61
Chapter 9. Two Ships Passing in the Night: Science Careers and Science Education Paula M. Rayman	63
Chapter 10. How We (Unintentionally) Make Scientific Careers Unattractive Michael S. Teitelbaum	71
Chapter 11. Lack of Minority Leadership: Possible Causes and Plausible Solutions Richard Tapia	81
Postscript	87
Editor and Author Biographical Sketches	94

Acknowledgments

This collection would not have been possible without the generous support of the Alfred P. Sloan Foundation. We are grateful to the Foundation not only for making this volume possible, but also for their continuing commitment to the collection and analysis of data on research, education, and careers in science and engineering. Michael Teitelbaum, Sloan Project Director, deserves special thanks, both as a contributor and as a colleague to the Commission on Professionals in Science and Technology.

We cannot express the depth of our appreciation to Eleanor Babco and the dedicated staff of the Commission. Eleanor has worked diligently to help us transform an all-day symposium held at a AAAS meeting into a timely volume designed for a variety of audiences and purposes. And she did it in record time!

Finally, as editors we are proud to acknowledge the individuals who contributed to the collection. They responded to our intermittent hectoring for the better part of a year with chapters that reflect the highest standards of scholarship and caring. We are blessed by their collegiality and devotion to the cause of human resource development.

Daryl E. Chubin and Willie Pearson, Jr.

Introduction

Origins

This collection grows out of an all-day symposium that we organized for the annual meeting of the American Association for the Advancement of Science (AAAS), which was held in February 2000 in Washington, DC.* The origins of the book, however, extend far deeper into a community, a literature, and our respective efforts as policy-conscious scholars to understand a problem for U.S. society that persists, nags, and frankly torments us – the determinants of who participates in science and technology.

The AAAS symposium sought to honor the memory of two close colleagues who were instrumental in harvesting the research, programmatic, and policy lessons of human resource development for science and technology (S&T). Through the Washington, DC-based data and analytic organization known as the Commission on Professionals in Science and Technology (CPST) <www.cpst.org>, Betty Vetter, the Commission's long-time executive director, and Alan Fechter, its past president and Executive Director, Office of Scientific and Engineering Personnel at the National Research Council, inspired most of the authors in this volume.

The work of Betty Vetter and Alan Fechter illuminated the formidable challenges posed by changing demographic, education, hiring, and career trends affecting S&T. As a decidedly data-based assembly, we assert that the latest information, scrutinized for accuracy and formatted for use by major categories of stakeholders – researchers, educators, administrators, students, and policymakers – is the preferred route to informed action. Those featured here have long been dedicated to deepening and applying – from classroom to boardroom – their understanding of supply, demand, composition, and utilization of science and engineering personnel.

The last comprehensive effort to frame human resource issues facing S&T was the 1994 book, *Who Will Do Science?*, edited by Pearson and Fechter. Although much has changed with the turn of the century, too much has regrettably remained the same. From educational preparation to workforce entry, promotion, and leadership, some segments of the population are welcomed and cultivated as scientists and engineers. Other segments that comprise a growing fraction of the population, start behind and stay behind. Too few – notably students of color, women, and persons with disabilities – catch up, persevere, excel, and complete degrees.

* The Richard Tapia addition to this collection was produced in preparation for a national forum held October 1999 in Houston, TX, and has been captured in “Promoting National Minority Leadership in science and Engineering: A Report on Proposed actions.” Richard Tapia, Daryl Chubin, and Cynthia Lanus, Rice University, October 2000 <http://ceee.rice.edu/Books/DV/leadership/index.html>.

Purpose

Our rationale is one that we hope other stakeholders embrace: In the 21st century, S&T is too important to American, indeed global, society, to allow its human resources to remain unplanned, uncoordinated, market-driven afterthoughts of a university-centered R&D system. We continue to draw certain segments of the population, repel others, import many, and waste much. Indeed, human resource issues encompass all sectors of the economy, types of institutions, career paths, and the composition of “talent pools” advancing throughout formal education and into the workforce.

Therefore, questions about participation – disaggregated by gender, race, ethnicity, disability, citizenship status, age, field, degree level, work activity, industry, and many more familiar dimensions of analysis – dominate this collection. But we offer something far different from a “data dump.” The book looks at all aspects of human resource development and utilization *together*. This approach has two advantages: first, people are seen as the main business of science and technology, not a byproduct of research and the decentralized, uneven, U.S. system of early childhood through postdoctoral preparation; and second, a more realistic examination is possible of institutional roles, responsibilities, and practices that will benefit the *system* as well as individuals within it – not just some participants, certain career choices, and select organizations.

Lest we forget, the Federal Government has intervened in the process of human resource development since at least the GI Bill, the National Defense Education Act of 1958, the civil rights legislation of the 1960s, Title IX in 1972, and the Americans With Disabilities Act of 1990. At the graduate level, Federal policy has always favored scientists and engineers as a national resource. But to this day, we have no Federal human resource development policy for S&T, last promised in the 1994 Clinton-Gore blueprint, *Science in the National Interest*.

However, the Clinton Administration has produced two reports germane to the topic at hand: *Meeting American’s Needs for the Scientific and Technological Challenges of the Twenty-First Century*, A White House Roundtable Dialogue for President Clinton’s Initiative on Race (produced by the Office of Science and Technology Policy, May 1999), and *Ensuring a Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century*, A Report of the National Science and Technology Council (March 2000). In addition, *Land of Plenty*, the Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development (September 2000), details the national imperative of a diverse workforce.

Given the repeal of affirmative action programs as we know them, the influx of foreign nationals in our graduate schools, and the technological challenges posed to education (especially K-16) by e-commerce, there is an array of human resource issues to weigh for action by all of us. The scholars here seek to do just that.

The collection distinguishes “What We Know” about who is being recruited, educated, and trained for careers in science and technology from “What We Need To Know.” Moreover, it identifies the data gaps, what information is needed to close them, and what issues emerge from human resource dilemmas of preparation and utilization? Then the authors turn to “What Can

We Do?” to discuss the policies and strategies that have worked and need to be institutionalized, or transferred to new settings. What are the startup and continuing costs of such efforts that we can expect to incur?

Contents and Uses

The three sections of the collection feature timely data and analyses that would be of practical use to researchers, educators, administrators, and policymakers alike. The text accompanying the numbers is short and interpretive. A concluding essay serves as a postscript for underscoring not only issues, but also an agenda for research and policy action.

In addition to use as a source in research, the collection could be used as a supplementary text in courses focused on human resources, from studies of work and the professions to science, technology, and society; public policy; management of technology to education, gender, or ethnic studies. Each section is preceded by a brief description that puts them into the context of human resource issues of the day. In addition, we offer a list of questions that prompted the original papers or anticipated themes that were likely to emerge from the discussion.

Part I – What We Know

We are writing this on a frigid morning in December 2000 when a headline on the front page of the *Washington Post* “Metro” section announces “Counting in the Math Field – 3 Ph.D. Candidates Become Trailblazers at U-Md. Graduation.” The story warms us, but a chill lingers. Of the 1119 Ph.D.s in mathematics awarded in 1999, only five were earned by African American women. Three awarded by one institution in 2000 is spectacular – but the exception, to be sure. In all fields of science and engineering, doctorates received annually by minorities – African Americans, Hispanics, and American Indians – remain in the *hundreds*. Women in these fields, while growing in number, earned around 7000 Ph.D.s in 1998.

Such disaggregated trends describe the pool of scientists and engineers – from formation in elementary and secondary education through college enrollment and subsequent degree-taking. Description alone does not account for the factors influencing who is prepared, selects a certain major, completes a degree, aspires to a particular career, and achieves in ways that reflect positively on science and engineering. As one of the new math Ph.D.s observes in the *Post* article, even at the graduate level, “When young women get into these classes where the teachers are men, the teachers call on the men more often. It’s not that women don’t have a knack for it, it’s that they’re not encouraged.”

This section asks “who is participating in S&T education and employment?” It establishes an empirical baseline by providing a rich disaggregated view of who is being prepared for, and who is advancing through, successive stages of S&T degree-taking. Opportunities are not uniform. Members of different groups and categories experience different classroom “climates” and react differently. Some leave, other resolve to persist. All as a result are probably changed significantly as personalities and professionals.

Babco and Golladay characterize, through major databases, the national workforce: its size, education, occupational specialization, principal work activities, mobility, and likely future composition given the issues of aging, citizenship, and quality. **Czujko** focuses on a single field, physics, during the last decade of the 20th century. It was a time of decline of interest in this college major, and perhaps more, but surely the “pipeline” metaphor should be abandoned for a construct that captures the complexity of education and career choice. **Fox** hones in on women in science and engineering, summarizing their choices and outcomes in education and academic performance. She concludes that “the relationship between gender, education, and status . . . is not a simple, linear progression.” **George, Van Horne, and Malcom** examine the shifting ground of affirmative action and how changes in law and policy are affecting graduate school enrollments of underrepresented minorities in science and engineering at our research universities. The results are not pretty and the trend lines are ominous. Finally, **Kuh** ponders for the S&T workforce what the Clinton Administration put on the national agenda: does the workforce look like America? Because diversity includes immigrants, U.S. minorities, and women, she asks what constitutes “underrepresentation” and reminds us that denominators matter.

While each reader can decide, based on these chapters, what it is we know and with what confidence, there are some questions to bear in mind:

1. Graduate enrollments in science and engineering (S&E) have declined for five consecutive years. Yet demand and hiring is brisk in a robust economy. What do these trends portend? And how does the national “big picture” offer misleading views once trends are disaggregated by major demographic, disciplinary, and sectoral categories?
2. Since the S&E workforce is projected to grow three times faster than other occupations, what are the primary challenges that national data illuminate – aging, sectoral differences in opportunity, increasing opportunity by those traditionally underparticipating?
3. Both the “single” and “double bind” hypotheses continue to be sustained empirically, i.e., being a woman, a minority, or both is a deterrent to success in S&E. What, then, are the prospects of career opportunity and advancement of women, and especially women of color, in S&E?
4. What do projections – disputed by some – on an IT worker shortage tell us about planning and deploying human resources nationally in an industry that is key to our economic future? What are the risks in crafting policies that hinge on such projections or other data that defy Census or Bureau of Labor Statistics categories and reflect a volatile global economy?
5. What does the gravitation of foreign students to graduate programs in certain fields, notably computer science and engineering and mathematics, coupled with the relative lack of interest by U.S. students in those fields, suggest to analysts of education and employment trends? How can such trends be used, for example, to inform admissions, recruitment, hiring, and promotion decisions?

CHAPTER ONE

The Scientific and Technological Workforce: Characteristics and Changes¹

Eleanor Babco and Mary Golladay

The nation's Scientific and Technological (S&T) workforce is critical as the country faces the challenges of globalization, technology, and equity in the next century. This group will determine the nation's ability to provide for its citizens and to compete effectively in the global marketplace, and to continue to improve the quality of life. This chapter provides information that addresses the following basic questions about the S&T workforce:

- How large is the S&T workforce? Who is included, and why?
- What is the educational level of the S&T workforce?
- Where are they employed?
- What are they doing?
- How old are they?
- What is the relationship between education and occupations?
- Why do persons in the S&T workforce change jobs?
- What will the future S&T workforce look like?

Data for the 1990s permit a closer examination of issues relating to the S&T workforce and its components than has been possible in previous decades. The National Science Foundation (NSF) has addressed its responsibility to identify, describe, and track the S&T workforce and its characteristics through its unified database, SESTAT (for Scientists and Engineers Statistical Data System). The system was put in place in the 1990s in response to the recommendations of a panel that examined NSF's reporting on scientists and engineers². Details of the system are summarized below. Data from the system are used to address the questions. This review presents information on those employed in S&T occupations, but will also emphasize those persons holding PhD degrees in science and engineering fields.

The SESTAT data base provides information on an estimated 10.6 million persons in the workforce in 1997 who had at least a bachelor's degree in a science or engineering (S&E) field or had a bachelor's degree in any field and were employed in an S&T occupation in 1990. The data base also contains information on an additional group of individuals (nearly 2 million persons) holding bachelor's degrees who were not in the labor force in 1997 but who remain part of the system because they met one of the criteria for inclusion in an earlier survey round,

¹ The authors wish to acknowledge the contributions of many persons who supplied data and analysis reported here and comments on earlier drafts: Joan Burrelli, Lawrence Burton, Maurya Green, Susan Hill, Kelly Kang, Nirmala Kannankutty, Richard Morrison, Linda Parker, John Tsapogas, Keith Wilkinson, and Christina Wise-Mohr. Opinions expressed are those of the authors and not necessarily of the Commission on Professionals in Science and Technology or the National Science Foundation.

² Committee on National Statistics. *Surveying the Nation's Scientists and Engineers A Data System for the 1990s*. National Academy Press. 1989.

usually education in a science or engineering field. The full SESTAT file for 1997 contains records on an estimated 12.5 million persons. About 10.1 million of those persons were employed in 1997.

Data on the S&T Workforce

Data on the S&T workforce in this chapter are drawn from the NSF's database, SESTAT. The database contains national estimates of surveys of individuals conducted in 1993 and biennially thereafter³ during the decade. Details of the surveys and the integrated database, with notations on its features and its limitations, are explained in *SESTAT: A Tool for Studying Scientists and Engineers in the United States*.⁴

The individuals included in the SESTAT database have at least a bachelor's degree, though not necessarily in science or engineering. Estimates for numbers of individuals who have earned bachelors or higher degrees in science and engineering fields since 1990 have been added to the database during the decade. Each of the surveyed individuals was asked about educational history and demographic characteristics and also about their occupations, employers and employment characteristics, work activities, and salary.

How Large is the S&T Workforce?

Estimates of the size of the S&T workforce can vary significantly depending on how one chooses to classify a scientist or engineer⁵. If only those persons employed in an S&T occupation, narrowly defined, are included there were approximately 3.4 million in this workforce in the United States in 1997. If, however, one wishes to include those persons with at least a bachelor's degree in a science or engineering field and who were employed, the group expands to more than 10 million individuals. The relationship between the "employed in S&T occupations" and "educated in science and engineering fields." is portrayed in Table 1.

⁴ Kannankutty, Nirmala and R. Keith Wilkinson. *SESTAT: A Tool for Studying Scientists and Engineers in the United States*. National Science Foundation, NSF 99-337. 1999.

⁵ Pollak, Melissa. *Counting the S&E Workforce – It's Not That Easy*. National Science Foundation, NSF 99-344. 1999.

⁵ The three surveys are The National Survey of College Graduates, The National Survey of Recent College Graduates, and the Survey of Doctorate Recipients. The first of these surveys is based on a sample drawn from the census of 1990, and includes persons who in 1990 held a bachelor's degree or higher. Education and occupation information was collected from these persons. Persons who reported holding S&T jobs were followed up in subsequent survey cycles. The surveys of recent college graduates add data from individuals who completed bachelor's degrees in science and engineering after April 1990. The survey of those holding doctorate degrees in science and engineering fields also includes additions from those receiving degrees since 1990.

Table 1. Employed science & engineering degree-holders by S&T/non-S&T employment and field of highest degree: 1997

	Total Employed	Employed in S&T	Employed in non-S&T
Total employed	10,585,600	3,369,400	7,216,200
Total with no S&E degree	528,000	294,600	233,400*
Total with S&E degree	10,057,600	3,074,800	6,982,800
S&E is highest degree	7,704,000	2,840,800	4,863,200
Computer & mathematical sciences	1,003,300	494,800	508,500
Life and related sciences	1,204,700	326,200	878,500
Physical and related sciences	619,200	334,100	285,100
Social and related sciences	1,854,800	199,900	1,654,900
Psychological sciences	1,112,800	221,400	891,400
Engineering	1,909,200	1,264,400	644,800
Non-S&E is highest degree	2,353,600	234,000	2,119,600

* These individuals were employed in an S&E occupation in a previous job.

Note: Details may not add totals due to rounding.

SOURCE: National Science Foundation, "Science and Engineering Workforce," *Science and Engineering Indicators: 2000*, NSB 00-1.

Which jobs are considered parts of S&T occupations, and which are not? Respondents to the various SESTAT surveys were asked to designate their occupation from a Job Code list containing over 120 options, including both S&T and non-S&T occupations. Most data summaries group individuals into 5 broad S&T categories, or a more detailed list of 25 S&T occupations. The five broad S&T categories, and the number of persons in each in 1997, are:

Persons Employed in S&T Occupations: 1997

Total	3,369,400
Computer/mathematical scientists	1,039,500
Life scientists	321,800
Physical scientists	284,900
Social scientists	167,300
Psychologists	181,700
Engineers	1,394,400

Several occupations not traditionally considered S&T occupations also are of interest because they often require considerable technical background and are the occupations of substantial percentages of persons with formal education in S&E fields. These include managers and administrators, health and related occupations, and teachers of subjects that are not in the narrow list of S&T occupations. The participation of persons with education in S&E fields who are working in these occupations will be examined below.

What is the Educational Level of the S&T Workforce?

A majority, 57 percent, of persons in S&T occupations have a bachelor's degree as their highest degree. Master's degrees are the highest degrees for an additional 29 percent, and 14 percent hold a doctorate degree (Table 2). These proportions vary dramatically by broad occupational categories. Among the broad groups, a majority of those in the largest group, the engineers, 67 percent, hold bachelor's degrees as their highest degree, with computer and mathematical scientists showing nearly as high a proportion, 65 percent. As a subset of those within each broad occupational group, those identified as holding the occupation of a teacher in postsecondary education for a related field show very high proportions of PhD degrees—more than half in each group except computer and mathematical scientists, where 37 percent hold the PhD.

Table 2.
Persons employed in S&T occupations by occupation and level of highest degree: 1997

Occupation	Level of Highest Degree			
	Total ¹	Bachelor's	Master's	Doctorate
Total S&T occupations	3,369,400	1,916,800	967,900	454,700
Scientists, total	1,995,100	1,000,200	592,000	375,300
Computer & mathematical scientists	1,039,500	675,300	301,600	59,000
Computer/information scientists	933,200	649,900	254,200	25,700
Mathematical scientists	34,700	11,900	15,900	6,900
Postsecondary teachers- computer & mathematical sciences	71,500	13,500	31,500	26,300
Life & related scientists	321,800	125,200	70,300	111,800
Agricultural & food scientists	43,000	22,200	10,900	9,800
Biological scientists	181,900	73,300	37,600	64,100
Environmental life scientists	20,200	14,600	4,200	1,200
Postsecondary teachers-life & related sciences	76,600	15,000	17,600	36,700
Physical & related scientists	284,900	131,700	69,100	83,700
Chemistry, except biochemistry	119,800	70,600	20,200	28,900
Earth scientists/geologists/oceanographers	68,600	34,900	23,100	10,500
Physicists/astronomers	31,500	7,400	9,000	15,100
Other physical & related scientists	16,700	8,100	7,100	1,400
Postsecondary teachers-physical & related sciences	48,200	10,700	9,700	27,800
Social & related scientists	167,300	41,800	56,100	66,500
Economists	45,100	15,900	21,100	7,800
Political & related scientists	9,100	5,100	3,200	900
Sociologists/anthropologists	15,800	7,000	5,200	3,600
Other social & related scientists	11,900	4,500	3,700	2,700
Postsecondary teachers-social & related sciences	85,300	9,300	22,900	51,600
Psychologists	181,700	26,200	95,000	54,300
Engineers	1,374,400	916,600	375,900	79,400
Aerospace/related engineers	72,500	40,900	27,300	4,300
Chemical engineers	76,300	49,300	19,900	7,100
Civil/architectural engineers	206,800	150,500	51,700	4,000
Electrical/related engineers	364,800	239,600	107,400	16,800
Industrial engineers	79,700	58,700	19,300	1,400
Mechanical engineers	271,100	200,300	61,600	9,000
Other engineers	269,200	171,800	79,500	17,700
Postsecondary teachers-engineering	33,900	5,400	9,300	19,200

¹ Includes professional degrees

Note: Details may not add totals due to rounding.

SOURCE: National Science Foundation, Division of Science Resources Studies, 1997 SESTAT Surveys

Where is the S&T Workforce Employed?

The S&T workforce includes persons either educated as or working as scientists and engineers. There were about 10.6 million of these individuals employed in 1997. Of this group, 69 percent were working in business and industry, 18 percent in education and 13 percent in government (Table 3). Of these employed persons, it has been noted that about a third—or 3.4 million—were working in S&T occupations. Sector of employment varies for occupational categories. Computer and mathematical scientists, and engineers, were overwhelmingly employed in industry (80 percent and 81 percent respectively), and physical scientists also were more likely to be employed in industry (55 percent). However, life scientists were more concentrated in academe, with 48 percent working there compared to only 32 percent in industry. Social scientists were more evenly divided between the two sectors: 45 percent employed in academe, compared to 43 percent in industry. Life scientists were more likely to be working in government compared with other scientists and engineers.

Table 3.
Employed U.S. scientists and engineers, by sector of employment: 1997

Occupation	Total	Sector of employment		
		Business/ industry	Educational institutions	Government
All occupations	10,585,600	7,264,900	1,953,500	1,367,300
S&T occupations	3,369,400	2,343,600	586,700	439,100
Computer/math scientists	1,039,500	828,900	121,200	89,400
Life/related scientists	321,800	102,700	154,500	64,600
Physical./related scientists	284,900	156,100	80,000	48,700
Social/related scientists	167,300	43,800	101,200	22,300
Psychologists	181,700	105,400	55,800	20,500
Engineers	1,374,400	1,106,700	74,100	193,600
Other occupations (nonS&T)	7,216,200	4,921,300	1,366,800	928,200

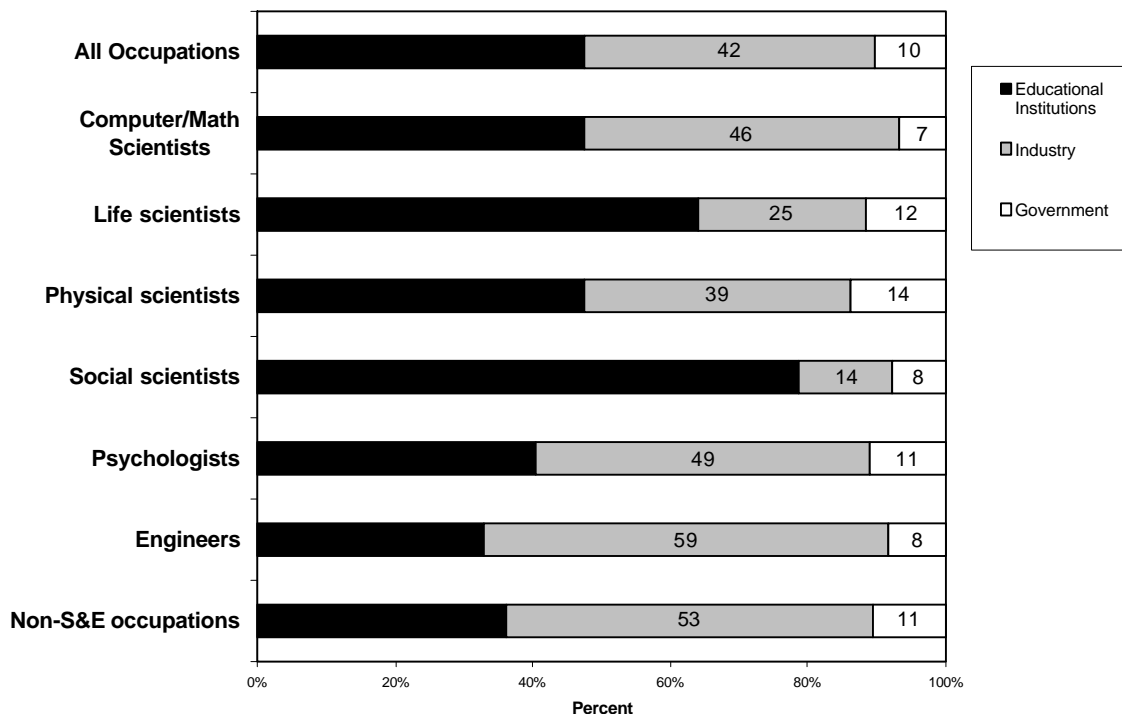
Note: Details may not add totals due to rounding.

SOURCE: National Science Foundation, Division of Science Resources Studies, 1997 SESTAT Surveys

Where are PhDs Employed?

The sector of employment for those in the S&T workforce who hold PhDs is more likely to be academe than it is for the total workforce. Even so, while higher proportions of PhDs in occupational groups are employed in educational institutions, only in the Computer and Mathematical Sciences, Life Sciences, and Social Sciences are a majority of the doctoral S&Es employed in educational institutions of any level (Figure 1).

Figure 1: Sector of Employment for Doctoral S&Es, by Occupation: 1997



SOURCE: NSF/SRS, Survey of Doctorate Recipients 1997

What Does the S&T Workforce Do?

The S&T workforce is engaged in a variety of activities. Among all persons in the S&T workforce in 1997, managing and supervising was the most common work activity, with 51 percent of this workforce reporting that they spent at least 10 percent of a typical work week engaged in the activity (Table 4). Computer applications were the second most frequently identified activity, followed by employee relations and sales.

Table 4. Work Activities of the S&T Workforce: 1997

Activity	Percent Identifying Activity*	Activity	Percent Identifying Activity*
Managing & Supervising	51%	Quality or Productivity	
Computer Applications	38%	Management	24%
Employee Relations	34%	Design	23%
Sales	34%	Applied Research	22%
Accounting, Finance	30%	Development	21%
Professional Services	31%	Basic Research	13%
Teaching	24%	Production, Operations	9%

*Taking at least 10% of typical work week

Work activities were related to employment sector and occupational category. For doctoral scientists and engineers working in academe, regardless of occupational category, teaching and research were the most frequently cited work activities (Figure 2). In private industry, activities of doctoral scientists and engineers were much more varied with research the predominant activity for Physical scientists, Life Scientists, and Social Scientists.

Figure 2: Primary or Secondary Work Activities of the Doctoral S&T Workforce

Occupation	Sector of Employment	
	4-year Colleges & Universities	Private Industry
Computer and Math Scientists	Teaching - 85% Research - 69% Computer Applications - 15%	Computer Applications - 72% Design or Development - 40% Research - 35%
Life Scientists	Research - 85% Teaching - 49% Management - 16%	Research - 78% Design or Development - 34% Management - 33%
Physical Scientists	Research - 77% Teaching - 68% Management - 13%	Research - 75% Design or Development - 52% Management - 21%
Social Scientists (excluding Psychologists)	Teaching - 91% Research - 68% Management - 11%	Research - 67% Management - 28% Professional Services - 25%
Psychologists	Research - 55% Professional Services - 55% Management - 37%	Professional Services - 91% Management - 19% Research - 9%
Engineers	Research - 79% Teaching - 72% Management - 11%	Design or Development - 66% Research - 47% Computer Applications - 23%
Non-S&E Occupations	Teaching - 52% Management - 43% Research - 42%	Management - 57% Design or Development - 23% Research - 19%

Notes: Primary or secondary work activities are engaged in most or second-most of the time in an average

Source: NSF/SRS, Survey of Doctorate Recipients, 1997

What is the Age Distribution of the S&T Workforce?

The S&T workforce is aging. Of those in the workforce who received a degree in a science or engineering field and were working in an S&T occupation in 1997 (about 3.4 million individuals) over half (53.6 percent) were over the age of 40. This compares with 48 percent who were over the age of 40 in 1993. Within the entire S&T workforce, about 40 percent of scientists and engineers were under the age of 40 in 1997, compared with 46 percent in 1993.

Does Education in an S&E Discipline Lead to Employment in an S&E Occupation?

It is possible to examine the relationship between formal degrees and occupation for individuals in the SESTAT database. Both highest degree and degree order are specified, with field of degree provided for all. The database reveals that individuals hold virtually any and all combinations of degrees. Among all individuals who are included in the full SESTAT data base by virtue of EITHER a degree in a S&E field or a S&T occupation, a substantial majority report a job code that places them outside of the traditional group of S&T occupations. Of the total employed in 1997—including those educated in S&E (i.e., having at least one degree in an S&E field) or holding an S&T job in 1993--the great majority (69%) were working in jobs that would not be considered an S&T occupation.

It is informative to look more closely at the large group whose occupations are in the “Non-S&T” group, and the role the S&E education might play in their work activity. One common approach is to look at the highest degree. Another option is to look at most recent, or last, degree. If an individual’s highest degree was in an S&E field, even then less than half of the population is employed in an S&T occupation. What jobs do these persons hold? Within the five largest job categories that are not considered S&T occupations, varying proportions of individuals reported that their highest degree in S&E was closely related to their job (Table 5). Together this group of five jobs accounts for about 2/3 of those in jobs not considered S&T jobs, yet whose highest degree was in S&E. The shares of each occupational group that believe their highest degree is closely related to their job range from 69 percent for those teaching, to only 10 percent for those in sales.

Table 5. Persons Employed in Non-S&T Occupations Whose Highest Degree is in S&E: 1997

Non S&T Occupation	Number	Highest Degree in S&E Closely Related to Job
Total Persons	4,863,200	32%
Managers & Administrators	1,405,000	30%
Sales & Marketing Occupations	757,500	10%
Non-S&E Teachers	454,300	67%
Technologists & Technicians	309,800	45%
Health & Related Occupations	294,800	61%

Source: Wilkinson, Keith, *How Large is the U.S. S&E Workforce?*
National Science Foundation, forthcoming, 2001

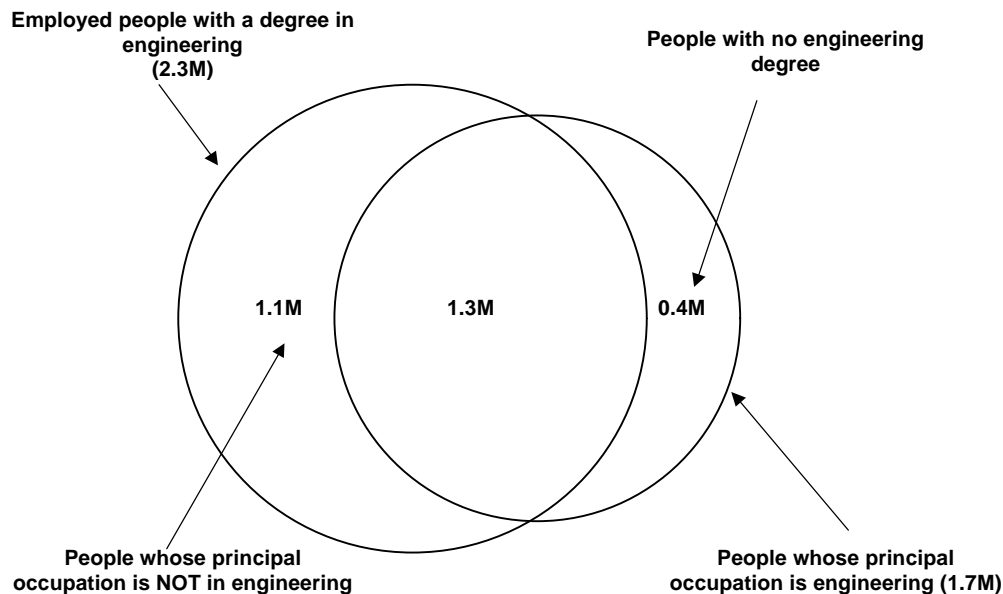
Many jobs use skills that require some background in S&E, and many with formal education in S&E find their knowledge useful in a wide range of jobs. Fine distinctions between S&T occupations and non-S&T occupations are clearly subject to different interpretations. The data suggest that a more productive and expanded view of what constitutes the S&T workforce would not only be more accurate but also would broaden the discussion of essential skills, educational needs for the modern day workforce, and employment policy.

What is the Relationship between Education and Occupation?

The patterns of degree awards, including fields of study and order of degrees, and their relationship to jobs, has been studied in detail by the Engineering Workforce Project at the NSF⁶. Two results from the project demonstrate some major findings about the relationships between education and occupation for engineers, and also suggest that similar analyses for other occupational groups would yield insights.

First, there is a lack of a clear-cut linkage between education and occupation, as demonstrated by the diagram relating these two attributes (Figure 3). When the analysis of education allows for noting ANY degree in an engineering field, there still are a substantial number, approaching half, who have a degree in engineering but do not hold an engineering occupation. (Of the 2.3 million persons with engineering degrees, 1.1 million do NOT hold engineering occupations.)

Figure 3. Employed Engineering Graduates and Engineers: 1997



NOTE: engineering graduates have a bachelor's or higher degree in engineering. A person whose principal occupation is an engineer may or may not be an engineering graduate.

Degree combinations for engineers were carefully examined to identify various combinations and their relationships to occupations. A frequently cited combination is engineering and business. Looking just at the population of engineers holding master's degrees (no higher degrees) does suggest that this combination may increase the likelihood that engineers will hold senior management positions. However, the likelihood that having a business degree will increase the probability of working as a senior manager is more pronounced in the earlier age

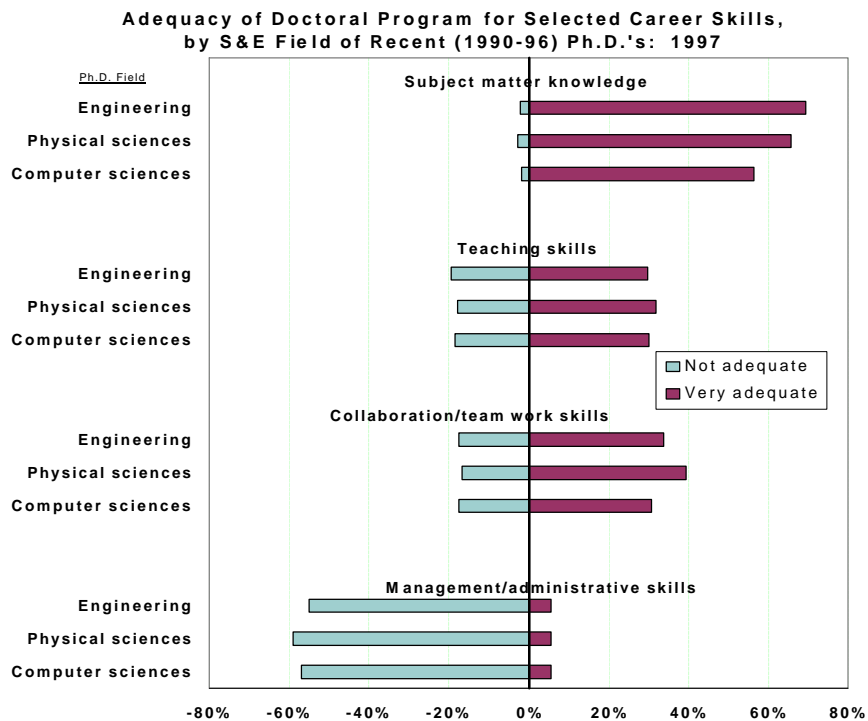
⁶ Burton, Lawrence and Linda Parker. *Engineering in the United States: An Overview of the Profession*. National Science Foundation, NSF forthcoming, 2001.

group than in the older⁷. More research is needed to determine whether these different patterns are driven by age, degree combination and/or level, some combinations of these variables, or unknown factors such as the types of managerial jobs these more recent engineering graduates hold. It has been demonstrated that almost all of the salary differential between male and female engineers is attributable to years of experience⁸.

How Adequate are Doctoral Programs for Preparing Persons for Career Skills?

Given the sector of employment and the work activities varying by sector, it is highly informative to examine the views of recent doctorates (those receiving degrees between 1990 and 1996) as to the adequacy of their doctoral programs. Of the three fields examined—engineering, physical sciences and computer science—there is little difference by field of PhD (Figure 4). Those PhDs in all three fields felt their subject matter knowledge was very adequate, with nearly 70 percent of the engineers rating their technical knowledge as very adequate. However, a sharply contrasting view was expressed in the management/administrative skills category where more than half of the PhDs in all three disciplines rated their skills as inadequate.

Figure 4.



SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Doctorate Recipients, 1997, unpublished tabulations.

⁷ Burton, Lawrence and Linda Parker. *The Education and Employment of Engineering Graduates*. National Science Foundation. NSF forthcoming, 2001.

⁸ Lal, Bhavya, Sam Yoon, Ken Carlson. *How Large is the Gap in Salaries of Male and Female Engineers?* National Science Foundation, NSF 99-352. 1999.

Why do Persons in the S&T Workforce Change Jobs?

Job mobility is cited as a factor critical to understanding the modern workforce. In addition to asking for job histories, the most recent cycle of SESTAT surveys asked those who changed jobs why they had done so. Their responses identified factors that should be noted by employers as well as analysts of the workforce. Of the slightly more than one-fourth of those who changed jobs (excluding from the examined group those who had only recently completed degrees to join the workforce), pay and/or promotions were the most common reason cited for job change (Figure 5). Working conditions was cited as the next most common reason for slightly under half of those changing employers, including those whose job they identified as of the same type. Career change was cited frequently by those changing jobs with the same employer or with a different employer.

Figure 5. Employed S&Ts' Reasons for Changing Jobs: 1995-1997

Did not change employer or job: 72%

Changed employer or job: 28%

Reason for changing (multiple responses)	Same Employer	Changed Status	
		Different Employer Same Job	Different Employer Different Job
Pay/promotion	69%	56%	56%
Working conditions	26%	45%	47%
Job location	16%	29%	31%
Career change	34%	14%	45%
Family-related	6%	14%	18%
Laid-off	11%	27%	20%

NOTE: Excludes most recent ('95 and '96) degree earners

SOURCE: NSF/SRS. SESTAT Data system.

The implications of these responses are that members of the S&T workforce respond to opportunities and needs in much the same way as others; the myths of S&T workers devoted to their disciplines above all else are not supported by the data. The S&T workforce responds to opportunity and acts independently, with members willing to move for many reasons including new opportunities and greater pay.

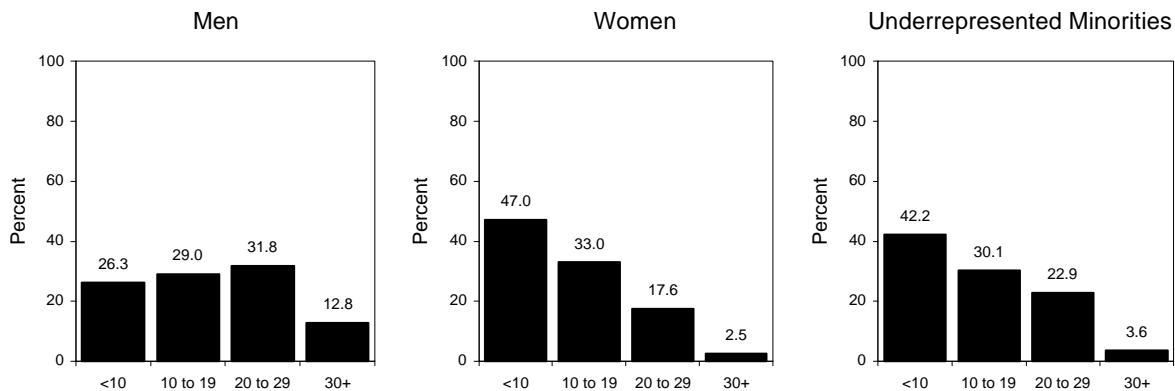
How Are S&T Faculty Changing?

The effects of new entrants on the pool of S&T faculty are difficult to see within the relatively brief time span of a few years. Examining cross-sectional information about faculty holding PhDs does permit some inferences to be made. Overall impacts of growing diversity in degree awards to previously underrepresented groups may be seen through comparisons of faculty by age groups.

While men follow a fairly traditional pattern, two groups of particular interest, women and underrepresented minorities (persons who are African American, Hispanic, and American Indian) who have received their degrees relatively recently, suggest by their distribution that gains have been made by those receiving degrees within the last 10 years, and also that the future will definitely offer a more diversified distribution (Figure 6).

Figure 6.

S&E faculty in tenure and tenure track positions in 4-year colleges, by years since doctorate: 1997



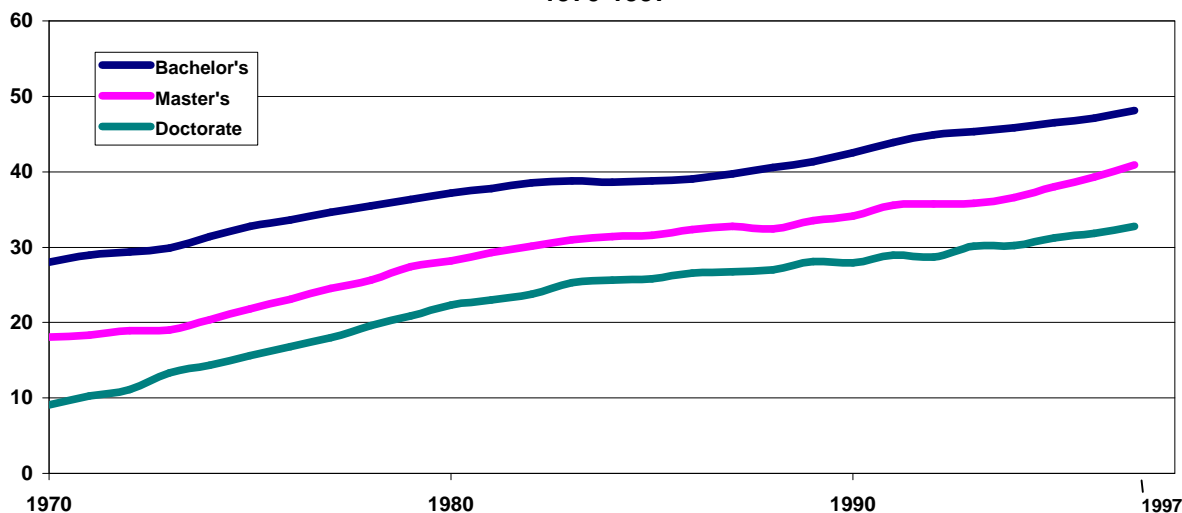
SOURCE: National Science Foundation, Women, Minorities, and Persons with Disabilities in Science and Engineering: 2000, NSF 00-327

What Will the Future S&T Workforce Look Like?

An important view of the future may be seen by examining the trends in degree awards. Persons receiving degrees are an important source of new entrants to the S&T workforce. Because the numbers added to the workforce from this important flow are considerably less than those that constitute the stock of the existing workforce are, change may seem almost imperceptible. Yet the progress of historically underrepresented groups of individuals in S&T occupations has been of great concern to those interested in building a diverse workforce that resembles the entire population.

Women have increased their percent of earned degrees in S&E fields at all levels since 1970, rising from 28 percent of S&E degrees to over 48 percent in 1997 at the bachelor's level (Figure 7). Their proportion has increased more dramatically at the doctorate level, where the proportion of degrees to women in S&E fields rose from 9 percent in 1970 to nearly 33 percent in 1997. Increases at the master's level have been intermediate between the bachelor's and doctorate degree levels.

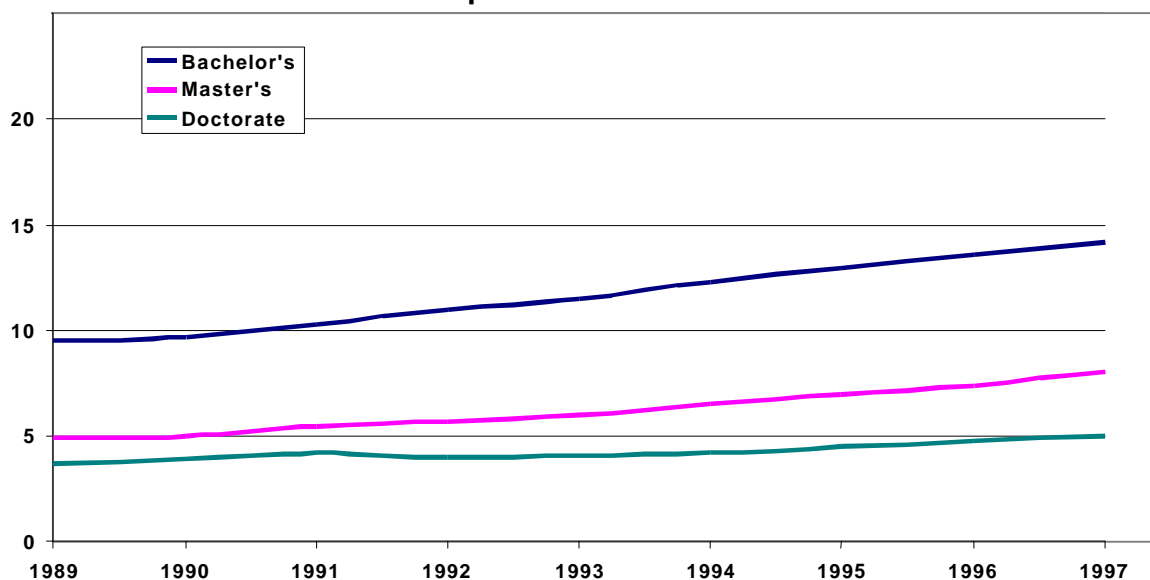
**Figure 7. Percent of Degrees in S&E Fields Earned by Women:
1970-1997**



SOURCE: National Science Foundation/SRS: Science and Engineering Degrees. (Hill, NSF 00-310)

Increases in the proportion of S&E degrees to underrepresented minorities have been at best gradual over the past 10 years. This group earned under 10 percent of S&E bachelor's degrees to U.S. citizens and permanent residents in 1989 and increased that percentage to just under 15 percent by 1997 (Figure 8). At the doctorate level, underrepresented minorities earned less than 5 percent of the S&E degrees awarded to U.S. citizens and permanent residents in 1989, and increased that percentage to only 7 percent in 1997.

**Figure 8. Percent of Degrees in S&E Fields Earned by
Underrepresented Minorities:**



NOTE: Underrepresented Minorities include Black, Hispanic, and American Indian.

SOURCE: National Science Foundation/Division of Science Resources Studies: Science and Engineering Degrees, by Race/Ethnicity. (Hill, NSF 00311).

The proportion of all S&E doctorates awarded to underrepresented minorities is even smaller when considered as part of the total group of doctorates. The proportion of doctorate degree awards to foreign citizens is highest at the doctorate level. U.S. citizens earned 67 percent of the S&E degrees from U.S. universities in 1989 as well as 1997.

Another useful indicator of the future S&T workforce is the enrollment in graduate science and engineering programs. Enrollment totals in S&E fields have been declining for several years. The recent increase, noted in 1999, is due to the increased enrollment of students who hold temporary visas; the enrollment of U.S. citizens and persons on permanent visas has continued to decline⁹. The overall pattern of decline does not hold for all discipline fields or for all demographic groups. Declines in physical and mathematical sciences, engineering and computer science contrast with increases in biosciences and health fields. Increased enrollment of graduate students who are African American, Hispanic, Native American or Asian contrast with sharp declines in enrollment of whites.

As yet unmentioned is a group of persons who are contributing to the S&T workforce but who do not hold the traditional credential of a bachelor's degree in any field. The size of this population, the level and type of any formal education or training it may have received, and the nature of its contribution to overall economic productivity remains unmeasured.

The Scientific and Technological Workforce is difficult to define precisely, as this chapter points out. However, regardless of our exact definition of the S&T workforce, it is important to reaffirm how critical it is to our nation as it faces challenges to continue improving the quality of life for our own citizens and as it continues to compete in the global marketplace in the coming millennium.

WEBSITES

Commission on Professionals in Science and Technology, <http://www.cpst.org>

National Science Foundation, <http://www.nsf.gov/sbe/srs>. This site provides statistics on United States scientists and engineers. It includes information on the database and its components, preformatted tables and a public use data file that can be used to generate custom tables.

National Science Foundation, *Characteristics of Science and Engineering Doctorate Recipients: Selected Trend Tables 1993, 1995, and 1997*. SRS 00-412.
<http://www.nsf.gov/sbe/srs/srs00412/start.htm>.

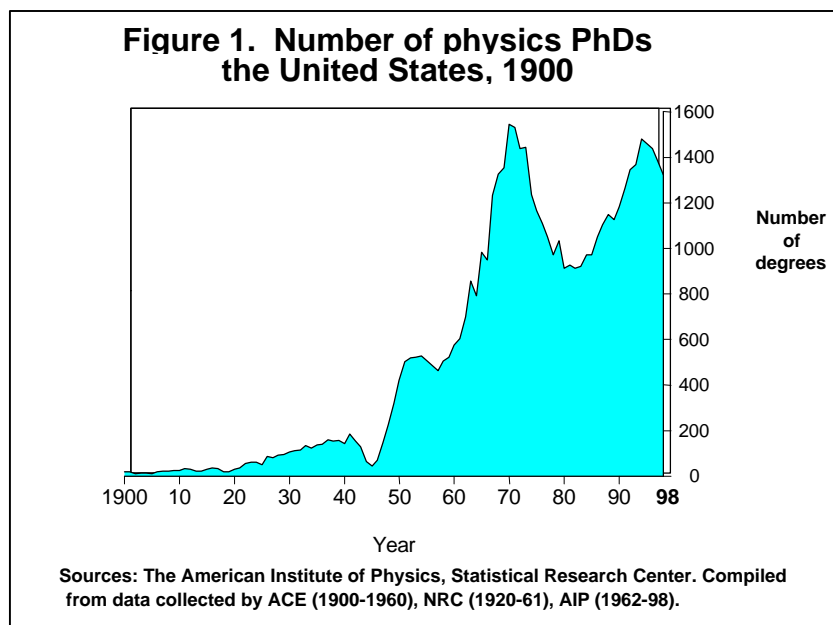
⁹ Burelli, Joan. *Graduate Enrollment in Science and Engineering Increases for the First Time Since 1993*. National Science Foundation, NSF 01-312.

CHAPTER TWO

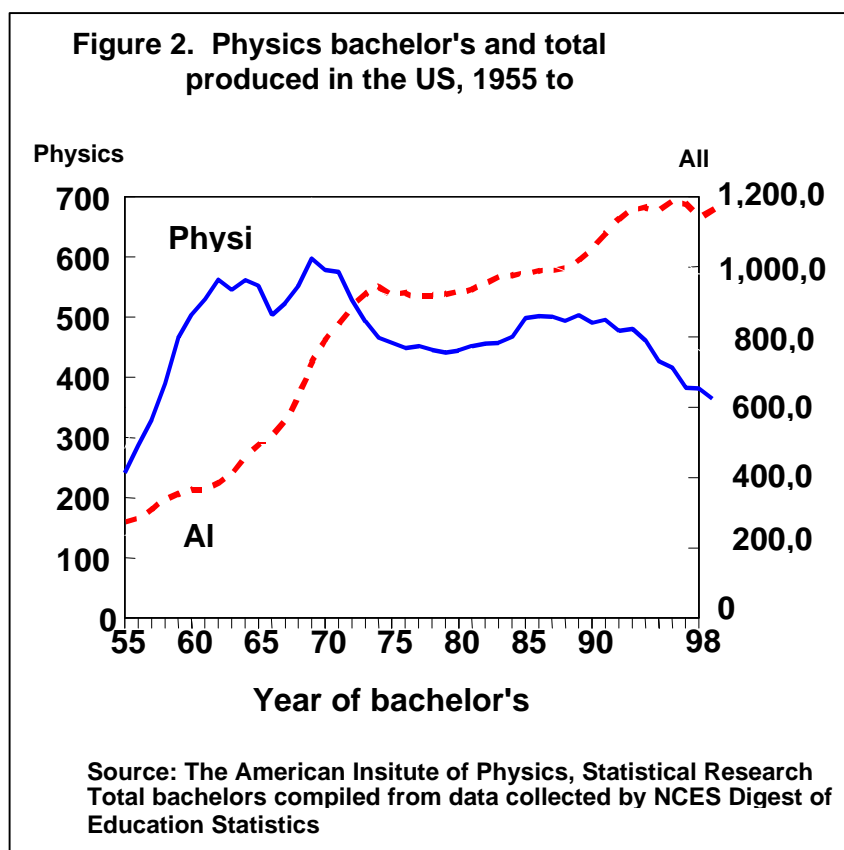
Why did fewer Americans major in physics during the 1990's?

Roman Czujko

This chapter focuses on physics, the field that I have been studying for nearly twenty years. Physics is a comparatively small field. Out of every 1000 bachelors degrees awarded each year in the U.S., fewer than 3 ½ are in physics. Similarly, only about 3% of all PhDs are awarded in physics. Yet despite its size, the trends we see in physics are not unique. They can and do tell us something about other fields. Thus, while the data focus on physics, our understanding of these trends has much broader applicability. Due to space constraints, my coverage of these trends will be superficial. For more detailed information, visit our web site at www.aip.org/statistics. One doesn't have to be a physicist to see that these data (**Figure 1**) represent a system under stress. One doesn't have to be a social scientist to see that the trends are being driven by more than a passion for knowledge and the desire to add to the knowledge base. Degree production is affected, in part, by economic and political developments in both the national and international arenas. The repercussions of World War II, Sputnik, and the international recessions of both 1970 and 1990 are very clear.



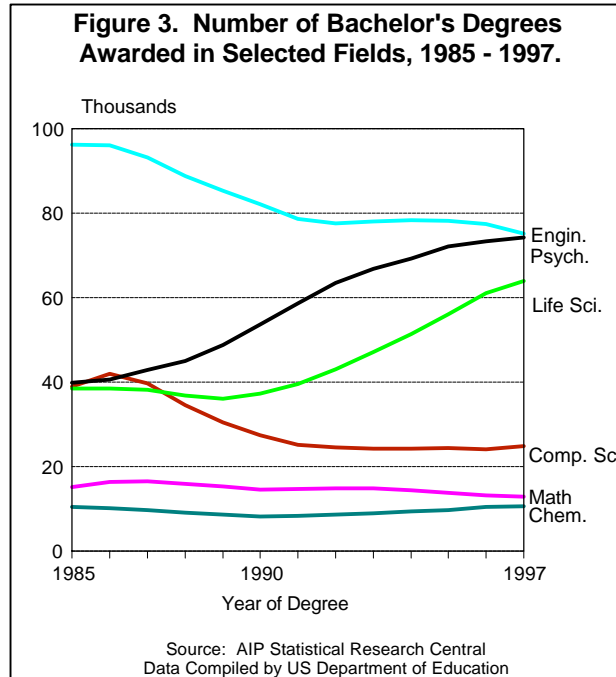
The number of physics bachelor's degrees awarded in 1998 is down to the levels last seen in the late 1950's (**Figure 2**). The decline during the 1990's in physics bachelors has been steeper at departments that offer a PhD and that, even though the overall trend appears to have bottomed out, the bachelors production at PhD departments continues to tick downward.



The number of bachelors degrees awarded in physics has been declining during the decade of the 1990's and the number of physics PhDs awarded has declined during the last half of the 1990's. At the same time, the total number of degrees awarded in the U.S. has gone up. Thus, it may be surprising to note that the declines are not unique to physics. Among those fields that declined, physics was not the hardest hit. In addition, these trends are not unique to the U.S. By way of example, graduate enrollments in Germany in physics, chemistry, and several other fields have dropped by half and more during the 1990's.

Where have the students gone and why? There are a number of different causes for the declines we have seen in physics and related disciplines.

Higher education is being driven, to a significant degree, by women. In 1997, women earned 55% of all bachelor's degrees, but only 19% of physics bachelor's degrees. In computer science, which declined between 1986 and 1996 (**Figure 3**), the percentage of those degrees earned by women dropped precipitously. By contrast, in two of the fastest growing bachelors fields - life science and psychology - the majority of degree recipients are women. The participation of women in higher education is not the only factor, but it is a major factor.



There has been an explosion in opportunities. In other words, compared to the past, there are many more fields that individuals can major in that offer intellectual stimulation or financial reward or both. By way of example, during the early 1970's, computer science was routinely part of the mathematics department. Now it is not only a stand alone department, but the title computer and information sciences does not come close to describing the wide array of different tasks that these students are trained to do. Similarly, there has been a dramatic increase over the last 10 years in the number of graduate departments that award degrees in the interface between two or more fields; one of those is often biology. In short, it is no longer possible to sit back and wait for the best students to come to you.

Students' choices of college major are driven, in part, by their perceptions of the job market and career opportunities. How do students learn about career opportunities and how much do they, in fact, know? The answer is little and the word perception is key. We continue to talk about the bad job market during the early 1990's. Those problems were caused, in large part, by a severe international recession that affected many fields and many countries. In fact, the U.S. is among the few countries to have recovered from that recession. In short, there is an erroneous perception that physics is not doing well in today's job market.

Physics departments are isolated from the world outside of academe. Many physics departments are still driven by the dominant goal of adding to the knowledge base, that is, conducting basic research and preparing students to become the next generation of basic researchers. Too few faculty understand the remarkable diversity of careers commonly pursued by people with physics degrees. Too few departments have modified their curriculum to address the needs of the majority of their students, that is, those students who do not become PhDs conducting basic research.

Graduate education in physics in the U.S. is arguably the finest in the world. Since the faculty are largely responsible for this status, it is easy to understand why they would both take pride in and focus heavily on their research and on training students to become the next generation of researchers.

However, too many faculty lose sight of the fact that the path from a physics bachelors to a physics PhD is atypical. In fact, the most common career path for a physics bachelor's (about 36%) is to enter the workforce and never earn an advanced degree. The second most common career path is to earn a masters degree in a field other than physics (about 26%) either immediately after earning their bachelors or after having been in the workforce for a period of time. To earn a PhD in physics is the third most common career path accomplished by only about 16% of physics bachelors.

What is the primary cause of the declines in physics enrollments and degrees? As often happens with the most interesting issues, a seemingly simple question turns out to be rather complex.

The very notion of primary cause assumes that there is one force moving the system. It also implies that the system is a unified whole. Both of these assumptions are, of course, incorrect.

First, the system is complex and there may be no one primary cause. Second, the relative impact of each of these causes is probably different in different institutions. Third, the process by which individual students decide on the field in which they eventually earn a bachelors degree may be unique and certainly changes over time.

In physics the vast majority of students report that they were initially attracted to the field out of an interest in the subject matter or a passion for the field. But the factors that attract a student to a particular discipline are not the same as the factors that keep the student studying the field. As Seymour¹ pointed out, few students make up their minds in freshman year of high school. It is common for people to change their minds several times between freshman year in high school and senior year in college. In fact, the decision isn't simply between physics and a related field. It is often between science and not science.

In light of these findings, we should stop referring to the education system as a pipeline. People do not simply flow through the system, with some leakage at different points. Rather the education system is a set of pools, with students flowing into and out of the science pool.

In summary, the world is wonderfully complex and the trends we see are not unique to physics or even to the U.S. If we are to understand what is driving the system at points and in what ways we might affect the outcomes, we need better information. We need a great deal more research into the complex decision matrix that students use in deciding on their college major and how the weighting of those factors changes during the student's time in the education system.

¹ E. Seymour and N.M. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences*, Westview Press, Boulder, 1997.

CHAPTER THREE

Women In Science And Engineering: What We Know About Education And Employment

Mary Frank Fox

In considering what we know about the education and employment of women in science and engineering (S/E), I concentrate upon doctoral-level scientists. My focus is on doctoral-level scientists for two reasons. First, issues of scientific research and its impact are particularly applicable for this group. Second and relatedly, the training of university students –and in turn, much of the future of science– is at the hands of doctoral-level scientists.

What do we know about women and doctoral-level education in S/E?

1. Women's share of doctoral degrees over the past 80 years does not represent a simple trend of increasing proportions over time. The proportions of doctoral degrees awarded to women in the 1920s (12.3%) and the 1930s (11%) are higher than the proportions in the 1940s (8.9%), the 1950s (6.7%), or even the 1960s (7.9%). It was the 1970s before the proportion of doctoral degrees awarded to women (15%) equaled or surpassed the pre-1940 levels (Fox, 1999). Continuing gains were made in the 1980s, a decade during which women earned more than a quarter (26%) of doctoral degrees; and in the 1990s (1990-98), 31% (CPST, 2000: calculated from Table 2-1).

2. S/E encompasses a wide range of fields, and women's degrees are far more concentrated by field than are men's. For 1990-98, over three quarters (77%) of doctoral degrees awarded to women in S/E were in psychology, social sciences, and life sciences. The concentration is a very persistent pattern: over the entire 78 year period, 1920-98, 79% of women's S/E doctoral degrees were concentrated in these fields (CPST, 2000: calculated from Table 2-1).

3. Women are just as apt as men to receive their doctoral degrees from top ranking departments. Across S/E fields, the pattern is one of similarity in doctoral origins of women and men (see Fox, 1999).

4. Data on doctoral origins, however, do not specify the character of that training – matters of inclusion and exclusion, nuances of advising, and evaluative practices as they operate for women and men. My research points to different experiences and outcomes of men and women doctoral students in their departments, research groups, and with advisors (Fox, 1998, 2000, 2001).

For examples: 1) Women are less likely to report that they are taken seriously by faculty, and that they are respected by faculty. 2) Despite strong preferences for collaboration by both men and women students, women report collaborating with fewer graduate students and fewer male faculty. 3) Women are more likely than men to view their relationship with their advisor as one of “student-and-faculty” rather than “mentee-mentor” or colleagues, suggesting greater social

distance for women. 4) In outcomes, women students published fewer papers than men in a prior three year period, and are less likely to report that they will, indeed receive their degrees.

What do we know about doctoral level women and employment in S/E?

Despite obstacles, women with doctoral degrees have progressed through the proverbial educational pipeline; they are a highly select group, who have already survived barriers of selection (both by themselves and by institutions) into S/E fields; and have acquired credentials for high-level participation in the profession. What is happening to them in employment? In summarizing outcomes for women, I focus on academic employment, because in academia ranks are clearly and uniformly specified as professorial levels, and are telling indicators of position. In Table 1, we observe the following patterns, which point toward the relationship between gender and status in S/E.

1. Across S/E fields, the higher the rank, the lower the proportion of women.
2. Just as women are concentrated in life sciences, psychology, and social sciences—so, correspondingly, in these, compared to other S/E fields, we find higher proportions of women at each rank.
3. Further, for each field except psychology, the proportion of women at the rank of full professor is meager. In half of the field categories, women are 7% or fewer of the full professors. In addition, studies that control for research productivity show that promotion rates from assistant to associate to full professor are lower and slower for women (Long, Allison, and McGinnis, 1993; Sonnert and Holton, 1995).

What are some implications here? What is the nature of the challenge?

Despite the numbers of women with doctoral degrees earned in the 1970s and 1980s, and the passage of years for these women to mature in professional time, the proportion of women who are full professors has not kept pace with the growth of women with doctorates. In 1973, women were 4% of the full professors in S/E fields; in 1987, 7%; in 1993, 10% (see Fox, 1999); and in 1997, only 11.6% (CPST, 2000: Table 5-1).

Twenty years ago, increasing numbers (and proportions) of women began to enter doctoral programs and complete degrees, and it was expected that rank would be “a matter of time” – time for women to mature professionally, and attain high positions. Even allowing up to fifteen years from receipt of doctoral degrees to rank of full professor, women’s degrees are not translating into expected rank over time (these discrepancies are documented in chemistry, in mathematics, and across fields in higher education; see Fox, 1996).

For science as for other fields, the relationship between gender, education, and status is complex – it is not a simple, linear progression of more education among women and improved social and economic status (see Fox, 1996). Practice and policy have tended to focus upon increasing the numbers of women in science. Increasing the numbers of women in science is important – both for reasons of social equity, and for use of talent (Pearson and Fechter, 1994). However,

increasing numbers of doctoral-level women in science, by itself, will not necessarily change patterns of gender and status in science and scientific employment. For this, we need to address matters beyond numbers in the educational pipeline (Fox, 1996, 1998, 2000). These include the character and quality of graduate education, range and scope of collaborative opportunities, access to professional networks, and evaluative practices – as they operate for women and under-represented, compared to majority-status, groups.

TABLE 1
Doctoral Scientists and Engineers in Academic Institutions,
by Field and Rank, 1997

Field	Total*	Full Professor	Associate Professor	Assistant Professor
Physical Sciences <i>%Women</i>	36,940 <i>13.3</i>	13,770 <i>4.2</i>	6,680 <i>13.5</i>	5,510 <i>26.1</i>
Math & Computer Sciences <i>%Women</i>	18,740 <i>14.2</i>	7,520 <i>6.7</i>	5,470 <i>14.3</i>	4,120 <i>24.1</i>
Life Sciences <i>%Women</i>	68,640 <i>27.8</i>	21,210 <i>13.1</i>	13,120 <i>22.9</i>	13,090 <i>36.7</i>
Psychology <i>%Women</i>	27,190 <i>43.1</i>	9,570 <i>22.5</i>	5,840 <i>44.3</i>	4,790 <i>61.0</i>
Social Sciences <i>%Women</i>	45,510 <i>28.3</i>	18,230 <i>14.9</i>	11,880 <i>32.4</i>	9,150 <i>39.6</i>
Engineering <i>%Women</i>	26,960 <i>6.5</i>	11,230 <i>1.4</i>	6,080 <i>6.3</i>	4,900 <i>13.7</i>
Total, all fields <i>%Women</i>	233,180 <i>25.1</i>	83,670 <i>11.6</i>	51,880 <i>25.7</i>	44,410 <i>36.9</i>

*Total includes instructor/lecturer, other faculty, and “does not apply.”

SOURCE: Commission on Professionals in Science and Technology. *Professional Women and Minorities: A Total Human Resource Data Compendium* [13th edition]. Washington, D.C., 2000: Table 5-1.

References

Commission on Professionals in Science and Technology (CPST). *Professional Women & Minorities: A Total Human Resources Data Compendium*. 13th edition. Washington: DC: CPST, 2000.

- Fox, Mary Frank. "Women, Academia, and Careers in Science and Engineering." In *The Equity Equation: Fostering the Advancement of Women in the Sciences, Mathematics, and Engineering*, edited by C. S. Davis, A. Ginorio, C. Hollenshead, B. Lazarus, and P. Rayman, pp. 265-289. San Francisco: Jossey-Bass, 1996.
- Fox, Mary Frank. "Women in Science and Engineering: Theory, Practice, and Policy in Programs." *Signs: Journal of Women in Culture and Society* 24(Autumn, 1998): 201-223.
- Fox, Mary Frank. "Gender, Hierarchy, and Science." In *Handbook of the Sociology of Gender*, edited by J. S. Chafetz, pp. 441-457. New York: Kluwer Academic/Plenum Publishers, 1999.
- Fox, Mary Frank. "Organizational Environments and Doctoral Degrees Awarded to Women in Science and Engineering Departments." *Women's Studies Quarterly* 28 (Spring/summer 2000): 47-61.
- Fox, Mary Frank. "Gender, Faculty, and Doctoral Education in Science and Engineering." In *Women in Research Universities*, edited by L. Hornig. New York: Kluwer Academic/Plenum, forthcoming 2001.
- Long, J. Scott; Allison, Paul; and McGinnis, Robert. "Rank-advancement in Academic Careers: Sex Differences and the Effects of Productivity." *American Sociological Review* 58 (1993):703-722.
- Pearson, Willie and Fechter, Alan, eds. *Who Will Do Science? Educating the Next Generation*. Baltimore: Johns Hopkins University Press, 1994.
- Sonnert, Gerhard and Holton, Gerald. *Gender Differences in Science Careers*. New Brunswick, New Jersey: Rutgers University Press, 1995.

CHAPTER FOUR

Making Strides?: Graduate Enrollment of Underrepresented Minorities in Science and Engineering

Yolanda S. George, Virginia V. Van Horne and Shirley M. Malcom

Introduction

Since 1996 a wave of judicial rulings, legislative referenda, and editorial opinions opposing affirmative action has swept across the United States. Given this context, in 1997-98, an American Association for the Advancement of Science study found a precipitous drop in the first-year graduate school enrollment of African American and Hispanic students in all science and engineering fields between 1996 and 1997 in Research I universities. These findings were reported in *Losing Ground: Science and Engineering Graduate Education of Black and Hispanic Americans* by Shirley M. Malcom, Virginia Van Horne, Catherine D. Gaddy, and Yolanda S. George, 1998. The objective of this study is to determine if the changing climate for affirmative action is continuing to affect the first-year graduate school enrollment of underrepresented minorities in science and engineering in Research I universities. The crux of our findings is that 1998 Science and Engineering first-year graduate student enrollment for underrepresented minorities in selected Research I universities rebounded from the 1997 decline, falling below 1996 enrollment.

Methods

AAAS staff surveyed 76 Research I universities with both high levels of R&D expenditures and significant graduate education programs. Universities were asked to provide numbers for first-time (new) graduate student enrollees (full and part-time) for 1994-95, 1995-96, 1996-97, 1997-98, and 1998-99 by schools or departments in computer sciences, engineering, mathematics, natural sciences, psychology, and social sciences. Numbers were requested for total number of students and total U.S. citizens and permanent residents by gender and race. Of the 65 respondents, 42 or 64.6% were able to provide data disaggregated by race. Of these 42 respondents, 30.9% were located in the South, 26.2% in the West, 23.8% in the East and 19.2% in the Midwest. The 42 respondents represent 48% of all Research I universities.

Key findings:

- ◆ The percent of first-year graduate student enrollment in selected Research I universities in all fields of science and engineering for U.S. Citizens and Permanent Residents from 1994 to 1998 continues to decrease, although the absolute numbers are increasing (Table 1). However, the number and combined percent of first-year graduate student enrollment of U.S. Citizens and Permanent Residents in computer sciences, engineering, mathematics, and natural sciences decreased from 1994 to 1997, while the percent remained stable for 1997 and 1998, and the absolute numbers increased (Table 2).

- ◆ The first-year graduate student enrollment in selected Research I universities in computer sciences, engineering, mathematics, and natural sciences for U.S. Citizens and Permanent Residents rose 14.4% from 1997 to 1998 and is 1.6% above 1996 enrollment. However, while the first-year graduate student enrollment in computer sciences, engineering, mathematics, and natural sciences in selected Research I universities for underrepresented minorities (African Americans, Hispanic Americans, and American Indians) rose 16.4% from 1997 to 1998, it is 6.8% below the 1996 enrollment (Table 3).
- ◆ Although the first-year graduate student enrollment in computer sciences, engineering, mathematics, and natural sciences in selected Research I universities for African Americans rose 22.7% from 1997 to 1998, it is 8.1% below the 1996 enrollment (Table 3).
- ◆ The first-year graduate student enrollment in computer sciences, engineering, mathematics, and natural sciences in selected Research I universities for Hispanic Americans rose 13.2% from 1997 to 1998, but it is 6.5% below the 1996 enrollment (Table 3).
- ◆ While the first-year graduate student enrollment in all fields of science and engineering in selected Research I universities for US Citizens and Permanent Residents rose 11.8% from 1997 to 1998, it is 3.4% below the 1996 enrollment. However, while the first-year graduate student enrollment in all fields of science and engineering in selected Research I universities for underrepresented minority students (African Americans, Hispanic Americans, and American Indians) rose 9.0% from 1997 to 1998, it is still 13% below the 1996 enrollment (Table 4).
- ◆ First-year graduate student enrollment in all fields of science and engineering in selected Research I universities for African Americans rose 15.7% from 1997 to 1998, but this is 10.2% below the 1996 enrollment (Table 4).
- ◆ From 1997 to 1998, first-year graduate student enrollment in all fields of science and engineering in selected Research I universities for Hispanic Americans rose 2.4% however, this is still 17.7% below the 1996 enrollment (Table 4).
- ◆ While first-year graduate student enrollment for US Citizens and Permanent Residents in selected Research I universities rose for all fields from 1997 to 1998 it is still below 1996 enrollments in psychology (-34.5%), in engineering (-10.1%), and in social sciences (-6.7%) (Table 6).
- ◆ Although first-year graduate student enrollment for underrepresented minorities (African Americans, American Indians, and Hispanic Americans) in selected Research I universities rose for all fields from 1997 to 1998, it is still below 1996 enrollments in psychology (-24.2%), engineering (-21.9%), social sciences (-10.5%), and natural sciences (-1.6%) (Table 7).
- ◆ For African Americans the first-year graduate student enrollment in selected Research I universities between 1996 and 1998 remained the same in mathematics, and about the same

in the natural sciences and is still below 1996 enrollments in engineering (-22.3%), social sciences (-12.5%), psychology (-12.2%), and (-10.4%) in computer sciences (Table 8).

- ◆ For Hispanic Americans the first-year graduate student enrollment in selected Research I universities between 1996 and 1998 rose in computer sciences and mathematics and is still below 1996 enrollments in psychology (-37.9%), engineering (-22.6%), natural sciences (-4.5%), and social sciences (-10.5%) (Table 9).

Conclusions

Given the 1998 to 1999 rebound for first-year graduate school enrollment of underrepresented minorities in science and engineering in selected Research I universities, it appears that the anti-affirmative action climate in the United States is one of several factors that negatively affected the 1997 to 1998 enrollments. Since a significantly higher number of underrepresented minorities enrolled in graduate schools in Research I universities for the first time in 1998 to 1999, it is likely that university administrators and faculty were sorting out what admission practices were appropriate and/or legal and possibly put forth more effort in terms of recruitment.

However, first-year graduate school enrollment in engineering in selected Research I universities for U.S. Citizens and Permanent Residents, particularly underrepresented minorities, is still below the 1996 enrollment, perhaps due to the strong job market in these fields. The 1998 enrollment of first-year graduate school students in psychology is also far below the 1996 enrollment. In addition, the 91% increase in mathematics for Hispanics from 1996 to 1998 should be noted.

For more information and continuing updates on minority graduate education see the *Making Strides – In Search of Structural Reform in Science, Mathematics, and Engineering Graduate Education* and the Professoriate, <http://ehrweb.aaas.org/mge/>.

Table 1---Number and Percent of First-year Graduate Student Enrollment in Selected Research I Universities in Computer Sciences, Engineering, Mathematics, Natural Sciences, Psychology, and Social Sciences (All Fields of Science and Engineering) for 1994-95 to 1998-99, N=42

Year	Total Number of Graduate Students	Total US Citizen & Permanent Residents	Underrepresented Minorities	African Americans	Hispanic Americans
1994	26,937	19,282 (71.6%)	2,180 (8.1%)	1,285 (4.8%)	790 (2.9%)
1995	26,261	18,648 (71.0%)	2,056(7.8%)	1,209 (4.6%)	758 (2.9%)
1996	26,631	18,374 (69.0%)	2,125 (8.0%)	1,191 (4.5%)	836 (3.1%)
1997	23,904	15,881 (66.4%)	1,696 (7.1%)	925 (3.9%)	672 (2.8%)
1998	27,805	17,756 (63.8%)	1,849 (6.6%)	1,070 (3.8%)	688 (2.5%)

*Underrepresented minorities include African Americans, Hispanics, and American Indians.

Table 2 ---Combined Number and Percent of First-year Graduate Student Enrollment in Selected Research I Universities in Computer Sciences, Engineering, Mathematics, and Natural Sciences for 1994-95 to 1998-99, N=42

Year	Total Number of Graduate Students	Total US Citizen & Permanent Residents	Underrepresented Minorities*	African Americans	Hispanic Americans
1994	19,486	13,345 (68.5%)	1,290 (6.6%)	691(3.5%)	544 (2.8%)
1995	19,080	12,711 (66.6%)	1,200 (6.3%)	679 (3.6%)	474 (2.5%)
1996	19,126	12,367 (64.6%)	1,221 (6.4%)	629 (3.3%)	540 (2.8%)
1997	17,518	10,984 (62.7%)	978 (5.6%)	471 (2.7%)	446 (2.6%)
1998	20,033	12,570 (62.7%)	1,138 (5.7%)	578 (2.9%)	505 (2.5%)

*Underrepresented minorities include African Americans, Hispanics, and American Indians.

Table 3---Percent Changes in First-year Graduate Enrollment in Selected Research I Universities in Computer Sciences, Engineering, Mathematics, and Natural Sciences, N =42

	1996	1997	% Change 96 to 97	1998	% Change 97 to 98	% Change 96 to 98
Total	19,126	17,518	-8.4	20,033	+14.4	+4.7
Total US& Permanent Residents	12,367	10,984	-11.2	12,570	+14.4	+1.6
Underrepresented Minorities*	1,221	978	-19.9	1,138	+16.4	-6.8
African Americans	629	471	-25.1	578	+22.7	-8.1
Hispanic Americans	540	446	-17.4	505	+13.2	-6.5

*Underrepresented minorities include African Americans, American Indians, and Hispanic Americans

Table 4---Percent Changes in First-year Graduate Student Enrollment in Selected Research I Universities in Computer Sciences, Engineering, Mathematics, and Natural Sciences, Psychology, and Social Sciences, (All Fields of Science and Engineering), N =42

	1996	1997	% Change 96 to 97	1998	% Change 97 to 98	% Change 96 to 98
Total	26,631	23,904	-10.2	27,805	+16.3	+ 4.4
Total US& Permanent Residents	18,374	15,881	-13.6	17,756	+11.8	- 3.4
Underrepresented Minorities*	2,125	1,696	-20.2	1,849	+ 9.0	-13.0
African Americans	1,191	925	-22.3	1,070	+15.7	-10.2
Hispanic Americans	836	672	-19.6	688	+ 2.4	-17.7

*Underrepresented minorities include African Americans, American Indians, and Hispanic Americans

Table 5---Percent Changes for First-year Graduate Student Enrollment in Selected Research I Universities by Fields, All Students, N=42

	1996	1997	% Changes 96 to 97	1998	% Changes 97 to 98	% Change 96 to 98
Computer Sciences	1,923	1,707	-11.2	2,051	+20.2	+ 6.7
Engineering	8,572	7,679	-10.4	8,631	+12.4	+ 0.7
Mathematics	1,097	998	- 9.0	1,244	+24.6	+13.4
Natural Sciences	7,534	7,134	- 5.3	8,107	+13.6	+7.6
Psychology	1,612	996	-38.2	1,105	+10.9	-31.5
Social Sciences	5,893	5,390	- 8.5	6,667	+23.7	+13.1

Table 6---Percent Changes for First-year Graduate Student Enrollment in Selected Research I Universities by Fields, U.S. Citizens and Permanent Residents, N=42

	1996	1997	% Changes 96 to 97	1998	% Changes 97 to 98	% Change 96 to 98
Computer Sciences	921	776	-15.7	962	+24.0	+ 4.5
Engineering	5,060	4,384	-13.4	4,547	+ 3.7	-10.1
Mathematics	679	567	-16.5	701	+23.6	+ 3.2
Natural Sciences	5,707	5,257	- 7.9	6,073	+15.5	+ 6.4
Psychology	1,508	903	-40.1	988	+ 9.4	-34.5
Social Sciences	4,499	3,994	-11.2	4,198	+ 5.1	- 6.7

Table 7---Percent Changes for First-year Graduate Student Enrollment in Selected Research I Universities by Fields, Underrepresented Minorities (African Americans, American Indians, and Hispanic Americans), N=42

	1996	1997	% Changes 96 to 97	1998	% Changes 97 to 98	% Change 96 to 98
Computer Sciences	84	49	-41.7	98	+100	+16.6
Engineering	480	367	-23.5	375	+2.2	-21.9
Mathematics	56	50	-10.7	74	+48	+32.1
Natural Sciences	601	512	-14.8	591	+15.4	- 1.6
Psychology	202	134	-33.7	153	+14.2	-24.2
Social Sciences	702	584	-16.8	628	+ 7.5	-10.5

Table 8---Percent Changes for First-year Graduate Student Enrollment in Selected Research I Universities by Fields, N=42 African Americans

	1996	1997	% Changes 96 to 97	1998	% Changes 97 to 98	% Change 96 to 98
Computer Sciences	67	29	-56.7	60	+106.9	-10.4
Engineering	202	152	-24.8	157	+ 3.3	-22.3
Mathematics	31	25	-19.4	31	+24.0	0
Natural Sciences	329	265	-19.5	330	+24.5	0
Psychology	98	80	-18.4	86	+ 7.5	-12.2
Social Sciences	464	374	-19.4	406	+8.6	-12.5

Table 9----Percent Changes for First-year Graduate Student Enrollment in Selected Research I Universities by Fields, N=42

Hispanic Americans

	1996	1997	% Changes 96 to 97	1998	% Changes 97 to 98	% Changes 96 to 98
Computer Sciences	16	19	+18.8	30	+57.9	+87.5
Engineering	256	193	-24.6	198	+ 2.6	-22.6
Mathematics	22	24	+ 9.1	42	+75.0	+90.9
Natural Sciences	246	210	-14.6	235	+11.9	- 4.5
Psychology	95	50	-47.4	59	+18.0	-37.9
Social Sciences	702	584	-16.8	628	+ 7.5	-10.5

CHAPTER FIVE

Reflecting America? Immigrants, Minorities and Women in the S&T Workforce

Charlotte Kuh

This chapter focuses on the current state of diversity in the science and technology workforce, including immigrants. In particular, I concentrate on philosophy. The philosophical questions I wish to discuss are what is underrepresentation? How do we recognize it when we see it? And, more fundamentally, why does it matter? If we were to say that the science and engineering workforce should reflect the American population, what would the operational significance of that statement be?

Here's a simple (and easy) example. Women make up slightly more than half of the American population. They are more than half of baccalaureate degree recipients. They are somewhat less than half of the labor force, they are 33% of S&E doctoral degrees, but still only 22 percent of the S&E labor force. Is there something wrong here? Are women underrepresented? The S&E workforce is becoming feminized but, particularly in the physical sciences, math sciences, and engineering, it doesn't reflect America at all.

We know that, failing a major military engagement or a revolution in family planning, the share of women in the population is unlikely to change much. So we can ask, is 22% a number we should worry about? I argue that it is, both from the viewpoint of science and engineering as disciplines and from the viewpoint of society as a whole. Science and engineering are impoverished if, for social and cultural reasons, these disciplines deny themselves the very best talent. Science and engineering are poorer for the absence of a woman who might have a fundamental insight or develop an especially clever device. From the point of view of society, we must never forget that women vote. If women are convinced that science and engineering are irrelevant to their world, then support of science and engineering is quite likely irrelevant to their preferences—and has a lower status on the public agenda as a result. Finally, families being what they are, women play a key role in informal education—they are mothers. To the extent that they feel that science and engineering are “hard” and “incomprehensible,” that view is inculcated in our children—and science and engineering lose both men and women as a result. I find it remarkable that the share of science and engineering in baccalaureate degrees remains constant at around a third, even as our economic growth depends increasingly on the products of scientific and engineering research. This may be partially the result of a generally held view that science is difficult—and many of our mothers were convinced that it was.

The same arguments hold for ethnic diversity, except more so. The American population is becoming more and more ethnically diverse. We deny ourselves talent if we believe that only white males can do science. Society loses commitment to science, if science remains the domain of white males, even as our society becomes more diverse.

These are generic arguments for reaching out to make science more inclusive. They don't speak to the question of over- or under- representation. But there is no reason to think that a desirable

distribution is uniform with every group being represented according to its proportion in the population. With women, for example, you would expect some inequality if women are more likely to take time out to have children. We would expect more women in those occupations that permit part-time or interrupted careers. For some minority groups, economic inequality might generate a preference for occupations with a higher economic return. It is difficult to object to someone from a poor family preferring to become an MD rather than a biochemist. It is understandable that such a person might choose a career in business rather than in academia. What we are trying to remedy is inequality of opportunity. We do not ask for equality of results.

There is very little blatant discrimination these days. The MIT report on women faculty in the Science Division¹ found that what rankled most were systematic differences in resources: space, teaching loads, and summer money. Further, there was under-representation of women in administrative positions (e.g., department chair) that controlled resources. The problem was not the “old” discrimination of sexist remarks or discriminatory hiring practices. In fact, many of the women would have preferred not to take on administrative duties. They’d rather spend their time doing science. Because women didn’t want to take on positions that would give them less time to do science—and, as a result, found themselves in a less strong negotiating position for academic perks, is something discriminatory going on?

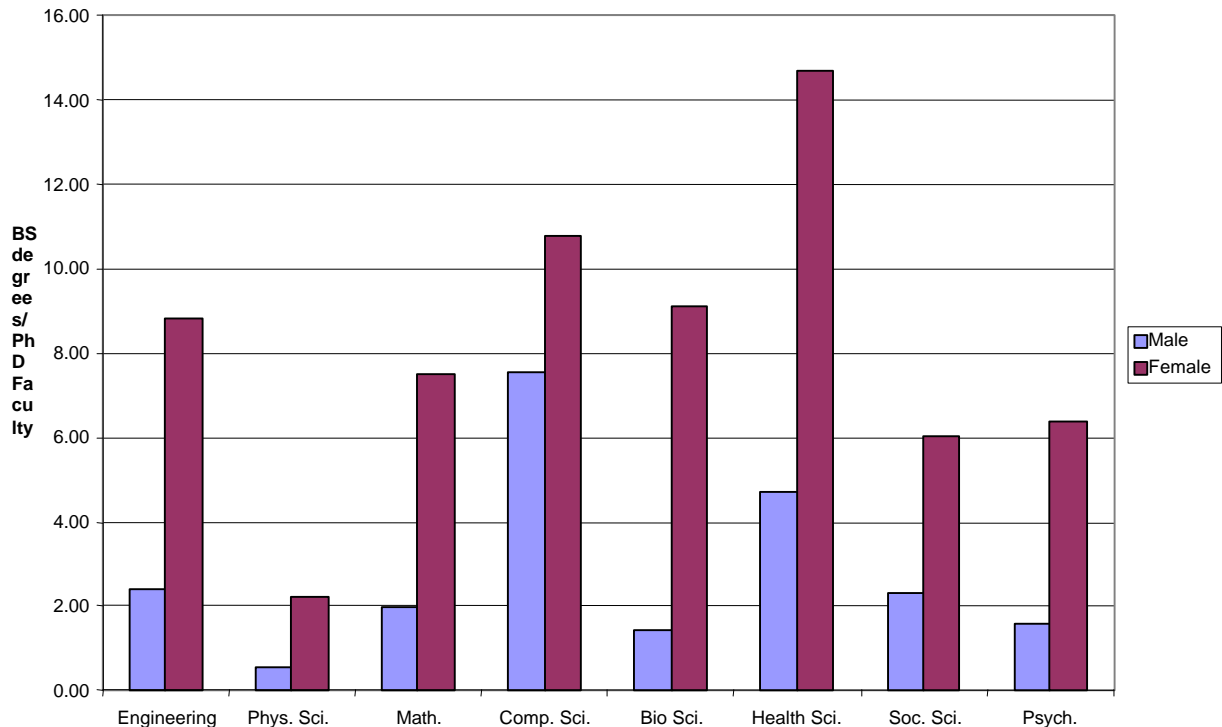
How can you tell if there is under-representation, given that what we observe is results, not opportunity? There is a report that should be coming out in 2001 that looks at differences in a variety of career outcomes for men and women Ph.D.s in science and engineering. One of the techniques used in the report is to estimate logit regressions in which a particular outcome, such as being tenured, depends on virtually everything that can be measured, both demographic measures and career and education characteristics. It turns out that years of experience since the Ph.D. explain a considerable amount of the difference in outcomes between men and women and that difference results from time spent raising children. Are women under-represented among tenured faculty? Yes. But if under-representation of women can be explained by a different pattern of work/family choice than men, is it a cause for concern and policy development? I would argue that it should be—that the scientific workplace should be more flexible and family friendly. But we don’t know if more American women would choose to do science and engineering even if the workplace were more family friendly.

These are difficult questions and they get at the difficulty we encounter when we say a group is “under-represented.” I tried one other way to get at differential representation. The notion underlying my approach is the idea of a role model. As is apparent from the numbers cited in previous chapters, the scientific workforce is more diverse today than it has ever been, but it still isn’t very diverse and, especially for women in engineering and the physical sciences and for underrepresented minorities in all fields, it isn’t diverse at all. I have a measure of this that you probably haven’t yet seen. For women, it is a measure of how many graduates there are in a field per faculty member. It is a rough measure of the chance that a member of a particular group may have seen a faculty member in their field that belongs to the same group. It has something to do with the ease with which a student can say, “Yes, there I am ten years from now!” The more constricted at the top is the pipeline, the greater will this ratio be. As can be

¹ *A Study on the Status of Women Faculty in Science at MIT*. MIT, 1997 in the MIT Faculty Newsletter, vol. XI, No. 4; March, 1999.

seen in Figure 1, the ratio, even in 1996, is unambiguously greater for women than for men in all fields. I should add that this measure isn't about mentoring. Mentoring is about a relationship and may depend as much on intellectual similarity as on gender or ethnicity. Hopefully the pool of potential mentors is greater than the pool of women faculty or it will be an uphill battle to increase the representation of women in fields in the physical sciences and engineering.

Figure 1. BS/Faculty ratios by gender

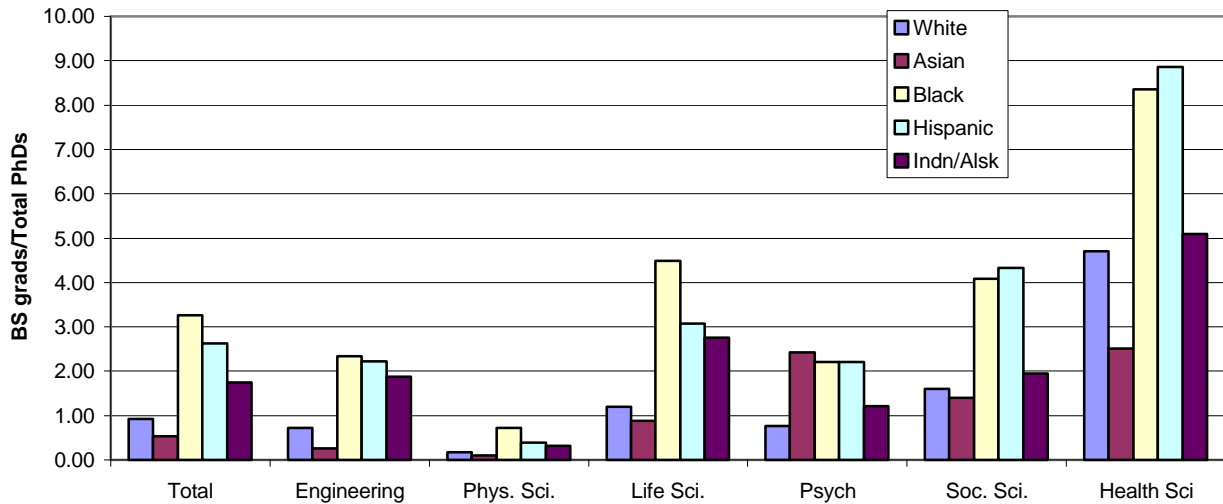


SOURCE: National Science Foundation/Division of Science Resources Studies, 1997 Survey of Doctorate Recipients

In the case of minorities, there are so few faculty members from some groups in some fields that I can't construct the same measure with publicly available data. So, in Figure 2, I've constructed the ratio of bachelor's degrees to total Ph.D.s. Again, it can be seen that there are much higher ratios for underrepresented minorities than for whites and, in some fields, Asian Americans. This disparity has two implications: 1) Minority students are much less likely to find people who look like them in the scientific work force, and 2) Minority faculty may find that they face much higher demands to mentor and encourage minority students than do their white counterparts. This makes even more imperative the need to expand mentoring of minority students beyond minority faculty.

The lesson to take home about this measure is that increasing diversity in science and engineering must be everybody's job. There are simply not enough women faculty or minority Ph.D.'s to rely on within group bootstrapping. We need to identify those places where women and minorities thrive and direct them there. Especially in the case of underrepresented minorities, there are too few not to treat each person as special and worthy of encouragement.

Figure 2. BS Grads per Total PhD's by Race



Source: National Science Foundation/Division of Science Resources Studies, 1997 Survey of Doctorate Recipients.

You will notice that “immigration” is in my title and I haven’t talked about it.

I call your attention to the work of Richard and Greg Attiyeh, who found that it was considerably more difficult for non-US citizens to be admitted to graduate school than for US citizens controlling for GRE scores². The 1997 paper by Espenshade and Rodriguez found that slightly higher proportions of non-US Ph.D. students completed the degree and in less time than their U.S. counterparts³. I have used the NRC assessment of research doctoral programs to see if there are differences in the quality of programs with higher proportions of international students within a field and find that the better programs all graduate about the same percentage of international Ph.D.s. For less distinguished programs, the proportion non-U.S. ranges from 0 to 100% -- essentially random. I find it very unlikely that graduate programs are denying places to U.S. minorities in favor of international students.

To conclude, I feel quite strongly that the U.S. needs more people to do science and engineering at most levels. The news about a bad academic job market for Ph.D.s shouldn’t disguise the overall need for scientific literacy and the ability to apply analytic reasoning to many problems in the workplace. We are not yet good at bringing underrepresented minorities into science and engineering. Getting better will involve identification of what works and commitment to implementing it at all stages of the educational process. If we can do that, I think we can build a science and engineering workforce that will reflect America.

² Attiyeh, G. and Attiyeh, R. "Testing for Bias in Graduate School Admissions." *Journal of Human Resources*. 32(3):524-548.

³ Espenshade, T. and Rodriguez, G. "Foreign Graduate Students in U.S. Doctoral Programs." Office of Population Research Working Paper, Princeton University, 1997.

Part II What We Need to Know

Despite the databases and ongoing analyses by federal agencies, professional societies, and independent scholars, there is much not known about *why* individuals turn on or off to certain interests. Put another way, how does curiosity turn into pursuit of a career? Many factors – and we would hope much information-seeking – intervene, leading to choices and decisions. If the previous section defined a baseline of what we know about education and employment in science and engineering, then this section will dwell less on data and more on the gaps in the empirical record. Identifying them will also reveal issues for further study and action.

The literature on human resources for S&T is littered with studies on supply and demand. We are better at the former than the latter. In a dynamic economy, imbalances between supply and demand are expected. Interventions in the market cannot only disrupt, but create bigger imbalances by expanding future supply that exceeds demand. Moreover, some sectors seem oblivious to the connection between supply and demand. For example, the growth in the ranks of postdoctoral researchers is in part due to the decreasing opportunities for assistant professors in universities. If this is a reliable market signal, then either production of Ph.D.s in certain fields should be tempered or opportunities for Ph.D.s outside of universities – either elsewhere in academe or in nonacademic sectors – should be trumpeted. Without one of these reactions, there is certain to be a mismatch in trained talent harboring expectations of an academic research career.

The chapters in this section explore how we think about, estimate, and model workforce supply and demand. **Nelson** adopts a futurist stance that is national in scope, systemic in approach, and aggressive in advocating individual and organizational preparation for change. **Finn** uses his vast experience with modeling, national studies, and predictions of “shortfalls” in personnel to examine two critical propositions: first, that demand cycles are inevitable and “work themselves out,” and second, that the structure of the economy is changing, which “education policy must recognize.” Finally, **Syverson** explores trends in applications to graduate school as a leading indicator of the future supply of scientists – and the perils of forecasting when demand for personnel with particular degrees and areas of specialization is uncertain.

Questions that an inquiring reader might entertain include the following:

1. Is there both a feasible and defensible response to the normative question, What *should* be the composition of the U.S. science and technology workforce?
2. Because career choice is determined by many factors in addition to individual talent, how might we design studies – not necessarily requiring longitudinal data – to investigate the factors influencing observed outcomes?
3. Have research and analysis focused excessively on issues of race, ethnicity, and gender without tackling the complicated role of socioeconomic class as a prime factor in S&E career preparation and participation?

4. How can national data be better utilized by all participants in the S&T system – policymakers, agency sponsors, research and education performing institutions of higher education, faculty, and students with career aspirations?
5. What are the trends on which we could have a better handle? That is, what data are strikingly incomplete or contradictory, which demand immediate attention, augmentation, and refinement?

CHAPTER I

From Forecasting to Foresight

Stephen D. Nelson

It is a truism that every player in the human resources chain for science and engineering – students, educational/training institutions, young professionals, employers, and policy makers, to name just a few – needs to make informed choices about the likelihood of future events. For example, students considering a career in science or engineering want to know about the level of future demand for their soon-to-be-developed skills. Educational institutions need to assess the numbers, types, and incoming skill-levels of prospective students, the need for the school’s finished products (trained professionals), and how to calibrate their educational/training process to mediate between the two. Young professionals, having already committed to a career in a scientific or engineering specialty, will want much more fine-scale information about where their career prospects can be maximized. Employers need to know where their sector (whether in the commercial or the non-profit world) is headed, what level of workforce their organization will need, what kinds of skills will be needed in their new employees, and what the supply of personnel is like. Policy makers need to know something about the probable demand across a large number of key sectors, what the supply of appropriately trained young people will be, and what policy levers – if any – can be manipulated in attempts to either attain or maintain a reasonable balance between supply and demand in the appropriate fields.

However, few if any of these players actually have the kinds of information or shared perspectives about likely futures that they need in order to make truly informed choices. More specifically, adequate information and shared perspectives do not characterize the situation for (a) any of these separate roles or segments, (b) the overall national science and engineering (S&E) human resources (HR) system as a whole, or (c) the dialogue, interplay, and exchange that needs to take place among the various segments. We do not have this information largely because: (1) gathering and analyzing trend information is difficult and expensive; (2) assembling that information into predictive models is prohibitively complex and involves many essentially unpredictable elements acting within the long lag time between the observation or expression of a demand state and a corresponding supply response; (3) mechanisms for effectively disseminating the needed information to all interested players are not adequate to the task; and (4) we do not, as a rule, think properly about what range of information is needed nor how precise we can expect predictions to be. The first three of these factors get periodic attention from various observers. I would like to address the fourth issue, and simply make the modest argument that we need to adopt new ways of thinking about and adapting to future developments in these areas. These new ways involve, in part, substituting the broader notion of *foresight* for the relatively simpler one of *forecasts*.

As used in the futures research community, the two concepts are quite distinct. A forecast essentially attempts to predict fairly specific results or outcomes, even if the prediction involves a range of values or a set of probabilities attached to the prediction. By contrast, foresight is a more general concept encompassing a wider range of approaches, types of information, and (even more importantly) attempts to *integrate* them – even if subjectively or in a “fuzzy” manner

– into a wholistic picture of the full situation. The S&E HR system, and its various elements within it, have significant needs for foresight (rather than simply forecasts) regarding many issues: markets (whether they are stable, shrinking, expanding, or entirely new); supply and demand, and their balance, in each market segment; the options open (or opening) for career directions by entering professionals; changes in the mix of skills and the levels of skills required for various market segments; recent or current employment/employability experiences by job candidates; and the current and projected needs of different types of employers.

Forecasting, which in the S&E human resources area is essentially either labor demand or supply modeling, is just one of many tools that need to be used, or that one should stay aware of, in the process of developing an evolving sense of probable futures. I do not mean so much to be critical of forecasting or predictions (which are certainly useful tools in the arsenal of all S&E HR players), as I do want to emphasize the need for, and the utility of, a considerably expanded way of approaching the task of trying to anticipate future events.

To illustrate the difference between forecasts and foresight in another way, and to place them in broader perspective, let us consider Michael Marien's (2000) "six realms of future-thinking," to which he refers colloquially as "five P's and a Q." The first and most elementary level, according to Marien, is trying to discern *probable* futures (by means of forecasts or predictions). The second level is articulating *possible* futures (specifying the range of what *could* happen, by means of scenarios and "wild-card" events). The third level is envisioning, from among the possible futures, one's *preferred* futures (by means of agendas, plans, or policies). The fourth arena is identifying *present trends*, particularly those that act as indicators of change in the system one is concerned with. The fifth is integrating all the foregoing into a *panoramic vision* of the issue area (by means of either formal models or less formalized overviews). And the sixth activity involves continually *questioning* and trying to reformulate the accepted understanding, to take account of newer or additional information.

Seen in this broader perspective, another reason for arguing for a broader approach becomes apparent. Predictions or forecasts can lead us to think too passively about the future, to see the forecast and its implicit vision of the future as inevitabilities, rather than as one possible outcome that may be likely if the system's major parameters are not changed. Even the best forecasts do not describe inevitabilities. They are best guesses, even well-informed best guesses, but they are always made within certain parameters or boundaries. And they can be wrong, sometimes spectacularly so, particularly if the underlying parameters change.* Events and outcomes in the future are less the product of "past-push" than we uncritically assume, and are often more drawn by "future-pull" than we are generally aware of.

The primary practical purpose of looking to the future is, after all, to make more intelligent choices in the present. "The future" is not something that just happens to us. We actively participate – or should, at any rate – in *choosing* from among alternative futures.

In sum, I argue that foresight (presumably informed by, but by no means limited to, forecasts) needs to be:

- (1) system-wide (i.e., conducted by every component in the S&E HR system – policy makers, agency sponsors, educational/training institutions certainly at the higher education level if not also below, graduate departments, potential employers); and
- (2) systemic (i.e., at the level of, and on behalf of, the system as a whole – for example, the nation); and
- (3) articulated, shared, and debated *between* all components of the system, rather than just done by each one separately.

Only in this way can we move toward developing satisfactory solutions to dilemmas such as how to meet the nation's needs for S&E personnel, while at the same time making sure that students have a realistic picture of their career prospects in a particular field.

Our situation in the S&T HR area, as in so many other areas of modern life, seems to become ever more complex and difficult to comprehend fully. But, as Ilya Prigogine once observed, "We cannot predict the future, but we can prepare for it."

Reference

Marien, Michael. De-mystifying Futures Thinking: Toward Balanced Science for a Viable 21st Century. Presentation as part of a panel on "Anticipating Science and Technology's Futures," at the 2000 Annual Meeting of the American Association for the Advancement of Science, Washington, DC, February 20, 2000.

* The area of speech-language pathology provides a vivid illustration of the difficulties of depending predominantly upon projections or forecasts. (In passing, it should be mentioned that this field is composed primarily of practitioners, rather than scientists – persons who, like engineers, use scientific information to diagnose and design solutions to problems. But the example is illustrative nonetheless) Throughout the 1980s and into the early 1990s, there were significant shortages of speech-language pathologists in medical settings. Forecasts projected that demand would continue to outstrip supply for the profession. As a result, universities tried to produce as many speech-language pathologists as possible, and the field became one of the fastest growing professions for a time. Unseen or under-appreciated by many was what was supporting the continuing demand for the field: namely, the nature of the Medicare reimbursement system for health care at the time. However, a provision of the 1997 Balanced Budget Act changed the Medicare reimbursement system from a fee-for-service basis to a "prospective payment" system. As a result, the incentives for institutions employing speech-language pathologists were turned upside-down. Previously institutions were paid more for providing more services. Now they were to be paid a flat sum per diem up front, and then had to decide, within legal limits, how much service to provide. So under the new system, the less service the institution provided (within its minimum requirements), the more profit the institution made, and the incentive was to pay the services staff as little as possible. As a result, many speech-language pathologists had to take significant pay cuts, and many positions were eliminated. Almost overnight the field became dead in the water, with an oversupply, rather than undersupply, of trained professionals for medical settings.

CHAPTER EVEN

Modeling Demand for PhD. Scientists and Engineers¹

Michael G. Finn

I worked with Alan Fechter on several projects relating to the subject of my remarks today, Modeling Demand for Scientists and Engineers. I spent two years working for Alan from 1988-90 at the NAS's Office of Scientific and Engineering Personnel (OSEP). During that time I supervised a study committee that is reconvened every few years pursuant to the Act that authorized the National Institutes of Health's (NIH's) training grants for graduate students and postdoctorates. I believe that 1989 was the last study in this series to model or project demand for Ph.D. scientists.

About that time Alan Fechter became more skeptical of attempts to look into the future in this way. I believe his concerns were two-fold: (1) a concern shared by all modelers that shocks to the system are virtually impossible to anticipate. Unforeseen events in the USSR led to a decline in military spending in the U.S. and for several years we were to see Federal R&D spending stop increasing. Also, (2) Alan picked a fight with the National Science Foundation (NSF) over its forecasts of shortfalls of scientists. Since the AAAS President expounded the NSF projections and shortage conclusions, I guess we could say AAAS was involved too. [1] Alan had a valid technical criticism of the analysis that underpinned the forecasts for B.S graduates. [7] However, what really created controversy was that the criticism he started grew. Within a short while many realized that the projected B.S. "shortfall" was based on no formal projection of demand at all, and some suspected the Director of NSF of overstating the case for a shortage because it seemed to help his efforts to double the NSF budget.

During the past 5-8 years I have heard many negative references to NSF's shortfall forecasts. I can only conclude that, at least in the realm of public opinion, Alan won that one. However, it has gone further. Now, virtually everyone says that you can't project future needs.

The next "manpower" study done by OSEP for the NIH was published in 1994 and it didn't project demand for scientists—even though the title was "Meeting the Nation's Needs for Biomedical and Behavioral Scientists." Instead, the study committee looked at alternative growth rates of the Biomedical work force (from zero up to the 1981-1991 rate) and estimated the number of job openings that would occur in each case. They then made the recommendation that NIH keep the number of pre-doctoral training grants at the then current level of 5,100 in the basic biomedical sciences.

The 1994 study was charged with establishing the nation's need for research personnel, the number of personnel needed in each subject area, and the extent of training that should be

¹ This document describes activities performed under a contract between the U.S. Department of Energy and Oak Ridge Associated Universities. Research for this document was supported by a grant from the Division of Sciences Resources of the National Science foundation to the Oak Ridge Institute for Science and Education.

provided such personnel. They made the recommendation not to change the number of pre-doctoral training grants based not on any modeling of future demand. Rather, they judged that,

“Universities are unlikely to increase faculty size dramatically in the near future, federal spending on biomedical research is not likely to increase in real terms in the near future, and private sector demand (viz., industry) is not likely to increase rapidly in the near future.”

“The best predictions for economic activity and R&D funding in the near future suggest that demand for basic biomedical scientists will grow slowly at best. Under these conditions maintenance of the current rate of entry of Ph.D.s in the biomedical sciences should provide an adequate supply for the years 1996-2001.” [8, p. 36]

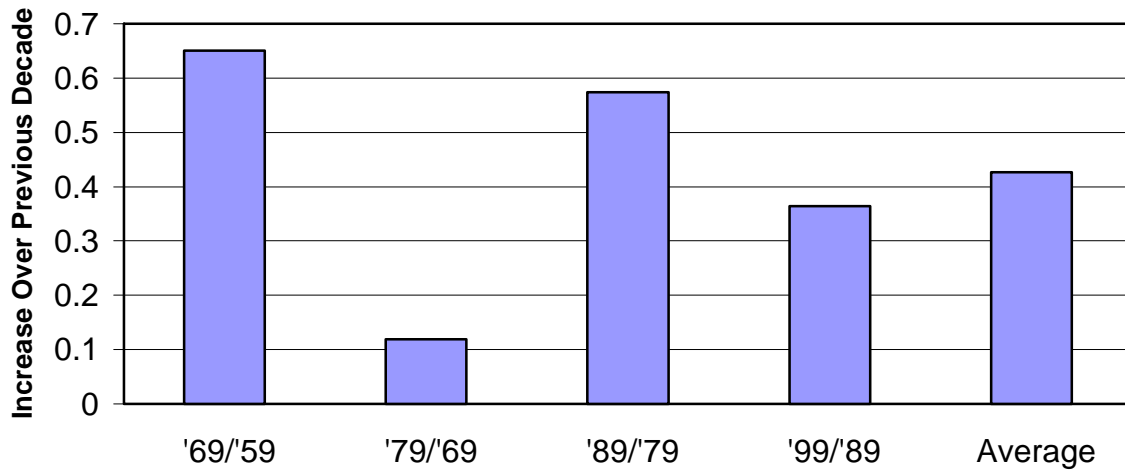
This seems to fit Nelson’s discussion of “forecast” in the previous chapter. Although this report did not project demand in any formal way, it did construct estimates of how many job openings would exist with no growth, the growth rate in the workforce that existed in the 1980s, and also half that growth rate. Implicitly, they chose the reduced growth rate when they recommended keeping pre-doctoral support at 1994 levels, because their own analysis revealed that the number of degree awards observed most recently, ...“would fall considerably short of the number needed to maintain the annual 1981-1991 growth rate.” [8, p. 32]

A few years later the widely reported Committee On Science, Engineering, and Public Policy study on graduate education took the same attitude towards modeling demand. [6] Its’ *laissez-faire* advice towards students is more of a philosophical position than a policy recommendation. Other reports such as the NAS Tilghman committee report, Trends in the Early Careers of Life Scientists, eschew any attempt to model demand, and substitute mere assertions that we had entered “an era of little growth.” [9, p. 80]

Thus, it is now typically the case that our serious labor market studies have no formal projections or modeling of demand. However, while NSF seems to have refrained from making forecasts during the 1990s, this has not prevented others from doing so. We might say that intuition has triumphed over more formal modeling.

So how has the intuition fared? Not well. Take the last National Research Sciences Act study: it judged that R&D spending and total employment growth of biomedical scientists would grow at a slower rate in the 1990s than in the 1980s. They were writing while we were struggling to come out of the 1993 recession. Total R&D spending had been growing slowly since the mid-1980s. However, later in the decade it began to make up time. Figure 1 shows increases in R&D spending by decade. It’s true that in the 1990s we did see a slowdown in total R&D growth relative to the 1980s. However, the increase was close to the four-decade average shown in Figure 1. Further, the growth of R&D spending accelerated during the 1990s. If we were to graph only the period after publication of the of the 1994 NRSA report it would be above the historical average.

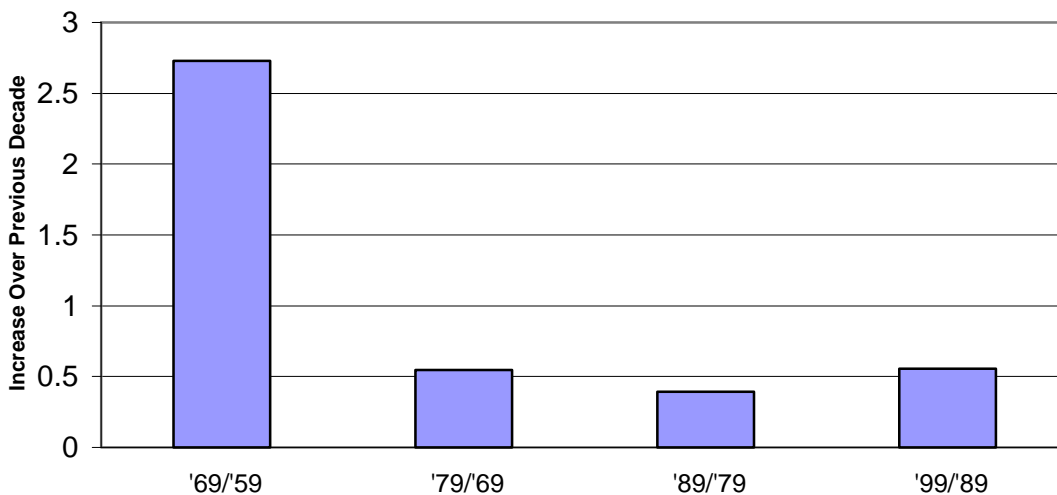
Increases in Total U.S. R&D Expenditures, 1959 to 1999, by Decade, in Constant Dollars



Source: NSF, National Patterns of R&D Resources: 1999 Data Update, Tables 1A, 7, 2000, <http://www.nsf.gov/sbe/srs/nsf00306/start.htm>.

The studies discussed above focused on life science or biomedical science labor markets. For these a more appropriate discussion of R&D would focus on R&D spending in areas that employ many of these scientists. The totals are affected by Defense and Energy R&D, which declined in the 1990s. We don't have data through 1999 for private sector R&D in these areas but, we do have data on Federal obligations for R&D in the health area. Figure 2 shows that Federal spending on health R&D grew at a faster rate in the 1990s than it did in the 1980s. The recently passed Federal budget for FY2000 included another double-digit increase for NIH.

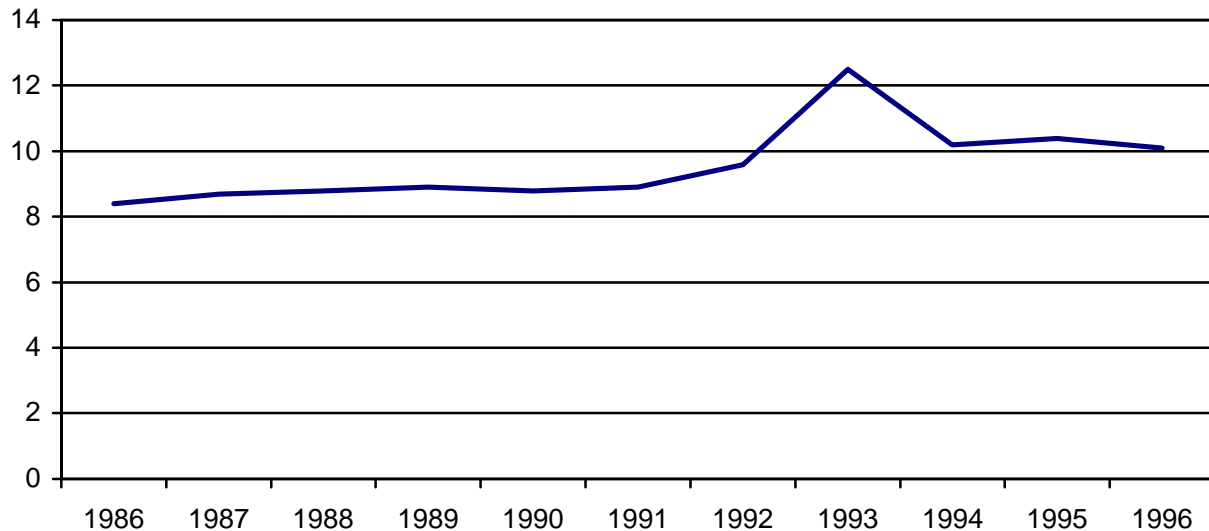
Increases in Federal Health R&D, 1959 to 1999, by Decade, in Constant Dollars



Source: NSF/SRS, Federal Research and Development Funding by Budget Function: Fiscal Years 1998-2000 Early Release Tables, 1999, www.nsf.gov/sbe/srs/srs99415.

Industry funded R&D has increased in the late 1990s. I don't have data through 1999 by industry but Figure 3 shows what has been happening with Drug Company funding of R&D from 1986 to 1996. While this is not comparable to the two previous because it is expressed as a percentage of sales, it shows no slowdown in R&D funding by drug companies, indeed after shooting up in 1993 it has stayed at a new higher level.

**Drug Company and Other (except Federal) R&D Funds
as Percent of Sales, 1986 to 1996**



Source: NSF/SRS, *Research and Development in Industry: 1995-96*, (NSF 99-312).

As an aside (because I'm only looking at demand modeling, not total supply/demand balance), one might ask whether labor has become more scarce in view of this incorrect forecast? Yes, NSF SESTAT data show unemployment and "Involuntary out-of-field" rates were down in 1997 to what might be called good (for job seekers) rates of 1.5 percent and 2.2 percent. Anecdotal reports indicate that the market for Ph.D. biological scientists has continued to improve for job seekers since 1997, and the rising R&D appropriations certainly suggest this is correct. Employers would, in fact, be in tough shape if the Congress had not changed the laws multiple times to ease immigration of scientists and engineers. In the life sciences in particular we have evidence of a dramatic growth in the fraction of the new additions to the workforce that is made up of foreign citizen Ph.D.s. [12]

The benefit of hindsight permits us to criticize all demand forecasts, whether based on intuition or modeling that uses historical data and assumptions about the future. It now seems clear that the demand pessimists writing in mid-1990s made a mistake in assuming that a few years of lower growth in demand meant that a new era of lower growth had arrived. One could even say that in the case of the life sciences there was a slowdown associated with the 1982 economic recession and they should have seen that this was only temporary when it came again with the 1993 recession.

There were a significant number of labor market professionals who doubted that we had entered a new era in the 1990's. I'm reminded of an impressive, but little publicized ad hoc working

group coordinated by Ken Brown at NSF's Science Resource Studies Division in 1993 which gave its results to White House Federal Coordinating Council for Science, Engineering, and Technology committee. Representatives of the Labor Department and other Federal agencies that employ scientists and engineers were convened into an interagency task force that met several times. They summarized the prevailing outlook as a choice between two views:

“Things will get better as problems work themselves out”

vs.

“Economic fundamentals have changed in ways that SEM education policy must recognize” [5]

Fechter was not afraid of jargon and would have said that the first view is that the slowdown in demand that was observable in 1993 could be viewed as a temporary cyclical phenomenon, and the second as a structural change, i.e. one that would remain after the recession. In the words of the ad hoc group headed by Ken Brown, a structural change might involve shifts in international competitiveness—other nations may be competing more aggressively with our technology companies with consequences for S/E labor markets. If this kind of structural change were happening, “At the very least, the federal government should moderate its support for the production of new SEM professionals until the situation is better understood.” [5, p. 7] The working group stated that while it tended to favor the first, more optimistic view, agreement was not unanimous.

That was nearly 7 years ago. There has been some structural change which has shifted demand away from energy and defense R&D towards more life science and computer science R&D. However, there has been no substantial overall shift away from work that requires the input of scientists and engineers.

So what does all this mean for demand projections and modeling? The simple fact is that responsible people in Washington are still very skittish about using demand projections to justify any policy to expand educational funding in science and technology. You can find distinguished economists aplenty to tell you how hard it is to produce a good demand projection—fewer that want to be involved in doing such dirty work. [10] The Bureau of Labor Statistics (BLS) still produces respectable employment projections for all occupations, but they are not disaggregated for Ph.D.s and their data is insufficient to do this.

Contrast this with the situation of the federal budget deficit or the projected future shortfall in the Social Security Trust Fund. I'm sure the Washington Post has published new projections from the Congressional Budget Office at least twice in the past year, each one showing a higher surplus over the next 10 years than the earlier one. These are treated with considerable seriousness by all concerned—in spite of the fact that their forecasting record is abysmal. Three years ago they thought we would have a significant budget deficit in 1999, rather than the substantial surplus we enjoyed.

Why do we like budget projections even though the groups who produce them are always wrong? I think it's because they help us to think about policy. We can ask whether we can afford to cut taxes and still meet future social insurance obligations. We can ask whether a

particular proposed tax cut could be implemented without causing a deficit in the future. The budget projections may not be correct but they provide discipline and a way to score proposed legal changes that have impact on the budget.

I continue to think that employment projections have the potential to be used in this constructive way for proposed changes in human resource investments, or proposed changes in immigration law. Of course, to do so we would have to have a model that incorporates supply and demand, that some authoritative source could be trusted to use to test alternative policy changes. We aren't there yet.

Some say lets not model future supply and demand. But as long as Congress, universities, corporations, and graduate students make long term investments they will feel the need to make some kind of assumptions about future labor market conditions for scientists and engineers.

I think we could make a case to use a type of extrapolation procedure to guide policy, if we can't agree on any more sophisticated modeling procedure. We can extrapolate the growth rate of Ph.D. employment, or we can try to model academic employment and extrapolate R&D employment as a function of R&D spending. It's easy to find reasons why this may not be a good guide to the future but hard to find an approach which works better, let alone one which both works better and which people understand.

One thing we can do to make such extrapolations more useful is to use the same historical data that produced the projections to produce more sophisticated projections. The simple extrapolation projects employment (or R&D spending) using the mean growth rate experienced during a past period. I would advocate the use of longer periods such as 30 to 40 years rather than shorter periods. Over these longer periods it is possible to also identify shorter periods of slow growth and fast growth. If the current level of Ph.D. production can sustain a growth rate of 3 percent in employment but no higher, we should ask, "How many 10-year periods over the last 50 years have had growth rates in employment in excess of 3 percent?" For a variety of different degree levels we can answer the question like the following: If history is our guide, what are the odds that this level of degree production will be sufficient to keep labor from becoming scarcer, without increased reliance on foreign labor. We can construct a table that would show those odds for different levels of degree production.

What I'm advocating is not much different from what Alan Fechter and the NRC committee tried to do in 1994. It differs, by relying on the hard data of history as our guide to the future, instead of expert judgments.

I could draw an analogy with something most of the people in this room are probably familiar with, retirement planning. Most of us have probably used some kind of retirement planning software—or at least we mean to—to decide whether we are saving enough to meet our retirement goals. You can create a spreadsheet model for yourself or use the free software available from a variety of sources such as the major mutual fund companies. You give these models your current retirement savings, age, and desired retirement age, and decide how your funds are to be allocated among different asset classes such as stocks and bonds. They all use simple extrapolations of historical rates of return for these asset classes to project your future

earnings and figure out how much you could spend each year if you bought an annuity at your selected retirement age.

I did this and my model said everything is fine; why with the recent run-up in stocks I'll have more income in retirement than I do now by working, even if I were to retire at the increasingly more popular age of 62. But a nagging voice said, there has to be something wrong with this picture. I then found a neat little paper titled, "The Retirement Calculator from Hell." [2]

In this paper, William Bernstein notes that the return on equities varies from the historical average from time to time. The longest time period of low stock market returns was the 17 year period from 1966 to 1982 when stocks did no more than to keep up with inflation, i.e. their real rate of return was not the historical average, but zero. A person who retired in 1966 and died this year would have received a rate of return that was near the historical norm of about a 7 percent return on stocks after inflation—if he didn't spend any. However, if he had tried to spend in retirement at an even rate assuming a 7 percent return he would have run out of money long before he died. [Or perhaps would have died early because of poverty?] The point is that its probably ok to count on the historical average for stock market returns over a 40 year period, but if you want to be secure then you have to allow for the fact that you might start out your golden years with a period of low returns. The best way to be sure you survive that is to spend about 2/3 what the historical average rate of return suggests you can until you are well into your retirement. At least this would work if history repeats itself.

The point of this analogy is that we can and should use historical statistics not only to project future behavior, but also to ask about worse case scenarios. With regard to the labor market for scientists there are two distinctly different worst case scenarios. For government agencies and other employers, the worst case is that degree awards stay constant or decline and the demand for scientists grows at the highest rate we have seen over any ten-year period over the last 50 years. For new PhDs that is the best case scenario; the worst case is the lowest rate of growth over any 10-year period in the last 50 years. I am suggesting we calculate the historical odds of each when we do projections based on extrapolations of past growth. And while we are at it, calculate the odds of less severe deviations from that trend that are big enough to cause a problem and will occur more than once every 50 years.

You might say that we could do that but our politicians want a simple answer and will demand it of those who do the projections. i.e., "Tell me, will we have a shortage or won't we?" Well, on that I want to end with a short story. I attended a Senate hearing about 10 years ago. Testifying were Erich Bloch, Director of NSF, Richard Atkinson, President of AAAS, and Al Trivelpiece. Bloch and Atkinson repeated their assertions that shortages will develop if we don't increase the number of graduate students. At the hearing, Senator Al Gore asked each what is the probability that you are wrong, what odds would you attach to this assertion? Each suggested small odds of being wrong, one number I recall is 100 to 1.

Were they wrong? I'm quite sure that none of the analyses prepared for them calculated odds that any particular outcome would occur. In this case it was the politician who asked the right question, and the scientists who were unprepared.

References

1. Atkinson, Richard C., Annual Address of the President of the American Association for the Advancement of Science, "Supply and Demand for Scientists and Engineers: A National Crisis in the Making," submitted to the Senate Commerce Subcommittee on Science Technology and Space, Hearing on Scientific Personnel Shortage, May 8, 1990.
2. Bernstein, William J., Efficient Frontier—An Online Journal of Practical Asset Allocation, "The Retirement Calculator from Hell," September 1998, <http://www.efficientfrontier.com/ef/998/index998.htm>.
3. Bloch, Erich, Position Paper: "Multiagency Graduate Student Support in Science and Engineering, National Science Foundation," Office of the Director, October 12, 1989.
4. Bloch, Erich, "Testimony for the U.S. Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology and Space," May 8, 1990.
5. Brown, Kenneth M., Report of the Ad Hoc Working Group on the Supply of Science, Engineering and Mathematics (SEM) Professionals, Washington, DC: National Science Foundation, September 9, 1993, <http://www.nsf.gov/sbe/srs/fccset/start.htm>.
6. Committee on Science Engineering and Public Policy (COSEPUP), Reshaping the Graduate Education of Scientists and Engineers, Washington, DC: National Academy Press 1995.
7. Fechter, Alan, "Engineering Shortages and Shortfalls: Myths and Realities," The Bridge, Volume 20, no. 2, Fall 1990.
8. National Research Council, Committee on National Needs for Biomedical and Behavioral Research Personnel, Meeting the Nation's Needs for Biomedical and Behavioral Scientists, Washington, D.C.: National Academy Press, 1994.
9. National Research Council, Committee on the Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists, Trends in the Early Careers of Life Scientists, Washington, D.C.: National Academy Press, 1998.
10. National Research Council, Forecasting Demand and Supply of Doctoral Scientists and Engineers: Report of a Workshop on Methodology, Washington, DC: National Academy Press 2000 <http://books.nap.edu/books/0309070899/html/R1.html>
11. National Science Foundation, Division of Science Resources Studies, Research and Development in Industry: 1995-96, NSF 99-312 Arlington, VA 1999.
12. Michael G. Finn, "Stay Rates of Foreign Doctorate Recipients from U.S. Universities, 1997", Oak Ridge, TN: Oak Ridge Institute for Science and Education, 2000.

CHAPTER EIGHT

What Can Application Trends Tell Us About the Future Demand for Graduate Education?

Peter Syverson

Introduction

Over the past few years the job market for new bachelor's-degree recipients has been unusually strong, with national unemployment rates at 4% and unemployment for bachelors-degree recipients at 1.6%. There is widespread concern that this hot job market for bachelor's-degree recipients, coupled with negative news about the availability of academic positions, will depress student demand for graduate education, especially among the most talented.

One potential measure of the demand for graduate education is the number of students applying to graduate programs. Changes over time in the number of applicants could serve as a gauge of changes in demand for graduate education. However, because there is no central registry of applicants to graduate school, developing a database of applicants would entail collecting information on individual applicants from U.S. graduate schools, and because students apply to more than one institution, duplicates would have to be removed by matching records across institutions. While this has been done for small groups of institutions, it has not and probably could not be done for a sample large enough to represent all graduate programs in the U.S.

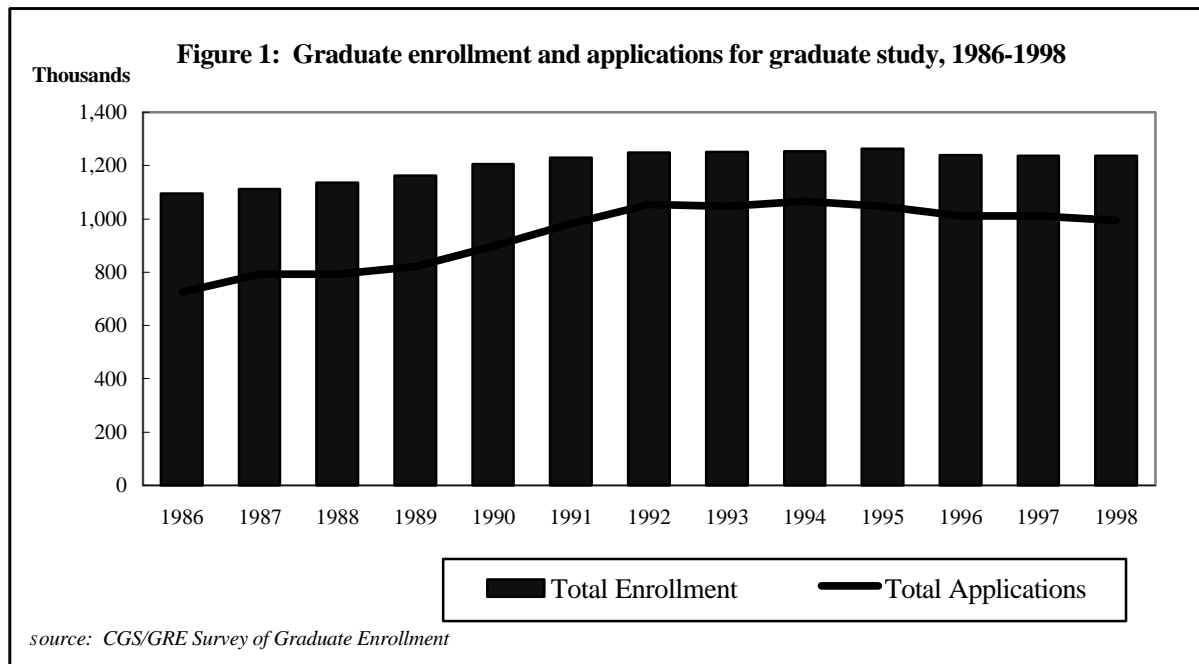
An alternative approach is to collect data on the number of applications to graduate programs and analyze the trend in applications over time. The CGS/GRE Survey of Graduate Enrollment¹ is an annual survey of approximately 680 institutions. In addition to statistics on graduate enrollment and degrees, the survey collects data on the total number of applications received by major field of study. Of course, this data source counts all of the applications for those who apply to more than one graduate school. However, so long as the average number of applications per applicant stays steady, the trend in applications should serve as a reasonable proxy for the trend in student interest in pursuing graduate degrees. The analysis that follows looks first at national trends in applications, then focuses on applications in science and engineering, including trends in the selectivity of science and engineering graduate programs.

Graduate Enrollment and Application Trends

Since 1986, graduate enrollment has experienced periods of rapid growth and slow decline. As displayed in Figure 1, graduate enrollment began the 1986 to 1998 period with 7 years of steady growth in enrollment and applications. During the 1986-1992 period graduate enrollment grew at a 2% annual rate, and applications rose by 7% a year. Beginning in 1992, graduate enrollment began to level off, as did the number of applications. The first indication of the oncoming

¹ *Graduate Enrollment and Degrees, 1986-1998* is the latest report from the CGS/GRE Survey of Graduate Enrollment and is available in PDF format on the Council of Graduate Schools (CGS) web site at <http://www.cgsnet.org/VirtualCenterResearch/graduateenrollment.htm>.

decline was a decrease in applications from 1994 to 1995. Graduate enrollment peaked in 1995 and then began a slow decline to 1998.



Graduate applications followed a similar path, from a swift increase to a steady decrease. There are two important things to note about the application trend line. First, since applications were growing faster than enrollments in the late 1980s and early 90s, graduate schools were becoming more selective. Second, the application trend peaked in 1994 and began to decrease one year before the graduate enrollment declined. At least here, application trends were an early indicator of the impending decrease in graduate enrollment.

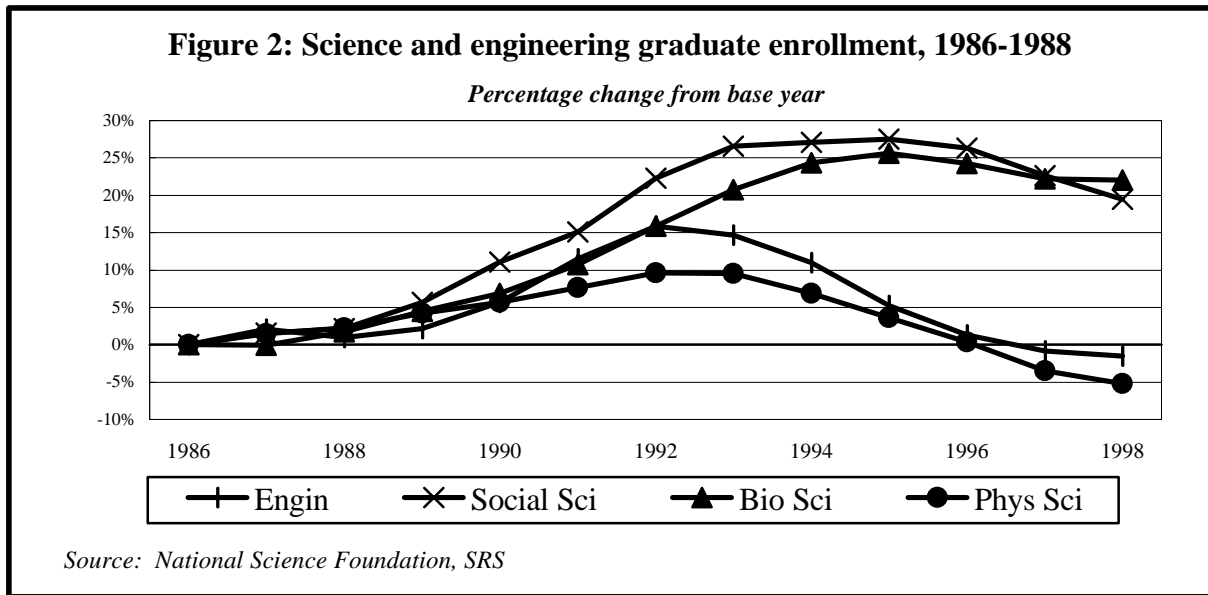
Science and Engineering Enrollment and Applications

Traditionally, scientists and engineers react to labor market trends earlier than other groups, and this happened in the 1990s. Science and engineering fields experienced rapid growth in the late 1980s and early 1990s but began to decrease in 1992, well ahead of total graduate enrollment, which did not decrease until 1996.

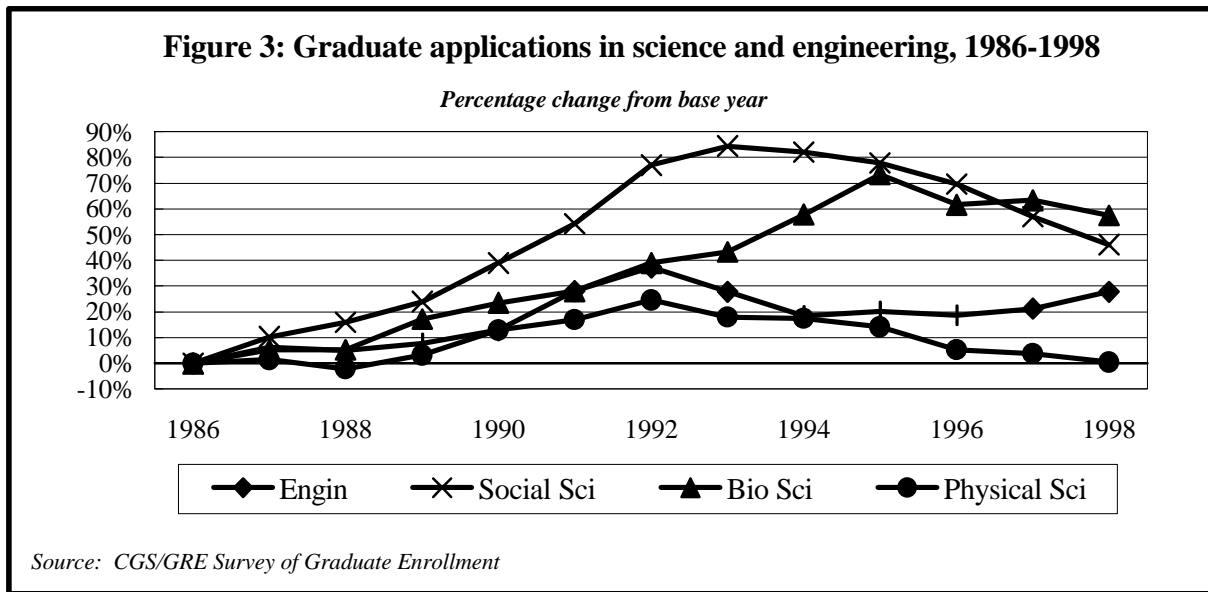
Figure 2 shows the enrollment trend as a series of annual percent changes from 1986 to 1998². Graduate enrollment in engineering and the physical sciences grew 10% and 15% respectively from 1986 to a peak in 1992 and declined through 1998. Enrollment in both fields was lower in 1998 than it was at the beginning of the survey period. In contrast, enrollment in the biological

² Figures 2 and 3 display enrollment and application trends as percentage change from base year. The percent change from the first year of the time series is computed by dividing each point in the time series by the first year's data. Since all the trend lines began at the zero point, this type of graph allows the display of data series of widely differing magnitudes on the same graph. Moreover, the reader can read the percent change in a data series from 1996 directly from the ordinate (vertical) axis.

and social sciences continued to grow until 1995, with declines thereafter. Enrollment in both the social and biological sciences was roughly 20% greater in 1998 as in 1986³.



As with graduate enrollment, applications to graduate programs in the sciences and engineering reflect the pattern of growth and decline but with far greater volatility (see Figure 3).



³ The key demographic factor that distinguishes the biological and social sciences from other science fields is the participation of women. In fact, graduate enrollment in the biological sciences is about evenly split between men and women, and in the social sciences 57% of graduate students are women. Enrollment in these fields has remained stable because the number of women in graduate programs continued to grow in the late 1990s as the number of men declined.

Applications in the physical sciences grew to 1992 and then declined to 1998, ending the period with no growth in applications. Engineering applications grew by 40% to 1992, declined sharply to 1994 and began to rise in 1997 and 1998. Much of the recent growth in engineering applications is due to a recent increase in applications from Pacific Rim countries, specifically India and China⁴.

At the same time, applications in the social sciences soared by 84% from 1986 to 1993 but declined rapidly to 1998. Applications to programs in the biological sciences grew by more than 70% to a peak in 1996, declined to 1998, but remained nearly 60% above their application totals in 1986.

Selectivity

As applications increased faster than enrollments, science and engineering programs became more selective. As shown in Table 1, overall acceptance rates in science and engineering decreased from 41% in 1986 to 36% in 1992. More surprisingly, acceptance rates remained stable from 1992 to 1996 even though the number of applications declined. Acceptance rates varied by field, with the biological sciences the most selective, accepting just 28% of applications submitted. In fact, acceptance rates in the biological sciences decreased throughout the period, as did acceptance rates in the social sciences. Social sciences were second at 31%, followed by the physical sciences at 40% and engineering at 42%.

Table 1. Graduate application acceptance rates in science and engineering, 1986-1998 (in Percent)

	1986	1992	1998
Total science and engineering	41	36	36
Biological sciences	38	32	28
Engineering	45	42	42
Physical sciences	40	37	40
Social sciences	40	32	31

*The acceptance rate is computed by dividing the number of applications accepted by the total number of applications.

Source: CGS/GRE Survey of Graduate Enrollment

enrollment. Slots in a graduate program are a finite good, and as demand exceeds supply, that good becomes more “expensive”. Graduate programs perform their market adjustments in the admission process.

Discussion

Probably the most telling moment in a time series is when the trend changes course, as applications did in 1995, foretelling the impending decrease in graduate enrollment. Early indications from the 1999 Survey of Graduate Enrollment⁵ indicate that applications have changed course once again, from annual decreases from 1995 to 1998 to a 2% increase from

The six years of rapid application growth from 1986 to 1992 show the limits to the responsiveness of the graduate education system to increased demand. The growth in graduate application of 7% a year outstripped the capacity of U.S. graduate programs and as a result, graduate programs became more selective. The rule of thumb in economics is that demand creates supply. While in the retail sector this is certainly true, this is not the case with graduate

While in the retail sector this is certainly true, this is not the case with graduate

⁴ Davis, Todd M. *Open Doors, 1998-99*, Institute for International Education, New York, NY.

1998 to 1999. All things being equal, we would expect graduate enrollment to turn from the current downward pattern to a slight increase in 2000.

Of course, application trends affect enrollment, but because there are so many decision-makers between the application and the enrollment decision, including the student, applications are at best a general indicator of where enrollment could go in the next year. In fact, independent of application trends, a number of institutions and programs are beginning to restrict the number of students admitted to better match graduate students with the financial support available.

Because of the indirect relationship between applications and enrollment, at best applications data are a predictor of the general direction enrollment might take in the next year. However, application trends are a good measure of the changing demand for graduate education. Application trends tell the graduate community how individuals are viewing their product.

What, then, can we extract from the trends in graduate applications to help in understanding the future demand for graduate education? Clearly, application numbers react strongly to changes in the perception of the labor market for bachelor's and advanced-degree recipients. When the employment situation for new bachelor's recipients improved in the mid 1990s, applications plummeted as potential graduate students entered the job market directly after graduation. Accordingly, tracking both the unemployment rate and graduate applications may be the best way to make a short-term forecast of the demand for graduate education. However, while national data may provide a general indicator of demand, the situation for any particular institution and graduate program will vary based on local conditions such as the regional economy, the nature of the institution, and the demographics of the local population. It is these local and regional variables that institutions need to assess as they plan for the future.

⁵ Syverson, Peter. *Data Sources*. CGS Communicator, January/February 2001, volume XXXIV, number 1, Washington DC.

Dart What Can We o

In “The Hurricane,” Rubin Carter says to Lesra Martin during their first visit: *It is important to transcend the places that hold us.* Those places are sometimes physical, but more often mental, indeed conceptual. We are trained in paradigms, with certain mindsets and world views. Breaking out of them, distancing ourselves to see – and perhaps to act – differently tests our discipline, our fortitude, and defines what moves us.

In this final section, we need to pose big questions – questions more of policy and strategy than of programs and practices, but above all, about *participation in a merit-based society.* For after the data are analyzed and claims evaluated, we are left to contemplate how to transcend the world as it is, including our own positions and allegiances, and shape policies that recognize and serve the *national need.*

The authors here discuss institutional roles and practices that hold some people back, slow others, and penalize science, technology, and society as a consequence. Barriers unrelated to capability or aspiration have no place in a democracy, yet they ripple through the human resource pool. As George Campbell, President of Cooper Union, puts it, “diversity at what price, exclusion at what cost?”¹

Rayman clarifies the multiple pathways that lead from science education into science-based careers. She suggests that while groups may vary in their response to structural barriers, gender alone seems not to be predictive of career choices in fledgling fields such as biotechnology. Moreover, she contends that university science departments would do well to rediscover the Master’s degree. **Teitelbaum** sorts key factors in choosing a career in science, as opposed to professions such as medicine, law, and business. He concludes what many suspected but had never systematically analyzed: do science for the love of it, because on rational grounds the costs and risks are high, the material returns comparatively modest. With such a cost-benefit analysis in hand, science, he warns, will lose the competition for student talent. Meanwhile, **Tapia** directs us to the end of the pipeline and beyond. Lost in the metaphor for human talent development is the issue of “leadership” in disciplines, sectors, and organizations. As educational transitions disproportionately remove persons traditionally underrepresented in S&E at each stage, future leaders are lost. How can law and public policy, as well as mentors and professional networks, help?

We should be mindful of several questions when reading these chapters, including:

1. How different should be the preparation for an academic v. an industrial career? Are hybrid, multidisciplinary programs that culminate in science-based masters degrees a model to emulate?
2. To many, the problem of recruitment and development of careers in science is rooted in an academic culture that, while honoring merit and open competition, is at the same time

¹ George Campbell, Jr., “Support Them and They Will Come,” *Issues in Science and Technology*, Winter 1999, www.nap.edu/issues/16.2/stalk.htm.

discriminatory and elitist based on factors such as sex, race, ethnicity, disability, age, and even geography. How does one change this culture? Do nonacademic institutions that are successfully reducing “glass ceilings” offer a model for change?

3. Should policies that favor the participation of U.S. students in S&E be instituted to limit the access of foreign students on temporary visas to U.S. graduate education? Or will the policies of other countries reverse the “brain drain” of foreign students to the U.S.? What if the U.S. ceases to be the “nation of choice” by the best and brightest foreign students?

4. Is a Federal human resource development for S&T policy needed to coordinate across the R&D agencies? Should funding criteria be tied explicitly to education and training of future S&E’s at all levels? By making retention an explicit expectation of their funding, would sponsors assist colleges in retaining undergraduates in S&E?

CHAPTER NINE

Two Ships Passing in the Night: Science Careers and Science Education

Paula M. Rayman

As we embark on a new century, we face a world of global proliferation of knowledge and of ever-changing technology. Just as centuries before us, human beings will be wrestling with ways to harness the new scientific know-how and technological break-through so they can advance conditions of human existence.

The success of this struggle will largely depend on the integration of knowledge emerging from different scientists, with differing needs and interests in different settings who pose a variety of problems and approaches to critical inquiry. As Cecily Selby (2000) has stated, “Good science is promoted by different approaches to a problem”. Questions of who will do science and where they will do it will demand thoughtful and visionary response.

By the end of the last century strides had been made to open science and technology to a more diverse workforce and the non-academic employment of scientists and technical personnel grew. However, serious problems remain concerning the education and training of future scientists, the replication of discriminatory and elitist patterns in science institutions and the difficulty of initiating a new culture for scientific work and science careers.

Two recent stories illustrate the challenge of creating connections between science education and science careers that maximize inclusion of diverse populations and diverse settings for the “doing” of science.

In 1995 as part of the Beijing Conference on Women, the United Nations and World Bank co-hosted a symposium on science, technology and gender issues (United Nations, 1995). Representatives came from around the world and lively discussions occurred on future goals for science and technology as if gender equity mattered. Very quickly, differences between men and women and between those from the industrialized nations and the developing countries emerged. Most of the male representatives professed that while it would be nice from a political perspective to have more equity for women in science and technology fields, it would make little difference for the future success of science. And both women and men from the industrialized nations started off with an emphasis on raising the numbers of women in underrepresented fields and breaking through the “glass ceiling” of upper mobility in these fields. The women from the developing nations, on the other hand, stressed the difference between “Big S” science occurring in the first world and “Small s” science occurring in the third world. They urged more attention to science and technology being done in non-academic, non-industrial settings, such as indigenous women’s knowledge of herbal medicines and intermediate technology methods of assuring clean water to rural communities.

The second story concerns a woman research fellow employed in a pharmaceutical firm. She recently participated in a small study of successful senior women scientists hosted by the Catalyst organization (Catalyst, 1999). In an interview question on the relationship between

academic training and employment, she recounts listening to the following conversation between two academic women taking a taxi on their way to a science conference:

“They said it’s a sellout for scientists to go into industry...and I didn’t say anything but I was appalled and realized that a lot of people have that attitude ...I didn’t sell out.... My efforts and my work are just important as whatever noble thing they think they’re doing.”
(Catalyst, 1999, p. 11)

From my own studies of young women and men in the sciences, the notion of failing science and being second-rate if you do not stay in the academy is widespread through the halls of colleges and universities (Rayman and Brett, 1993; Radcliffe Public Policy Institute Team Report, 1999).

These illustrations of the dilemmas we face in creating a diverse climate and culture for future science and technology endeavors provoke a response. I suggest that right now we have two ships passing in the night: science education, wedded to old formulas of success, and future science career pathways in both the private sector and public arena, which demand a new definition of success. Our young people are not being prepared in our education institutions to meet the demands for the future scientific ventures key for human advancement. This will exact great private costs to individual young people and exact social costs for the scientific community and our nation as a whole. Individuals will lose their opportunity to contribute to science, the scientific community and to the larger society.

Shifting Terrain

Almost 50 years ago, Professor Robert Merton in his studies of the normative structure and culture of science, described the fierce competition among scientists to be the “discover”. The urgency of original discovery produced great intellectual pressure and a work environment that fostered competition rather than cooperation. This resulted in the science profession, which promoted single-mindedness and a construction of life around devotion to the scientific enterprise above all else.

Later on, others also commented that the culture of science was based on aggressive behavior (Traweek, 1984), gender biased (Etzkowitz et. Al, 1992) and promulgating forms of communication “that seek to reduce one of the protagonists to rubble in the course of scientific discussion (Widnall, 1988). This cultural terrain, called by Betty Vetter and colleagues, the “chilly climate”, has resulted in attracting and retaining those who thrive under those conditions and those who do not have been effectively “weeded out.” Many social science studies have documented the ways the prevailing patterns of study and work organization in science were thought to be “universal” and ensured the replication of those already in place (e.g. Rossi, 1965; Frank-Fox, 1985; Vetter, 1987; Rosser, 1990; Tobias, 1990; Hewitt and Seymor, 1991; Matyas and Malcolm, 1991; Sonnert and Holton, 1995; Hanson, 1996).

But the culture of doing science that emerged from the academies of the 16th and 17th centuries and the strict gender, race and class segregated roles that prevailed through the rise of industrialization are increasingly counter productive in an age of economic globalization, information technology and erosion of distinct gender, race and class categories. In earlier times,

both the students and the faculty of the academy were white males. Today, notes Robert Birgeneau in “A Study on the Status of Women Faculty in Science at MIT” our students reflect the diversity and richness of the American population but our faculty, on the other hand, “remains overwhelmingly white male”. He goes on to say that this means “we are not taking advantage of the tremendous talents of the absolute majority of the population in filling our faculty rank.” (MIT, 1999).

It is also an age of increasing economic inequity, environmental threats, and demographic problems. The need for science to discover solutions has never been greater. To do so, old patterns of who does science and where science gets done demand fundamental change. As Arthur Singer wrote in the early 1990’s, the talents of all young people with the ability to pursue careers in science “should be encouraged and their paths cleared of artificial barriers” (Pathways Report, 1993, p. iii). As economist Marina v.N. Whitman (1999) suggests, this new world means new rules.

Current Educational Picture: Progress And Procrastination

In the year 2000, while we have made some progress towards removing artificial barriers that continue to weed people out of science, we still have a long way to go. On the positive side, according to the National Science Foundation (1996), at the end of the twentieth century, nearly half the science and engineering bachelor degree recipients are women. Non Asian minorities now make up 6% of the total science and engineering labor force. Women and minorities are making major contributions to new fields in science such as ecology, environmental studies and industrial engineering management.

However, on the kindergarten through high school levels of education females and non-Asian minorities remain underrepresented in upper level science and math classes (Davis et al., 1996). In colleges and universities, women and non-Asian minorities continue to be underrepresented as majors in the physical sciences, math and engineering and in all fields on the graduate, post-doc, junior faculty and most notably senior faculty levels (Pearson and Fechter, 1994). For example, in 1996 in the United States, women constituted 51% of the population and 46% of the labor force but only 22% of scientists and engineers.

In a very thoughtful study, Who Succeeds in Science?, Sonnert and Holton (1995) discuss two theoretical models to explain why women have not succeeded in science. (The models can also be applied to the lack of success among non-Asian minorities). The first, the deficit model, assumes the women and men’s goals are the same but that structural barriers -legal, political and social- are barriers to women’s accomplishment.

The second, the difference model, emphasizes that women have differing perspectives from men, the result of either innate differences or gender-role socialization. Research to date casts doubt on the genetic basis for differences (Maccoby and Jacklin, 1974; Eccles, 1987).

Another set of research studies confirms that gender-specific socialization reinforces women to be less competitive, less self-driven, more relational and more apt to have multiple role identity (e.g. as a caregiver and as a scientist). The very characteristics the current culture of science

rewards—aggressive, competitive, and single-minded—drive many women away (Eccles, 1987; Tannen, 1990; Barnett and Rivers, 1996; Miller and Stiver, 1997).

For minorities, there is a growing body of research documenting barriers they have faced (Rayman and Brett, 1993; Pearson and Fechter, 1994; Davis et al., 1996). These include lack of adequate preparation in K-12 education and lack of teacher encouragement and role models. In the Pathways study, done in the early 1990's, I found that many non-Asian minority youth stressed the importance of a future where they “could make a difference in the community”. Aside from entering medicine, most of these young people did not see a connection between science and math future careers and “making a difference”.

This brings us to another barrier raised by the woman pharmaceutical employee. In her taxi ride she overheard biased remarks about scientists who choose careers outside of the academy. As the Catalyst report notes, “academic advisors are generally not in a position to describe accurately or promote opportunities for research in industry” (Catalyst, 1999, p. 11). This lack of knowledge reflects both the prejudice that exists in the academy towards science done outside of its borders and the lack of communication between those inside and outside of the ivory towers.

There are many reasons why the current science education pedagogy and prejudices are counter productive: the majority of jobs in science and in the future will be outside of the academy; women and minorities seek careers where they can both “work and have a life” and “make a difference” and science achievement will itself be diminished if talent is lost by faculty bent on replicating their fields with people who look like them and by departments which promote flawed claims to a meritocracy resting on discriminatory practices.

The Future Of Science Careers

What kinds of science careers await the next generation? In the advanced industrialized nations, the organization of work is undergoing a radical shift. One out of four people are working part-time or full-time off site from central offices. New forms of technology blur distinctions between home and work and push the time clocks from typical 9 to 5 jobs to 24/7 schedules. The future workplace will continue to see the time and space dimensions undergo transformation.

For scientists, much of the shift has been from the academy to the private sector, which now employs 72% of those with bachelor degrees, 59% of those who have master's degrees and 57% of those with doctorates (US Bureau of Labor Statistics, 1997). The shift has also been from large multinationals to smaller venture start-ups and from BIG S endeavors to exploration of intermediate technologies and integration with non-Western sources of knowledge.

At the Radcliffe Public Policy Center we recently conducted a study of the professional careers of scientists in the biotechnology industry which was funded by the Alfred P. Sloan Foundation (Radcliffe Public Policy Institute Team Report, 1999). Radcliffe and Sloan were interested in biotech because several of its characteristics are prototypical of the kind of workplaces that will

become increasingly common in the 21st century. They are small firms with a high preponderance of knowledge-based workers and exist within a culture of job fluidity.

One of the significant findings from the Radcliffe study was that the biotech work environment was reported to be more favorable to career development for women than careers in academic science. Women constituted 50% of biotech employees, much higher than in the average biology or chemistry department in academia. Women experienced the freedom from the “publish or perish” culture of the academy and thus had more flexibility with managing the multiple roles of family caregiver and scientist. One female Ph.D. associate director stated, “I understood biotech to give you as a scientist more independence, less organizational structure, and a little more freedom compared to academic” (Professional Pathways, 1999, p. 7). She and other respondents also commented on the collaborative, friendly work culture in biotech in contrast to the hierarchical control in the academy.

Both men and women respondents from the biotech study stressed the importance of having a career where you felt you could really “make a difference”. They spoke deeply about how much they valued actually seeing their work benefit the larger society. This sense of shared mission among biotech workers played a major role in offsetting the uncertainties present in the new economy.

A third noteworthy finding concerns the sense of achievement from a cross section of employees in the biotech field. From those with technical training certificates or bachelor degrees to those with master’s, doctorates or post-docs, there was a common experience of doing meaningful work and being recognized as doing good work by other colleagues. This stands in contrast to the academy where one has a sense of shame if only a master’s is obtained.

Biotechnology rests on the skills and abilities of many different kinds of workers which allows the industry to be a home for those with a variety of educational backgrounds. Those with bachelor and masters degrees in fact were the most likely to report a sense of career security since they could most easily “hop scotch” from one biotech firm to the next.

Lessons For The Future

If our goal for the future is to have both our ships rowing in the same direction then we need to seriously address how to change the conditions for science education and the culture of scientific workplaces. A good place to begin an agenda for change is setting forth some first principles to guide new practices and policies.

A first principle is the necessity of understanding that we need a “Science for All”. Our science educational framework from K-12 to post-doc training must be organized so that we attract and retain as many of our talented youth as possible. Children from all backgrounds can build upon the curiosity every four year old has to be a natural scientist and have a dream of becoming a “discover”. In middle school and high school all students should be taught science in a way that connects their lessons to issues that have meaning in their lives – to music, health concerns, environmental challenges, computer design. Before graduating high school all students should be exposed to the variety of jobs and careers one can enter as a scientist and this exposure should

continue in colleges and universities, so that there is not a bias against a pathway outside of the academy.

One excellent suggestion for a change in the teaching of science is the creation of a general Master's of Science degree. (Tobias, 1999) This Master's degree is for students interested in a wider variety of career options than provided by traditional graduate programs in science. The expectation would be to provide young scientists with the equivalent professional base and flexible career options enjoyed by law school graduates and MBA's in the new economy.

Another principle is that we need a "Science That Makes a Difference." Women and non-Asian minority students in particular voice their desire to study and work in fields which clearly have a connection to the betterment of their communities and to the larger society. For too long, science education and science workplaces have gotten caught up in either/or boundary issues regarding basic research and applied research. A third approach, some are calling "Jeffersonian Science", would connect the endeavor of basic research with the larger society's interest. (Holton & Sonnert, 1999, Fall) A noted historical example is President Jefferson's strong support for the Lewis and Clark expedition, a basic research endeavor but one that Jefferson understood would have great significance for the young nation.

Lastly, we need to have our science education and our science workplaces embrace a culture, which in Dudley Herschbach words, "Cultivates People In." This assumption stands in opposition to a culture that has long existed that "weeds people out". As a Nobel Prize winning chemist, Herschbach has been a leader in opening the doorways of science. As one example of his effort, during his chemistry classes at Harvard, Professor Herschbach created a "resurrection" point system whereby students who did not initially do well on tests could, after getting tutorial help, aim to do better. (Herschbach, 1996) If they achieved their goal they could "resurrect" their entire grade. Thus, a student instead of feeling like a failure after doing so poorly on an exam could ask for help and by taking up the challenge, could be "cultivated in" not "weeded out".

This assumption of a culture of "cultivating in" in a world of increasing globalization also means widening our lens of defining science. As our third world women scientists taught us for the Beijing Conference "Small s" science is incredibly significant for much of the globe's population and needs to be acknowledged and even applauded by those practicing "Big S" science.

What is success in science has as much to do with indigenous women in an Indian village finding ways to purify their village's water supply as it does getting women assistant professors promoted to tenure at an American university. Given the sweeping future of science occupations we need to educate young people for a full spectrum of careers and jobs so that all of them can dream of becoming a scientist.

Bibliography

Barnett, R. C. and Rivers, C. 1996. She Works, He Works: How Two-Income Families are Happy, Healthy, and Thriving. Cambridge, MA: Harvard University Press.

- Catalyst. 1999. Women Scientists in Industry: A Winning Formula for Companies. New York, NY: Catalyst.
- Davis, C. et al. 1996. The Equity Equation: Fostering the Advancement of Women in the Sciences, Mathematics, and Engineering. San Francisco: Jossey-Bass Publishers.
- Eccles, J. S. 1987. Gender Roles and Women's Achievement-Related Decisions. Psychology of Women Quarterly. 11, 135-172.
- Etzkowitz, H. 1992. Individual Investigators and Their Research Groups. Minerva. Spring.
- Frank-Fox, M. 1985. Location, Sex-Typing and Salary Among Academics. Work and Occupations. 12, 186-205.
- Hanson, S. L. 1996. Lost Talent: Women in the Sciences. Philadelphia: Temple University Press.
- Herschbach, D. R. 1996. Teaching Chemistry as a Liberal Art. AAC&U Liberal Education. 82(4), 10-17.
- Hewitt, N. and Seymour, E. 1991. Factors Contributing to High Attrition Rates Among Science and Engineering Undergraduate Majors. Report to the Alfred P. Sloan Foundation. April, 26, 1991.
- Holton, G. and Sonnert, G. 1999, Fall. A Vision of Jeffersonian Science: Rethinking what Research Government Should Fund. Issues in Science and Technology. 16(1), 61-65.
- Maccoby, E. E. and Jacklin, C.N. 1974. The Psychology of Sex Differences. Palo Alto, CA: Stanford University Press.
- Matyas, M. L. and Malcolm, S.M. 1991. Investing in Human Potential: Science and Engineering at the Crossroads. Washington, DC: American Association for the Advancement of Science.
- Miller, J.B. and Stiver, I.P. 1997. The healing connection: How women form relationships in therapy and in life. Boston, MA: Beacon Press.
- MIT. 1999. A Study on the Status of Women Faculty in Science at MIT: How a Committee on Women Faculty came to be established by the Dean of the School of Science, what the Committee and the Dean learned and accomplished, and recommendations for the future. Cambridge: Massachusetts Institute of Technology.
- National Science Foundation. 1998. Women and Minorities in Science and Engineering. Washington, DC: National Science Foundation.
- Pearson, W and Fetcher, A. 1994. Who will do science? Educating the next generation. Baltimore, MD: The John Hopkins University Press

- Radcliffe Public Policy Institute. 1999. Professional Pathways: Examining Work, Family, and Community in the Biotechnology Industry. An Executive Summary. Team report to the Alfred P. Sloan Foundation. Cambridge, MA.
- Rayman, P. and Brett, B. 1993. Pathways for women in the sciences. Wellesley College Center for Research on Women.
- Rosser, S. V. 1990. Female Friendly Science: Applying Women's Studies Methods and Theories to Attract Students. New York: Pergamon Press.
- Rossi, A. S. 1965. Women in Science: Why So Few? Science. 148, 1196-1201.
- Selby, S. C. 2000. A Century of Women Scientist. Radcliffe Quarterly. 85(3), 14.
- Sonnert, G. and Holton, G. 1995. Who Succeeds in Science? The Gender Dimension. New Brunswick, NJ: Rutgers University Press.
- Tannen, D. 1990. You Just Don't Understand: Women and Men in Conversation. New York Morrow.
- Tobias, S. 1992. "Who Will Do Mathematics and Science?" The College Board News. 20 (5). June, 3.
- Tobias, S. 1999. Conceptualizing a New Degree (Remarks by Sheila Tobias at a gathering of educators, industry and government agency representatives, convened to discuss "Emerging Fields in Science"). Commission on Professionals in Science and Technology: October 13, 1999.
- Traweek, S. 1984. "High Energy Physics: A Male Preserve." Technology Review. 87, 42-43.
- US Bureau of Labor Statistics. 1997. Employment and Earnings. Employed US scientists and engineers, by highest degree attained, occupation, and employment sector: Table E-2. Washington, DC: Department of Labor.
- United Nations. 1995. Fourth World Conference on Women. Beijing Declaration and Platform for Action. Available at gopher://gopher.undp.org:70/00/unconfs/women/off/a—20.en. February 9, 2000.
- Vetter, B. 1987. "Women's Progress." Mosaic. 18 (1), 2-9.
- Whitman, M. v.N. 1999. New World, New Rules: the changing role of the American corporation. Boston, MA: Harvard Business School Press.
- Widnall, S. E. 1988. AAAS Presidential Lecture: Voices from the Pipeline. Science. 241, 1740-1745.

CHAPTER TEN

How We (Unintentionally) Make Scientific Careers Unattractive

Michael S. Teitelbaum

Over the past decades, there have been periodic alarms about argued insufficiencies in the capacities or interest of American students in careers in scientific and technical fields. The post-Sputnik period is a prominent example of such concerns, and resulted in very large expansions in public funding for undergraduate and graduate education in these fields during the 1960s, followed by alleged oversupplies of doctoral recipients during the 1970s.

During the late 1980s, the then-leadership of the National Science Foundation and of some leading research universities argued that a “looming shortfall” of scientists and engineers during the late 1990s could be discerned from projections produced by the NSF’s late Division of Policy Research and Analysis.¹ When by 1992 it became apparent that the trend was if anything in the direction opposite to that forecast, i.e. a growing surplus of scientists and engineers rather than the forecasted “shortfall,” the NSF experienced the embarrassment of a most interesting Congressional investigation and hearings, led by Congressman Howard Wolpe, then-Chair of the Subcommittee on Investigations and Oversight of the House Committee on Science, Space and Technology and its Ranking Minority Member Congressman Sherwood Boehlert.²

While such experiences require us to view skeptically current or future claims of “shortages” of scientists and engineers, there is a broad consensus that it should be a goal of American policy to offer appropriate encouragement to those with the capacities and interests needed to enter into science and engineering careers. This paper will explore whether our practices may unintentionally be operating in opposition to these goals.

This paper focuses only upon the “science” component (the smaller part) of “science and engineering.” The two cannot be easily combined for this purpose because educational requirements and careers in science differ greatly from those in engineering.

The question for discussion may be stated simply as follows: Those pursuing careers in science need to embody considerable talents of intelligence and analytic capacity. How might such talented young people analyze the alternatives lying before them? Are the incentives and disincentives that have evolved operating to attract them to scientific careers, or are they making

¹ Accessible reports on these materials may be found in, e.g. Constance Holden, “Wanted: 675,000 Future Scientists and Engineers,” *Science*, 30 June 1989, pp. 1536-1537; testimony of Erich Bloch, Director, National Science Foundation, before U.S. Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology, and Space. Hearing on Shortage of Engineers and Scientists, May 8, 1990, p. 25.

² U.S. House of Representative, Committee on Science, Space, and Technology, Subcommittee on Investigations and Oversight, Projecting Science and Engineering Personnel Requirements from the 1990s: How Good are the Numbers? Washington, DC: National Academy Press, 1998.

such careers relatively unattractive, not in an absolute sense but rather relative to other available career choices?

We begin by noting the obvious point that any professional career requires substantial investment of time and financial resources in higher education, usually well beyond the bachelor's level. For a scientific career, a PhD (and depending on discipline a postdoctoral fellowship post-PhD) has become a baseline requirement. The costs of meeting such educational requirements are very substantial. They include university tuition and fees, living expenses over what can be many years of graduate study, and foregone income during these years ("opportunity costs").

Of course, scientific careers can offer much in return. There is, first, the wonderful intellectual challenge of scientific research and discovery--a life of the mind that addresses fundamental puzzles, a life that is worthy of sacrifice and love. Many of the world's scientists will attest that their interest in science is deeply personal, often a lifelong fascination with the wonders of nature and the beauty of scientific theory and experiment to gain understanding of it. For many, indeed, a life of science is a "calling," analogous in many ways to those in the spheres of religion and artistic expression.

There is, in addition, the sense of real contribution that scientific research can offer the world and its peoples. Most if not all scientists were attracted to their careers by some combination of these essential elements, for value-based reasons similar to those attracting others to the worlds of art, religion, and the humanities.

Careers in science therefore are worthy of self-sacrifice. Yet the talented young people needed in science have many other alternative career options. Hence if such careers are to continue to attract enough highly intelligent entrants, three rather minimalist standards must be met. These may be summarized in the following question format:

1. Does the science career path offer a reasonable likelihood that those who have made the sacrifices needed to attain the science PhD's will have access to the "practice" of scientific research?

It needs to be said first that no one should argue that the earning of PhD carries with it some kind of "entitlement" to a scientific career. However, if we expect young Americans to undertake 6-10+ years of post-baccalaureate education in preparation for a science career, there does need to be at least a decent probability that most of those who successfully complete such preparation will be able to find entry-level positions that allow them to practice their beloved science.

Were this to be otherwise, it would hardly be ethical to encourage new entrants to undertake such extended postgraduate study, nor would it be sensible for governments and universities to subsidize the high costs of such education. In short, this is hardly a controversial standard to which we ought to hold the structures by which we educate and employ young scientists.

2. Can those contemplating a career in science realistically aspire to a middle class life style, roughly parallel to those experienced in other professions?

Careers in science need not promise wealth to attract talented young people, but they do need to allow those entering them to aspire reasonably to a middle-class lifestyle: to buy a home, take occasional vacations, invest in their children's wellbeing and education, etc.

3. Is the trajectory of a career in science compatible with a typical adult "life", i.e. does the career path fit realistically with marriage, family-building, and the biological constraints of human reproduction?

If scientific careers are to continue to attract the kind of outstanding talent we seek, they must offer an education and career trajectory that allows those who pursue it to fall in love, marry, begin a family, and otherwise behave like adult professionals other than the monastic clergy.

With such standards in mind, what might we say about how well careers in scientific fields today measure up in a comparative framework that compares them with other professional careers that also require substantial investments of time and financial resources in post-baccalaureate education? Put another way: *How would an intelligent, well-informed college senior with capabilities and interests in science and mathematics make a rational choice among postgraduate degrees preparing them for careers in science, medicine, law and business (those requiring an MBA or similar postgraduate degree)?*

Reasonable Likelihood of Ability to "Practice"

As noted earlier, there must be at least a reasonable likelihood that those who make the sacrifices inherent in post-baccalaureate graduate degrees will be have an opportunity to "practice" the career for which they have prepared. How do the occupational sectors under discussion here differ in this regard?

Within scientific fields, there is much variability. In those with substantial industry presence (chemistry, biotech), there is often dynamic demand for those earning graduate degrees, thereby amply meeting the requirements of this standard. Meanwhile, for other fields (e.g., physics, mathematics, ecology), where labor market demand is concentrated in academe, recent trends have been unfavorable, with significant proportions of recent PhDs finding the labor market for this background ranging from "chilly" to "dismal."³

For medicine, law, and business, the likelihood of opportunities to "practice" tends to be more favorable, although there is still substantial variation. In medicine, it is rare to hear of a recent MD who finds it impossible to find a position in which to practice his/her chosen profession of medicine. There is, of course, a good deal of variation by medical specialty, but overall the balance of supply and demand seems to be reasonably healthy for those contemplating undertaking medical education.

In law, too, there seem to be few cases in which a legal degree cannot be effectively put to professional use. In part this is because lawyers can establish their own practices if there are insufficient job offers available from law firms, and in part because American society sees a

³ See, for example, Office of Scientific and Engineering Personnel, National Research Council, Trends in the Early Careers of Life Scientists. Washington, DC: National Academy Press, 1998.

legal background as appropriate for a broad range of occupations beyond the direct practice of law. According to the American Bar Association, approximately 55-60% of lawyers practice in law firms (of all sizes); about 25% are employed by governmental bodies and the judiciary; about 14% in business; and less than 3% in public interest occupations.⁴

Similarly those graduating with an MBA generally find ample job opportunities, with the quality and remuneration levels involved varying greatly with the perceived quality of the MBA. Many business schools invest a great deal of effort and resources in facilitating initial job placement for their graduates, and then advertise the placement success of their graduates as evidence of the attractiveness of their degree.

Middle Class Aspirations

Such aspirations can be affected by at least four elements: the burden of accumulated educational debt; the opportunity costs of required graduate education; expected remuneration rates in the career; and pension benefit accumulation.

Educational debt burden: If a career path predictably involves the accumulation of a large burden of educational debt, this can be a powerful deterrent to entry unless expected remuneration after degree completion is large enough to rapidly pay off such debts. In this regard, debts burdens accumulated by those pursuing science PhDs tend to be smaller than those in the other fields being considered here.

While the costs of a science PhD are actually quite large, graduate study in most scientific fields is heavily subsidized by American society (unlike graduate study in engineering and in most of the humanities, social sciences, and arts). These subsidies are based explicitly upon the argument that scientists produce “social goods” which benefit society overall, but which cannot be wholly captured by the individual scientist. (Of course, if a PhD scientist is unable to “practice” scientific research, the social good of the PhD is less obvious.) The implicit argument is that while those undertaking graduate study in the law or medicine or business can realistically expect to capture much of economic benefit of their professional work, this is less so with scientists, who therefore need to be subsidized in the public interest. In those scientific fields for which postdoctoral fellowships are essential, postdocs are typically are paid as “employees” under research grants, albeit usually at very low levels of remuneration. [For a full discussion of these issues, see the recent National Academies report Enhancing the Postdoctoral Experience for Scientists and Engineers.⁵

Hence, in terms of educational debt, science graduate education tends to be more attractive than that in fields such as medicine, law and business, where it is normally expected that the would-be doctor, lawyer or business professional will finance his/her own graduate degree. Loans are made available, but most such students graduate accompanied by a high burden of accumulated

⁴ Personal communication, American Bar Association, 1999.

⁵ Committee on Science, Engineering and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Enhancing the Postdoctoral Experience for Scientists and Engineers: A Guide for Postdoctoral Scholars, Advisers, Institutions, Funding Organizations, and Disciplinary Societies. Washington, DC: National Academy Press, 2000.

debt. For example, the Association of American Medical Colleges reports that recent recipients of the MD degree hold a mean personal debt of \$91,000.⁶ Comparable quantitative data are not available on the debt burdens of recent recipients of law and MBA degrees. They are probably lower than those for MDs, in part because the length of the relevant degrees is much shorter, but anecdotally such debts do seem to be substantial.

Opportunity costs of extended graduate/postdoc education. The direct costs of graduate education, whether paid by the graduate student or via public subsidies, can be very large. Yet for some fields the largest costs of all are what economists call “opportunity costs”, i.e. the income and benefits that must be forgone during the years of graduate study. The magnitudes of such opportunity costs vary greatly, depending both upon the number of years required in graduate and postdoctoral study, combined with the wide range of annual wages and benefits that must be foregone. The longer the period spent as a postgraduate student and apprentice, the more years of income foregone. The higher the average remuneration available in the career in question, the higher the opportunity cost per year of graduate study and apprenticeship.

Remuneration: What about expected earnings from which accumulated educational debts might be repaid? For the three fields for which substantial educational debt burdens are common, prospective earnings are relatively high, though with much variability. Physicians’ earnings show means of \$120-210,000/year, varying considerably by medical specialty.⁷ According to another authoritative estimate from a nearly a decade ago, physicians receive the highest average salaries reported for any occupational category, approaching an average of \$200,000 per year⁸. American physicians have managed for decades to boost their earnings more rapidly than any other major profession.⁹

Lawyers’ earnings are similarly variable: very high in large firms, low for public interest lawyers, higher in large law firms than in individual practice, and varying greatly by location. Entry-level offers for recent graduates from the top 25 law schools have been rising rapidly in recent years, with a median range of \$69-86,000 reported for 1999.¹⁰

Similarly, economic returns to a two-year MBA degree can be very high, but vary greatly due to wide quality range of MBA programs and high variability of business earnings depending on industry, firm and region.¹¹ Andersen Consulting reports starting salaries of \$30,000 for those with undergraduate degrees vs. \$60,000 for those with an MBA and five years work experience.¹² Those receiving MBA degrees from leading business schools generally receive very attractive compensation rates.

⁶ Personal communication, Association of American Medical Colleges, 1999.

⁷ Personal communication, American Medical Association, 1999.

⁸ American Medical Association, Socioeconomic Characteristics of Medical Practice, as cited in Bok, op. cit., Figure 4-6.

⁹ Derek Bok, The Cost of Talent, (New York: The Free Press, 1993), p. 120.

¹⁰ Data from American Bar Association, 1999.

¹¹ At the top, CEO salaries for Fortune 500 companies have risen dramatically over the past two decades, and by 1990 exceeded \$600,000 on average. At middle management levels, salaries also rose sharply during the past twenty years, and averaged ca. \$65,000 around 1990. Forbes, cited in Bok, op. cit., Figure 4-4.

¹² Gregory Wilcox, A>MBA= on your resume could double paycheck@, The Register-Guard, Eugene, OR, November 12, 1995.

In contrast, economic returns to scientists have long been generally unattractive. One study concluded that between 1983 and 1991, salaries rose at a slower pace than those for other professions: natural scientists= earnings (not adjusted for inflation) increased by 31 percent and mathematical/computer scientists= by 45 percent, while those for lawyers/judges increased by 59 percent and for physicians by 98 percent.¹³ At present, average salaries for scientists are relatively low for professionals with many years of post-baccalaureate education---on the order of half those reported by physicians. However, there are some scientific fields experiencing dynamic for-profit growth e.g. computer science and biotechnology, and in these remuneration can be very attractive.

In a perceptive 1993 book, Derek Bok, himself a lawyer and former dean of Harvard Law School and President of Harvard, offers the following summary assessment of the shifts he reports away from graduate degrees in the arts and sciences in general and towards professional degrees in law and business:

Money also seems to have contributed to the most important set of career changes that took place in the past twenty-five years: the movement of tens of thousands of highly educated students away from teaching and government service into more highly paid jobs in private business [and] law practice....not only did the numbers of young people entering schools of law and business double and treble; their intellectual level also rose significantly. In 1950, law and MBA students were only of average ability; their test scores were far below those of classmates in medical schools, engineering, or graduate (Ph.D.) studies. By the 1990, the situation had changed; the quality of students seeking admission to schools of law and business now rivaled that of applicants to any other graduate or professional school. ...many factors enter into the choice of a career. Among them, however, large, persistent differences in earning play a substantial part...Such differences do much to explain the substantial shifts that occurred over the past twenty years away from teaching and government service toward law and business.¹⁴

In general, then, the three fields under consideration here in which most graduates carry heavy educational debt burdens—medicine, law, and business--- tend to be fields in which professional remuneration levels are attractive, while the opposite is true of most scientific fields.

Accumulation of Pension Assets

Another element that must be considered is the number of years in which individuals are able to accumulate tax-sheltered pension assets, which because of compound growth are best initiated as early as possible in a career. Graduate students and postdocs, even if formally considered “employees”, rarely receive any retirement benefits. If they are in fields in which the time to degree (PhD or MD) is long and required apprenticeship positions such as postdocs and residencies stretch out over many years, they must forego pension asset accumulations for nearly

¹³ Data from U.S. Census Bureau cited in David S. North, Soothing the Establishment: The Impact of Foreign-Born Scientists and Engineers on America. (New York: University Press of America, 1995), p. 23.

¹⁴ Derek Bok, The Cost of Talent, (New York: The Free Press, 1993), pp. 89 and 91.

a full decade relative to those accumulated by lawyers (although they may be unaware of this difference).

Assigning a monetary value to such differences is difficult due to the variations in pension plans and the vagaries of investment markets, but most experts on pension benefits would conclude that such a difference in years of accumulation can result in very large ultimate pension assets and hence net worth at older ages.

Compatibility of alternatives careers with a typical adult “life”

This assessment relates partly to the length of postgraduate training required by different careers, and in part to the career paths themselves in terms of the age at which a reasonably stable career status can be achieved. These elements, in turn, must be compared with the age patterns of family-building, human reproduction, and other elements of what might be considered a normal life course.

In terms of these comparative timetables of the several careers under discussion, it is perhaps surprising that the least compatible with a normal adult “life” may be that offered to science PhDs who seek academic careers. There are three elements here that combine to yield this effect: the length of time to the PhD, the baseline requirement for such a career; the time that must be spent post-PhD in a postdoctoral position or equivalent; and the time required to attain academic tenure.

The years to the PhD from entry into graduate studies has been rising steadily over the past several decades. The median now is 6-7 years, with lower numbers in fields such as chemistry and mathematics and higher numbers in the basic biomedical sciences (where the average had risen to 7.83 years by 1997, with a median age at the time of degree of nearly 31 years.¹⁵

The second element is whether or not the field requires a postdoctoral period before a would-be scientist is deemed fully qualified. There is considerable variation among scientific fields on this subject. Postdocs are uncommon in mathematics, for example, but nearly essential in most biomedical sciences. Fields such as chemistry and physics lie somewhere between these two extremes.

Next there is the question of how many years is spent on average in such a postdoctoral status. There is much concern that the postdoc has become a kind of “holding pattern” for recent PhDs unable to in permanent fulltime positions. This may be especially the case in the life sciences.¹⁶

This means that at the extremes of scientific fields, the field with the youngest fully-qualified entrants is probably mathematics, at about age 26. The oldest is that of the life sciences, as

¹⁵ Data taken from the Survey of Earned Doctorates, as reported in Committee on National Needs for Biomedical and Behavioral Scientists, National Research Council, Addressing the Nation’s Changing Needs for Biomedical and Behavioral Scientists. (Washington, DC: National Academy Press, 2000), Table G-1.

¹⁶ Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists, National Research Council, Trends in the Early Research Careers of Life Scientists. (Washington, DC: National Academy Press, 1998), pp. 28-31.

summarized concisely by the 1998 NRC report Trends in the Early Research Careers of Life Scientists:

The career prospects in 1998 for a graduate student or postdoctoral fellow in the life sciences are very different from those of someone who trained in the 1960s or 1970s. Today's life scientist will commonly have started graduate school at a slightly greater age and will have taken 2 years longer to obtain the PhD. This year's PhD recipient is on the average 32 years old...[Postdoctoral positions in the life sciences] have no fixed length of tenure. It is not unusual for a trainee to spend 5 years or more as a postdoctoral fellow. Consequently, the average life scientist will be 35-40 years old before obtaining his or her first permanent job.¹⁷

Finally, those seeking academic careers must then deal with the standard six-year period of contingent appointment as assistant professor. This means that for scientific fields taken together, the age range at which a stable academic appointment can be achieved ranges from the youngest of about 31 for mathematics to about 40 or over for the life sciences.

Postgraduate education for physicians is also extended well beyond the BA. The typical trajectory lasts 7 years: four years of medical school, followed by three years of internship/residency (with some specialized fields requiring longer residencies). Hence, the MD degree might be expected to be earned at the age of 25, and full professional status achieved upon completion of the residency at the age of 28 (higher for some specialties).

In contrast to both science and medicine, the MBA career trajectory includes a post-baccalaureate degree of only two years. Even this short time-to-degree may be too long for many ambitious students: Harvard Business School has considered shortening the term of its MBA to an optional 16-18 month period, under pressure from business school students who consider the two-year degree too slow.¹⁸ At the same time, many MBA programs seek applicants who have already been working for 2-3 years following the BA. Hence a person pursuing the MBA might expect to be deemed fully qualified at the age of 25-26.

Finally, U.S. legal education generally requires a three-year commitment, and typically follows immediately after the BA is earned. Recipients of law degrees must also pass the bar exam to be fully qualified, but this can often be undertaken while already employed. Hence a person pursuing a law degree might expect to be seen as fully qualified by the age of 25 or so. If this person then joins a law firm as an "associate", there would be a subsequent period of roughly five years before he/she could be sure of a stable long-term career position.

In summary, then, graduate degree holders in law and business tend to be viewed as fully qualified at around the age of 25-26; medical degree holders at around 28; and science PhD holders at ages ranging from 26 to 33, depending on discipline.

¹⁷ Committee on Dimensions ..., p. 63.

¹⁸ John S. McClenahan, James Bredin, and Tanya Clark, "The MBA: Where in the world is it headed?" Industry Week, May 15, 1995, pp. 44-45.

Within the science category, the most problematic fields in terms of compatibility with “normal life” obviously would be one characterized by the longest time-to-degree, the longest period of apprenticeship, and the longest period of appointment to the first full-fledged career position. These are the characteristics of the academic life sciences, and within them the basic biomedical sciences, which represent by far the largest fields of PhD science in terms of numbers.

While such compatibility issues arise for both men and women entering these fields, they would seem to be most problematic for women biomedical scientists who also wish to have families. Notwithstanding substantial shifts in norms regarding the sharing of family responsibilities, the realities of mammalian reproduction mean that the burden of childbearing necessarily falls most heavily upon the female. The physical and psychological burdens of gestation, parturition and lactation are all felt primarily by women, and the time costs of parenting, while they can be more easily shared, also in practice tend to fall more heavily on women.

It would seem, therefore, that fields in which a career cannot be firmly established before the mid- or late-30s impose special stresses upon women who have not chosen to exclude marriage and/or childbearing from their plans. It is, then, perhaps a paradox that it is precisely the biomedical fields among the sciences that have attracted the highest percentages of women.

Conclusions

Notwithstanding a general consensus on the importance of attracting significant numbers of outstanding young people to scientific careers, a variety of forces have conspired---with no one intending this outcome---to a relative deterioration of such careers when compared with those in medicine, law and business. The main forces involved are lengthening time to degree and lengthening time in postdoc/apprenticeship roles. These forces are most visible in the academic biomedical sciences, and pose special incompatibilities for women who wish to combine a professional career in science with a typical middle-class family situation. It is then surprising that these same fields attract higher percentages of young women to graduate study than do the physical sciences and mathematics.

CHAPTER E EVEN

Lack of Minority Leadership: Possible Causes and Plausible Solutions

Richard Tapia

Introduction

This chapter reports on a National Science Foundation-sponsored summit meeting, held at Rice University, October 1999. The primary focus of this chapter is on preparing the next generation of minority leaders in S&E.

Despite a generation of intense efforts, the nation continues to face the dilemma of perilously low minority representation in Science and Engineering (S&E). Even more troubling and threatening to future success is the lack of the next generation's minority national leadership. Who will replace the critically few senior minority leaders if we do not identify, nurture, and guide potential leaders into places of authority?

Among those attending the summit, I see senior faculty at important research institutions, leaders of national professional societies, industry leaders, university presidents and senior administrators, and managers of national laboratories who happen to be underrepresented minorities. You are the existence proof that underrepresented minorities can be leaders. It would be good to ask you what factors you credit for your success – how you got where you are today. We should ask the question - what worked for us – to see if those lessons learned can be applied to create many more of us.

In that vein, let me talk about my own personal experience and what helped me to become a leader. It was never in my design to be a leader. In fact, I grew up quite shy and quiet. I was not a star student in high school. I loved mathematics, but I also loved cars, and did not strive to be an academic star. No counselor or teacher ever advised me to go to college, so I went to work right after high school at a muffler factory. An older co-worker convinced me not to make the same mistake that he had made as a young person, that I was too smart to do what I was doing, and that I should go to college. I enrolled in community college, did very well, transferred to UCLA, and ultimately got a PhD there.

If you ask me how my leadership evolved from those humble beginnings, I would say that one of the best things that ever happened to me was to go to the Army Mathematics Research Center at the University of Wisconsin, one of the premier research institutions at that time. I met some of the finest mathematicians in the world, and also caring people who actually talked to me. I attended lectures, learned how to ask questions, and started to become more forward, more outspoken, and less shy. I co-authored papers with some of the finest mathematicians in the world. When I left that center, people knew me; I had established a network of important mathematicians that gave me a strong base for leadership *in my field* that exists even until today. Let me explicitly make the point so that nobody misses it – I was given an incredible opportunity, and I took full advantage of it.

Today we will be talking about those two things – institutions and individuals – what institutions need to do to promote minority leadership and what individuals need to do to promote themselves as leaders.

What Institutions Must Do

We must face the fact that the quality of a person's institution is in large part going to determine how well positioned the person is to fulfill leadership potential. If MIT, Stanford, Caltech, UC-Berkeley are producing leaders in terms of national organizations and professional societies, then we must have representation in these places, because the culture is such that you can't come in the back door. It is very hard to come in from the school that is not part of the network. You could say that's not fair. I agree, it's not fair, but that's the way it is, and trying to change that would be much harder, in my opinion, than changing the representation issue. Bowen and Bok, in *The Shape of the River*, argue that underrepresented minorities going to selective schools do turn out to be leaders, in fact, become leaders in proportions greater than the majority.

Let's just tell it like it is. A PhD from Caltech, Princeton, or Stanford is going to have several points up over a PhD from a less esteemed majority or minority-serving institution. We do the leadership issue a disservice if we treat this fact as an ugly little secret that can't be talked about. We must face it and deal with it. Given this fact shouldn't we strive to get more underrepresented students into prestigious schools and then hold the institutions accountable for nurturing and preparing these students? I challenge these institutions: what leading university will step forward and distinguish itself with an innovative program to triple or quadruple its PhD underrepresented minority production?

There are underrepresented minority students who have had first-rate educations who look like majority students, and in every way are as capable and as sophisticated. It really isn't an issue if they go to Stanford, Berkeley, Caltech, or Cornell. They're going to do well. But that's not the bulk of the underrepresented minority population. And for schools that say, "we're going to fight for the first pool," I ask, what are you contributing to the nation's representation with that tactic? If you fight for members of the first pool by offering more money or more perks, you really haven't done anything to address the issue of underrepresentation. You've made your school look better. You can say, "oh, look we're leading the nation," or whatever you want to say, but what have you done for the global pool, what have you done for the underrepresentation crisis? You haven't done anything.

Instead of just fighting over the best students, I would like to ask that we identify and support the "second pool," the diamonds in the rough that don't look like traditional candidates. Of course, I have biases here, because I myself was part of the second pool, and because I've had success with students from the second pool at Rice. By second pool, we don't mean second class. The second pool consists of individuals who are certainly talented and capable, and can succeed given proper guidance, but who either have not been properly developed or properly evaluated. It is this second pool that we are losing. They take special effort. They require mentoring, guiding, and sometimes remediation. They may make a slower start. In our department, we have mostly the second pool, and we produce quality graduates. Our second-pool minority students have been combined with first-pool traditional students, and to our credit we have

learned how to make it work. After one or two years, our second-pool students often are viewed as comparable to anyone in the department. So Rice has shown that what we propose – looking more at second pool – can be done successfully.

I'd like to say again that I came from this second pool, so I have some particular sensitivity here. I frequently tell our Graduate Admissions committee when I'm arguing for a certain minority student applicant, that they would not have accepted me based on the traditional criteria that they are applying. Our department is not that different from others. If we had gotten the quality of traditional applicants that Stanford gets, the faculty would have been extremely happy, we would have accepted them, and it would have been impossible to get a second-pool minority student accepted. But we didn't, so we accepted students who didn't have all A's necessarily or who had low board scores, but who had faculty saying this person is a very creative person. We have case after case of success under these parameters. Now we challenge other selective schools to do what Rice did.

Of course, if we look to this second pool, then we most likely will have to do more to help students overcome some lack of preparation. Retention activities are always important, but they are absolutely critical with this group. These students may face what I call the "moment of truth." This is the time when you change comfort levels. You go from a situation where you have been quite comfortable to one where you are uncomfortable. For an African American student it could be moving from a school that was predominantly African American to a school that is predominantly majority. It could be a change that occurs at first grade, middle or high school, college, graduate school, faculty, at a job, or even at a high-level leadership position. At Rice, it frequently happens to students who have come from minority schools. The main problem they're dealing with is feeling isolated and alone in an unfamiliar and seemingly unfriendly environment. The academic problems may or may not be present, but certainly the students are dominated by a drastic change in environment. A support group of caring individuals – some peer, some faculty – must intervene to smooth the transition and reduce the possibility of losing individuals at these critical junctures.

Universities must do more to support these activities as part of their mission. Retention activities must become much more a formal part of the reward system throughout all levels of the university – undergraduate through tenure. To be successful, programs must be integrated into departments and not relegated to "minority land" led solely by staff. The scientific community is elitist about this activity as well. They will not respect it if it is not led by faculty members who understand faculty culture. At Rice, we have been quite successful with a model of faculty leading our retention programs with extensive staff support. Universities should also reward faculty for their participation in these very time-intensive activities. It must become a formal part of the university reward system if we are to change the culture.

I'd like to ask that we hold presidents accountable for mandating change. Presidents talk a good game, but they must go down to the level of the dean and the chairs and say, "Look, this is a part of the mission and you must play a role in this. You will be held accountable. In turn, success in these areas will be reflected in the reward system." We must align the reward system with the mission. I have seen far too many times individuals who buy into the mission, work really hard with students (which costs them something, in terms of research productivity), then suffer at the

time of promotion or at a time of tenure, because while the university said this was of value, it wasn't valued enough to be a part of the evaluation process.

I believe departments should be the unit of accountability. I don't believe all individuals should be the same. I think some faculty members are very good at certain things and others at other things, but I think a department is a sufficiently large unit to say it's good or bad at supporting our mission. It's done a good job of bringing in nontraditional students, nurturing them and educating them as well. When departments are faced with this, however, they will say, "But how do we stay in the 'Top 10' and still do this?" I say, the accountability system should be such that you can't get into the Top 10 if you *don't*. We must make representation a criterion in judging how well departments are doing.

We must deal with the risk-averse problem in faculty hiring. Departments must say, "We are being held accountable for more than just research. Look, this person is a good researcher, but will he also give us many dimensions that we have never had?" When I was hired, I was not the first choice. I know that. The first choice went on to a very undistinguished career. I was hired as a second choice. But I don't think I was evaluated with the expectation that I'd bring dimensions of teaching, of nurturing, of mentoring, of research, of national visibility. And yet, I can honestly say that I didn't doubt that I would do all those things even though those doing the hiring were not able to predict that.

As we move up through the selection ranks – undergraduate admissions, graduate admissions, then departmental hiring – selection becomes more and more traditional. By far, departmental hiring is the most traditional. I think most individuals in a department want to replicate themselves. I am good; therefore good people will look just like me. The department itself is extremely risk averse when a candidate looks a little different, and this surely includes underrepresented minorities. The dimensions in which they can contribute seem not to be evaluated at hiring time. I believe that departmental hiring is perhaps the most problematic of all the admissions, if you will allow me to call it "admissions."

One difficulty that I have encountered with my own minority students is placing them after graduation in positions where they will be challenged. I think that they have started to reach their potential, they're ready to go, but they can't get the experience, the post doc experience, the faculty experience at a university that would be challenging to them, and yet I believe that they would be competitive there. They just need an entrée; they just need a way to get there, they need a similar opportunity to what I had at the University of Wisconsin. Perhaps what we need is a national high-level intern program where students are placed with leaders in their field. They would bring with them full funding and the research director would be charged with guaranteeing that the student is fully integrated into the research group. Funding agencies like NSF could make a real difference with such a program.

What Individuals Must Do

Building a solid research career is the first essential to leadership in science. Throughout my career, it has been important to me to be recognized as a mathematician who happened to be a minority. I realized that I would be evaluated on my research credentials. The scientific

community is elitist about this topic. They will not respect or promote the professional minority who does not have these credentials. I don't want to be a professional minority who happens to be a mathematician. I want to be a mathematician who happens to be a minority.

Because of this, I counsel students to get tenure first before they start doing outreach. Build your career as a scientist first, and then you will have a strong foundation on which to give to others.

Yet I find minority graduate students choosing the "comfortable" advisors. They tend to avoid the aggressive advisor or the aggressive research group. Their choice often will be a junior, non-tenured faculty member, or maybe a minority faculty member, and that's not always the best choice. This creates a double whammy for minority leadership. It puts too much burden on the young minority faculty member who is really trying to get tenure or go forward, and it doesn't position the student to establish a strong network. I believe these are things that can be dealt with through proper mentoring and advising. I've had numerous minority students at Rice who have said, "Oh no, I could never work with that person." But they did, and it was a wonderful experience.

Individuals must be bold in their *self*-development and *self*-promotion if they are to attain national leadership positions. Some minority students are bold and daring by nature or through positive experiences with risk-taking. As we all recognize however, the majority of underrepresented minority students are not. I have found in my work here at Rice that underrepresented minorities frequently shy away from self-promotion and are highly averse to risk-taking. Or sometimes they just don't know how to navigate the waters of the scientific research world, making mentoring so essential to these students. A fundamental theorem of mentoring underrepresented minorities is this: assume students don't know what they should do and that they need your advice. A hands-off approach in mentoring underrepresented minorities just doesn't work. Oftentimes, I play the role of a caring father when the students that I mentor need correction or advice. If you must err, err on the side of too much rather than too little intervention. I have had students tell me – we didn't know we needed mentoring; we didn't want mentoring, but now we realize that it was of great value.

Networking is absolutely critical to leadership, yet networking requires the boldness that we are talking about. It is highly unlikely that one can build a strong network through timidity. Professional development in networking is essential for underrepresented minorities. When you take minority students to conferences, *require* them to look for opportunities to network. Don't assume they will just naturally do this. *Insist* that they ask questions of speakers in their area. Introduce them to your network of colleagues and include them in both social and professional situations. Also insist that they attend colloquia when they are at home and get to know the faculty in their department. That way they can become a part of their network as well. We all walk a tightrope of being too pushy and aggressive or too timid and passive, but if the student or young faculty member shows a genuine interest in the science, that will be valued by the senior person. Otherwise it will come across as self-promotion for its own sake.

Let your students know that *you* sometimes volunteer to give talks, that you have done your own share of self-promotion. Encourage students to *make* every opportunity to give talks and write

papers. Professional rejection and failure hurts, but it won't kill you. We all have to learn to deal with failure.

We must insist that institutions change, and yet that is such a long, slow process that we can't wait for institutions to solve the problems of leadership for us. We must as individuals do all that we can to support and promote potential underrepresented minority leaders. Those attending the summit are examples that it can be done.

To conclude, here are some questions that I suggest as possible topics for our discussion.

1. Can leadership be developed without first solving the underrepresented minority problem?
2. How much of a scientist does one have to be to be a successful leader? Is an end run around research desirable or advisable?
3. Is it easier to close the leadership gap than to close the scientific representation gap at level-one research schools and other important places?
4. Some get PhDs in science and move immediately into educational outreach or administrative positions. Should underrepresented minorities emulate this activity?
5. Can minority leadership problems be solved by minorities alone or any one segment of a population?
6. What categories do we need when evaluating success for underrepresented minorities, i.e. is it enough to treat all Hispanics as one?

I hope some of these issues I've shared with you will stimulate good conversation.

DO T CRIPT

In 1994, Pearson and Fechter asked *Who Will Do Science and Engineering?* This was as much a metaphor as a rhetorical question. In this volume, we have suggested that “doing” science and engineering well is the supposed path to leadership – in the discipline, in the profession, in the community, in the society. Where leaders come from is an ultimate question that presupposes others: Can leadership qualities be directly cultivated? Or does a succession of opportunities and experiences endow one with those qualities? Are mentors necessary? Or do achievements alone in illuminating the potential for leadership?

Culture and Law

If we start at the other end of the journey, we confront certain realities. In a feature on Cal-Berkeley linguistics professor John H. McWhorter, author of *Losing the Race: Self-Sabotage in Black America*, a *Washington Post* staff writer states that “The stubborn achievement gap separating black and white students is a problem that has baffled educators for years....” Yet, according to Harvard researcher Ronald F. Ferguson, “The more we look at the data, the more we move away from a simple cultural explanation. There are behavioral differences that you can observe between racial groups, but they tend not to be behaviors that help you predict achievement.”¹

In the aggregate, gaps abound. The U.S. college-age population is about 30 percent minority, yet minority achievement in engineering lags: only 10 percent of those awarded baccalaureates, 3 percent Ph.D.s, and just 6 percent of the engineering workforce. A modest pool shrinks quickly. No wonder few ascend to leadership posts. The only remedy – long-term and painstaking – is restocking the pool. This puts the emphasis squarely on the issue of *access*, with academic preparation for future careers and the transition from high school to undergraduate study corollary concerns.²

Fortunately, most U.S. colleges value diversity and defend affirmative action. Many are not willing to abandon race as a factor in admissions decisions, which circuit courts recently sustained in cases involving the universities of Washington and Michigan.³ With these recent decisions, which conflict with the 1996 *Hopwood* decision that banned race-sensitive admissions policies in Texas, Mississippi, and Louisiana universities, a review by the U.S. Supreme Court seems inevitable.

¹ Michael A. Fletcher, “The Linguist’s Fighting Words,” *Washington Post*, Jan. 3, 2001, p. C8.

² George Campbell Jr., Ronni Denes, and Catherine Morrison, eds., *Access Denied: Race, Ethnicity and the Scientific Enterprise* (New York, NY: Oxford, 2000).

³ See Elizabeth Greene, “Diversity Education Is Required at Most U.S. Colleges Responding to a Survey,” *Chronicle of Higher Education*, Oct. 24, 2000; Sara Hebel, “Appeals Court Says Colleges May Consider Applicants’ Race in Striving for Diversity,” *Chronicle of Higher Education*, Dec. 6, 2000; Constance Holden, “Court Backs Michigan Policy on Diversity,” *Science*, vol. 290, Dec. 22, 2000, p. 2227; and William Darity, Jr., “Give Affirmative Action Time to Act,” *Chronicle of Higher Education*, Dec. 1, 2000.

Evidence, then, that diversity enhances education, will not necessarily carry the day.⁴ Indeed, the gap between culture and law cannot be ignored. Most Americans resent affirmative action. They confuse equality of opportunity with equality of outcomes. They equate programs that consider race, ethnicity, or gender as imposing quotas. So the very decisions that provide minorities opportunities stigmatize them in the process. To many, their presence connotes institutionalized practices that assure favored consideration while compensating for a lack of qualification.

All of these stereotypes penalize individuals for their group identity. They are part of the dynamic that science and engineering must overcome if ascribed characteristics are to recede in the structure of opportunity that a merit-based community claims to afford students and professionals alike. The discussion at the 2000 AAAS symposium mirrored these and other deep-seated *assumptions*. Among them, and the conjectures they trigger, are the following:

- **Science is about talent, not about gender or ethnicity.** It is about what we do, not who we are. Attention to equity is seen to distract from excellence, as if they cannot coexist. In a diverse community that has long welcomed citizens of foreign nationality, there is great consciousness, reinforced by census categories and requests for self-identification, about who is participating and who is not – with the inevitable search for explanations that range from individual differences in interest and aptitude to structural barriers of prejudice and discrimination – verbal discouragement to glass ceilings.
- **Some institutions are productive of women scientists, others of minority scientists.** Data that display retention rates by institution, separately for minority and majority students, as NACME publishes for engineering undergraduates, would remind us which are serving diversity and which are not. This should be a performance indicator of human resource development that sponsors, research performers, and employers could all use in decisionmaking.⁵ A stellar example is the Meyerhoff Scholars Program operating since 1988 at the University of Maryland, Baltimore County (UMBC). While the ingredients of this program's effectiveness have been well-documented, a most crucial component is the leadership provided by the UMBC President and the institutional environment for supporting excellence irrespective of student gender, color, or ethnicity.⁶
- **Science careers do not compare favorably to medicine, law, and business.** But students may also not be well-informed, as the Teitelbaum chapter suggests, about the costs, the

⁴ See Patricia Gurin www.umich.edu/~urel/admissions, which supports the findings of William Bowen and Derek Bok, *The Shape of the River: Long-Term Consequences of Considering Race in College and University Admissions*, Princeton, NJ: Princeton University Press, 1998, on the benefits of affirmative action during undergraduate study for minorities.

⁵ For such an institutional analysis at the graduate level, see Shirley M. Malcom, "Minority Production in SME Fields: Distributing the Work?" *Making Strides*, vol. 2, July 2000, pp. 1-6.

⁶ Kenneth I. Maton, Freeman A. Hrabowski III, and Carol L. Schmitt, "African American College Students Excelling in the Sciences: College and Postcollege Outcomes in the Meyerhoff Scholars Program," *Journal of Research in Science Teaching*, vol. 37, 2000, pp. 629-654. Also see Brent Staples, "Preaching the Gospel of Academic Excellence," *New York Times*, June 5, 2000; and Diana Jean Schemo, "U. of Maryland Branch Is Beacon for Minorities in Math and Science," *New York Times*, Oct. 14, 2000.

returns, and the opportunities forgone by their choices. The calculus may be different for foreign-born students and for those seeking a career in engineering. To be sure, Federal agencies have paid scant attention to informing career calculus beyond considerations of undergraduate finance. Graduate students and postdocs are demanding more information, and a more formalized process of, information dissemination about costs incurred and recent outcomes for degree recipients. They also insist on reducing the length of time to degree completion. All are issues affecting recruitment and retention. They should be targets for negotiation and reform.

The decentralized character of graduate admissions and the persistence of professor autonomy in recruiting and integrating the “best and the brightest” into the laboratory structure militates against institutional reform in graduate education. The size of stipends, the presence or absence of mentoring and other support mechanisms, will continue to dominate student decisionmaking.⁷ However, if selecting science as a career declines as a rational choice relative to other professions, we are left with gut feeling – do it for the love of the subject, not for the riches or the glory that may never materialize.

Technology and the Future of Diversity

What emerges from the discussion of February 2000, and indeed the contributions to this collection, is a need for political will to “market diversity.” Today’s leaders – white males – must insist that more diversity – women and persons of color who have demonstrated a quality of purpose and performance, is required in leadership positions of every organization regardless of industry or sector. It will take more than leadership, however, to translate diversity into opportunities for full participation in science and engineering.

We live in an information society, a “digital economy.” The “digital divide” is “a gap in technology access between groups defined by income, race, gender, or education.”⁸ Digital divide is now the shorthand for “haves v. have nots.” It has become a new metaphor for gaps – economic and educational – that represent differential life chances. Lack of access to technology, or lack of know-how in using it, is the “itch” that policy must “scratch.”⁹

Economists, like Peter Drucker and Lester Thurow have provided a broad-brush glimpse of knowledge workers in the 21st century. “As the digital economy expands, more people will have jobs creating, maintaining, and operating the technologies that go into making up the economy” – computers, software, telecommunication networks, the Internet and e-commerce protocols. While digital automation changes the composition of jobs and raises incomes, it does not raise – not yet anyway – the unemployment rate.¹⁰

⁷ But see the “Re-visioning the Ph.D.” project, headquartered at the University of Washington www.depts.washington.edu/envision/.

⁸ Bonnie Bracey, “A Different Divide: Teachers and Other Professionals,” *Edutopia*, Spring 2000 www.glef.org/edutopia/newsletters/spring2000/bracey.html.

⁹ Much of this section is based on Daryl E. Chubin, “The ‘Digital Divide’: More than a Metaphor, or Scratching the Policy Itch,” GEM Consortium Annual Board of Directors Meeting, Washington, DC, May 24, 2000.

¹⁰ Robert D. Atkinson, “Digital Automation and the new Workforce,” *Information Impacts Magazine*, April 2000 www.cisp.org/imp/april_2000/04_00atkinson.htm.

Nevertheless, economists tend to ignore what they can't measure quantitatively. In *Science and Engineering Indicators—2000*, a congressionally-mandated biennial statistical analysis of the state of science and engineering, a chapter on information technology (IT) says this about the digital divide:

People who are more affluent, more highly educated, and in higher-status occupations are more likely to have home personal computers and Internet access. Even after controlling for differences in income, blacks lag whites in ownership of home computers and in linking to the Internet. . . . in 1998, 46.6 percent of white Americans owned a home computer compared to 23.2 percent of black Americans – a gap that increased by nearly 7 percentage points from 1994. . . . a white two-parent household earning less than \$35,000 is nearly three times as likely to have Internet access as a comparable black household and nearly four times as likely . . . as an Hispanic household in the same income category.¹¹

In schools, the effects of technology access can be even more pernicious. ETS found in 1998 that students who used computers strictly for drill and practice routines – who disproportionately happen to be minority – actually did worse than other students on achievement tests. Teacher surveys show that while the majority of teachers use computers in instruction, they also claim not to be well-prepared for the task. Clearly, how schools use their new technology “will determine whether they help students bridge the digital divide, or push them into it.”¹²

Through the Internet educational institutions – while still filling an important role in the creation and dissemination of knowledge – have become linked inextricably to communities and experiences beyond their immediate campuses. Thus, we must incorporate into our approaches to education reform, job training, and public literacy a technological consciousness that goes beyond becoming adept or working smarter. The co-chair of the President's Information Technology Advisory Committee (PITAC) has put the IT revolution this way: “Will this be a transformation just for Wall Street, the Fortune 1000, and the new ‘dot-coms’? Or will Main Street and the millions participate fully.”¹³ The digital divide must cross “Main Street” to reach, as Shirley Malcom says, “the other side of the information highway.” When persons of color are missing from the mainstream – be it the research literature or seats at the table where policies are developed to govern and apply tools – communities suffer.

Technology suffers, too, by the lack of diversity. That is why advanced degrees in science and engineering are one way to counter disconnection and exclusion. “Ownership” includes the ability to participate in the design of the next generation of tools, in expanding choices, creating opportunities, entrepreneurship, and markets for what a community needs.¹⁴ At stake, then, is

¹¹ National Science Board, NSB 00-1, 2000, pp. 9-3, 9-35. A commentary to *Indicators—2000* further states “If we are to understand and deal with the socioeconomic, ethical, legal, and workforce implications of these [IT] systems, we will need to support a research agenda that crosses disciplines, languages, and cultures. National Science Board, *Science and Technology Policy: Past and Prologue*, A Companion to Science and Engineering Indicators—2000, NSB-00-87.

¹² *USA Today*, Apr. 26, 2000.

¹³ Irving Wladawsky-Berger, “Resolving the Digital Divide: Information, Access, and Opportunity,” *Hispanic Engineer*, April/May 2000, pp. 52-54.

¹⁴ PITAC, *Resolving the Digital Divide: Information, Access, and Opportunity*, 2000.

much *more* than access. The digital divide is but a surface indicator of deeper divisions and inequities. As the NRC's Computer Science and Telecommunications Board has suggested, we could use a "marginalization index" to measure "the extent to which specific populations are excluded from participation in the information infrastructure."¹⁵

The Policy Imperative

To develop human resources is to cultivate talent that comes in all colors, shapes, and sizes. Those "packages" will reflect an unprecedented diversity of cultural roots and perspectives in the 21st century. Thus we must be mindful that any retrenchment from a commitment to our ethnically and economically diverse population will extract too high a societal price – a talent deficit – in the knowledge-based economy. Equity and excellence are the twin pillars of any human resources development policy.

A critical shared responsibility in higher education is that of providing access to all students. Science and engineering careers have proved to be effective pathways for social mobility for significant numbers of our young people. They deserve the opportunities to enter careers – whether or not in science and technology occupations – that they find attractive and personally satisfying. As a nation, we cannot afford to have any citizen underrepresented in our strategies for meeting the challenges ahead. Neither gender nor ethnicity, nationality, nor disability should be predictive of career choice, success, or potential in the future of any American.

Developing human resources for science and engineering goes beyond the formal system of education or agency allocations known as "the R&D budget." As the late Congressman George Brown and, more recently, chemist Mary Good argue, we need to think about trained personnel as something more than a byproduct of research investments. Who participates in the science and engineering workforce is not just an R&D budget issue; it is a *policy* issue. The policy needed must reflect a cultural attitude toward investments in knowledge that enable the next generation to contribute in new ways for society to navigate uncharted waters – and innovate as it grows. Such a policy is for the continued health of science and technology, and is inseparable from our nation's long-term security.¹⁶

The Clinton Administration pledged in its science policy blueprint of August 1994 that "The NSTC [National Science and Technology Council] will produce a human resources development policy for sustaining excellence and promoting diversity in the science and technology workforce."¹⁷ The pledge remains unfulfilled, the federal agencies lacking the mandate or the resources to develop new scientists and engineers as a core part of their missions.¹⁸ Instead, we import talent under temporary visas for fear of jobs being exported offshore. We treat content- and technology-savvy mathematics and science teachers as

¹⁵ NSB, *Indicators—2000*, p. 9-42.

¹⁶ Seeds of a policy are contained in National Science Board, *Preparing Our Children: Math and Science in the National Interest*, March 1999, NSB 99-31.

¹⁷ William J. Clinton, *Science in the National Interest*, 1994.

¹⁸ A disappointing Administration effort that analyzes the problem but contains little in policy remedies is National Science and Technology Council, *Ensuring A Strong U.S. Scientific, Technical, and Engineering Workforce in the 21st Century*, White House Office of Science and Technology Policy, April 2000.

anomalies rather than necessities. And we invest in research-intensive universities as if they are the only institutions of higher education that matter.

The demands of diversity must teach us other lessons: connect K-12 and higher education in a more seamless and accountable system; replicate the successes of minority-serving institutions in majority institutions; recognize two-year and community colleges as the magnet for minority and adult learners already in the workforce; rediscover, or reinvent the master's degree in science; and assimilate the contributions of distance education – self- and company-financed – to the digital economy as a global workforce that is more skills- than degree-based.¹⁹

Industry is ahead of academe in acting on these workforce imperatives. One effort to share learning about best practices across sectors, disciplines, and workplaces in the recruitment, management, and reward of a diverse workforce that is typically team-based and increasingly geographically-dispersed is the two-year-old National Academy of Engineering Committee (and Action Forum) on Diversity in the Engineering Workforce.²⁰ Connecting what is known to happen on-the-job to academic training and skills – communication, persuasion, leadership – to excel in high-tech work environments is a challenge both to producers and consumers of the 21st century workforce.

For this reason alone, Federal policy represents incentives and justifications to be exploited. The Equal Opportunity in Science and Engineering Act of 1980 (Title 42 of U.S. Code 1885-1885d) directs the National Science Foundation to undertake programs to increase participation by underrepresented groups and to promote the advancement of these groups in science and engineering fields. No other R&D agency has such a legislative mandate. Either the missions of the other agencies should be expanded to include the development of technical personnel or NSF should be funded to lead a national initiative that will yield the precious resource that will ensure U.S. leadership. This is a viable path to Tapia's vision of leadership and our shared responsibility to educate the next generation.

Prospects: Participation and Leadership

As the demographic kaleidoscope of the U.S. population shifts, the words “majority” and “minority” begin to lose meaning. Policy can accelerate the migration from the margins to the mainstream and draw strength from the diversity of our population – the same diversity of color and gender that should be no more predictive of individual aspiration or achievement than one's

¹⁹ Many of these trends are discussed in National Science Board, *Preparing Our Children: Math and Science Education in the National Interest*, 1999, NSB 99-31. Also see Sheila Tobias et al., *Rethinking Science as a Career: Perceptions and Realities in the Physical Sciences* (Tucson, AZ: Research Corp., 1995); and the Alfred P. Sloan Foundation's Science Master's Initiative at www.sloan.org.

²⁰ Various web sites provide insight to how corporations, nonprofit organizations, and professional associations are demonstrating the value added by diversity in the workforce. For examples of NAE-related activities, see www.GM.com, www.FIRST.org, and www.HENAAC.org.

place of birth. Not all young people will elect to pursue careers as scientists, doctors, engineers, mathematicians, or teachers, but all deserve the chance to make their own choices. It is to those choices and these professionals that a human resource policy should be dedicated.

Tapia has contributed a road map that charts the pathways and distances to success. Of course, in preparing for a journey in science or engineering, “success” comes in various forms and at several junctions. The journey begins by acting on the conviction that science and engineering should not be the province of the few. Those who earn the opportunity to be a leader, in Tapia’s terms, must use their own accomplishments to advance the journey of others. Leadership is power derived from the recognition of achievement, so the issue is not “underrepresentation” or diversity of the talent pool, but how to grow more leaders who happen to be racial and ethnic minorities.

This collection began as a day-long symposium held at an annual meeting of the American Association for the Advancement of Science. It was an occasion for collective reflection on data and the dilemmas they pose. But the preceding analysis and commentary will not reach fruition if we fail to ask: How can we do better develop human potential for science, engineering, and the nation? It is clear to those represented in this volume that none of this should be left to chance. Market forces may be powerful, but they bend to certain interests and are impervious to others. That is one role of policy – to expose the barriers and opportunities that Federal intervention can act upon.

So we end this collection by reiterating a thought bordering on a plea that was introduced early and often in these pages: participation in science and engineering will not just “happen.” It takes the caring and perseverance of many – students and their supporters alike. Public policy must serve the national interest and all of its citizens in developing human resources with a sound science and mathematics foundation. Only a systematic policy that extends beyond ideology, missions, and the localism that our country holds dear, a policy replete with incentives for compliance and consequences for indifference, will command the attention and energy of the federal R&D agencies, their constituencies, and all who teach, mentor, employ, and lead knowledge workers of the 21st century. We hold the future in our heads, our words, and most of all, in our deeds.

IO RAPHICA KETCHE

Editors

Daryl E. Chubin is Senior Policy Officer for the National Science Board (see www.nsf.gov/nsb) at the National Science Foundation (NSF). He joined NSF in 1993 as Division Director for Research, Evaluation and Communication in the Directorate for Education and Human Resources. During 1997, Dr. Chubin served on detail as Assistant Director for Social and Behavioral Sciences (and Education) at the White House Office of Science and Technology Policy. His Federal career began in 1986 at the Office of Technology Assessment, U.S. Congress, where he directed projects that resulted in the reports *Educating Scientists and Engineers: Grade School to Grad School* (1988) and *Federally Funded Research: Decisions for a Decade* (1991).

Prior to 1986, Chubin taught at four universities, and currently is Adjunct Professor in two Washington, DC, area programs. He has published seven books and numerous policy reports, articles, and commentaries, including *Rethinking Science as a Career: Perceptions and Realities in the Physical Sciences* (co-authored, 1995), and *Science, Technology, and Society: A Sourcebook on Research and Practice* (co-edited, 2000).

Chubin is a Fellow of the American Association for the Advancement of Science (AAAS), Chair-elect of AAAS Section X—Societal Impacts of Science and Engineering, President of the Commission on Professionals in Science and Technology, and a member of the NAE Forum on Diversity in the Engineering Workforce.

Willie Pearson, Jr. is a Professor of Sociology at Wake Forest University and an Adjunct in Medical Education in its School of Medicine. Dr. Pearson received his Ph.D. in sociology from Southern Illinois University in Carbondale in 1981. In 1993, he received Southern Illinois University's College of Liberal Arts' Alumni Achievement Award. He has held postdoctoral fellowships at the Educational Testing Service and the Office of Technology Assessment, Congress of the United States.

Dr. Pearson's research has centered on the career patterns of Ph.D. scientists (particularly African Americans), human resources issues in science and engineering, science policy, and comparative family studies. He recent projects include a study of the career patterns of African American Ph.D. chemists, and the status of African Americans in engineering.

Dr. Pearson serves or has served on committees, advisory boards, and panels at the National Institutes of Health, National Science Foundation, American Chemical Society, American Association for the Advancement of Science, Sloan Foundation, American Sociological Association, Sigma XI, and the National Research Council. He was elected president of the Mid-South Sociological Association (1987); a member of the Executive Council, American Sociological Association's Section on Science, Knowledge, and Technology (1989-91); and a Governor of the National Conferences on Undergraduate Research (1994-2000).

Authors

Eleanor L. Babco was trained as a chemist, and has spent the past 35 years focusing her professional attention on education and employment data about scientists and engineers. She serves as the Executive Director of the Commission on Professionals in Science and Technology, a nonprofit corporation that has provided human resource data and information on scientists, engineers and technicians for over four decades. She serves as editor and primary writer for CPST publications including the periodical *CPST Comments*, *Salaries of Scientists, Engineers and Technicians*; and *Professional Women and Minorities: A Total Human Resource Data Compendium*. She has written two special reports on the status of African Americans and Hispanic Americans in science and engineering.

Babco conducts applied research on supply and demand, and other education and employment issues, including participation of women and minorities, and promotes exchange of data among professional societies, business/industrial corporations, educational institutions and government agencies. She has developed an online guide to data on scientists and engineers.

Roman Czujko is the Director of the Statistical Research Center of the American Institute of Physics. He has been a staff member of this unit for twenty years and has directed it for the last 9 years. The Statistical Research Center conducts studies that document the trends in education in physics and related disciplines from high school through the PhD. The Center also conducts studies on the careers of physicists and related scientists from initial employment through the retirement process.

Roman's research has focused primarily on employment and common career paths of physicists and related scientists at all degree levels, the transition from school to work, and the representation of women in physics. Mr. Czujko is currently the vice president of CPST, has been on the Executive Committee of the Board of Directors for the last three years and a commissioner for over a dozen years. He earned a master's degree in Social Psychology from the University of Oregon and a bachelor's from Rutgers University.

Michael G. Finn is a senior economist at the Oak Ridge Institute for Science and Education in Oak Ridge, Tennessee. Previously he served as Director of Studies and Surveys at the National Research Council's Office of Scientific and Engineering Personnel, and as a research associate at the Center Institute for Human Resource Research at Ohio State University. His research interests include the immigration and the labor market for scientists and engineers and he also assists in the administration of the NSF Graduate Research Fellowship Program.

He received a Ph.D. degree in economics from the University of Wisconsin, Madison.

Mary Frank Fox is professor of sociology in the School of History, Technology, and Society, and co-director of the Center for Study of Women, Science, and Technology at Georgia Institute of Technology. Her research focuses upon gender, science, and academia. Her publications, appearing in over thirty different scholarly journals and collections, include analyses of salary, publication productivity, work attitudes and behavior, and educational and career patterns among scientists and academics.

She is associate editor of *Sex Roles*, past associate editor (and co-founder) of *Gender & Society*, chair of the editorial board of the international *Handbook of Science and Technology Studies*, and member of the editorial advisory boards of *Social Science of Science* and the Vanderbilt University book series on Issues in Higher Education. Among her appointments, offices, and awards are: research panel on *Careers of Life Scientists*, and consultant for *Study of Gender Differences in Science and Engineering*, National Research Council/National Academy of Sciences; past president, Sociologists for Women in Society (SWS), and SWS Feminist Lecturer 2000 (award to “prominent feminist scholar who has made a commitment to social change”); and numerous offices in the American Sociological Association.

Yolanda S. George is Deputy Director and Program Director, Directorate for Education and Human Resources Programs, American Association for the Advancement of Science (AAAS), Washington, DC. Her duties and responsibilities include conceptualizing, developing, planning, implementing multi-year science, mathematics, and technology (SMT) education and research and evaluation projects and initiatives on preK-graduate education of minorities, girls and children with disabilities. Collaborators in these initiatives include colleges and universities, state departments of education, school districts, professional associations, and community and youth serving organizations. Current projects include National Science Foundation-funded projects on minority graduate education and development of a digital library for undergraduate educators and a Department of Energy-funded project on postsecondary education recruitment and retention and upward mobility of women in engineering and science, worldwide.

Ms. George has served as the Director of Development for the Association for Science and Technology Centers (ASTC); the Director of the Professional Development Program (PDP), a SMT precollege, undergraduate retention, and pre-graduate programs for girls and minorities at the University of California, Berkeley; and as a research biologist at Lawrence Livermore National Laboratory (LLNL). She currently serves on boards or committees for the Once and Future Action Network, sponsored by UNIFEM; Women in Engineering Programs & Advocates Network – WEPAN; Award Advisory Committee, Maria Mitchell Women in Science Award; California State University, Los Angeles, ACCESS Program; and the Boys and Girls Club of America, Computer Technology Centers Project, Atlanta, GA.

She has authored or co-authored reports on SMT human resources and inquiry-based K-12 SMT education. Ms. George received a B.S. and M.S. degree in biology from Xavier University of Louisiana and Atlanta University, respectively.

Mary J. Golladay directs the Human Resources Statistics Program for the Division of Science Resources Studies Division of the National Science Foundation. The program collects, analyzes and disseminates data on science and engineering education and the scientific and technical workforce. Products from the program include survey results and a data system, SESTAT, containing national estimates on the 1990s workforce; the biennial report *Women, Minorities and Persons with Disabilities in Science and Engineering*; and other analytical reports and studies.

Prior to joining the National Science Foundation, Dr. Golladay held positions at the National Center for Education Statistics, U.S. Department of Education. She taught education administration at the University of Wisconsin-Madison and taught high school mathematics. Her bachelor's degree in mathematics was earned at the University of Puget Sound and master's and PhD degrees in mathematics education at Northwestern University.

Charlotte V. Kuh is Deputy Director of the Policy and Global Affairs Division in the National Research Council. In that capacity she oversees the Board on Higher Education and Workforce, which is responsible for studies conducted by the NRC concerned with flows of science and engineering talent, graduate education and post-doctoral outcomes and the assessment of quality of doctoral programs. She is also oversees two large operational programs that select over three hundred post-doctoral fellows annually for positions in national laboratories and that select recipients for pre- and post-doctoral fellowship programs sponsored by the Ford Foundation and Howard Hughes Medical Institute.

Prior to coming to the National Research Council in 1995, Dr. Kuh spent eight years at the Educational Testing Service, where she was director of the Graduate Record Examinations. During that time she initiated the first computerization of a national admissions test and a program of research designed to introduce measurement of a broader range of student talents for use in graduate admissions. Dr. Kuh has also served as a manager at AT&T where she worked on legal issues, strategic planning, macroeconomics and revenue forecasting.

Prior to moving to AT&T, she taught for five years at the Harvard Graduate School of Education and at Stanford University. As a faculty member, her research interests centered around demand and supply for faculty and the economics and finance of education. She has served on a number of National Research Council study committees and on advisory committees for the Bunting Institute at Radcliffe, the National Science Foundation, the Law School at New York University and on the Executive Committee of the Council of Delegates of the American Council of Learned Societies. She is a member of the higher education working group at the National Bureau for Economic Research.

She received her B.A., magna cum laude, in economics, from Harvard University and her Ph.D., also in economics, from Yale.

Shirley M. Malcom is Head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS). The directorate includes AAAS programs in education, activities for underrepresented groups, and public understanding of science and technology. Dr. Malcom was head of the AAAS Office of Opportunities in Science from 1979 to 1989. Between 1977 and 1979, she served as program officer in the Science Education Directorate of the National Science Foundation (NSF). Prior to this, she held the rank of assistant professor of biology, University of North Carolina, Wilmington. Other work experience includes two years as a high school science teacher. Dr. Malcom received her doctorate in ecology from The Pennsylvania State University; master's degree in zoology from the University of California, Los Angeles; and bachelor's degree with distinction in zoology from the University of Washington. In addition she holds eight honorary degrees.

Dr. Malcom serves on several boards, including American Museum of Natural History, Howard Heinz Endowment, and National Center on Education and the Economy. She serves as a trustee of Adelphi University, as a Regent of Morgan State University and as a trustee of Caltech. In addition she has chaired a number of national committees addressing education reform and access to scientific and technical education, careers and literacy. Dr. Malcom is also a former trustee of the Carnegie Corporation of New York. In 1995 Dr. Malcom was elected a fellow of the American Academy of Arts and Sciences. She was a member of the National Science Board, the policymaking body of the National Science Foundation, from 1994 to 1998 and currently serves on the President's Committee of Advisors on Science and Technology.

Stephen D. Nelson is Associate Director of Science and Policy Programs at the American Association for the Advancement of Science. In this role he assists the Director in overall operations of the directorate; acts as senior advisor to the R&D Budget and Policy Program and the AAAS Science and Engineering Fellowship Program; organizes the annual AAAS Colloquium on Science and Technology Policy; and serves as staff officer to AAAS's Committee on Science, Engineering and Public Policy, as well as staff officer for both the AAAS Philip Hauge Abelson Prize and the William D. Carey Lectureship. In addition, he has responsibility for portions of the direct assistance program within the AAAS Research Competitiveness Service. From 1990 to 1999 he was Program Director of AAAS's Science, Technology and Government Program in the SPP Directorate. Nelson has co-authored or co-edited 42 volumes published by AAAS on federal funding for research and development and other issues in science and technology policy.

Prior to joining AAAS, Nelson was Senior Professional Associate at the Institute of Medicine, National Academy of Sciences, working on a study of the organizational structure of the National Institutes of Health. He also served for six years as Administrative Officer for Science and Technology Policy at the American Psychological Association. Before coming to Washington, DC in 1977, Nelson was Project Director at the Center for Research on Utilization of Scientific Knowledge, Institute for Social Research, University of Michigan. He also taught in both the psychology and sociology departments at Michigan. Nelson received his B.A. in psychology from Kansas State University, and his Ph.D. in social psychology from the University of Michigan.

Paula Rayman, PhD, is the Linda S. Wilson Director of the Radcliffe Public Policy Center. The Center's mission is to advance women in society through scholarly research and promoting public understanding. In 1995, Dr. Rayman developed and directed the New Economic Equation (NEE) project to address the connected economic, workplace, and family concerns facing Americans today. From information developed through the NEE project, Dr. Rayman and her colleagues at the Center have launched two studies: the Radcliffe-Fleet Bank Project and the Sloan Foundation Biotechnology Industry Study. These projects examine the work, family, and community integration issues that affect workers in banking and biotechnology. In addition, she directed "Project Dissemination: A National Call for Integrating Work, Family, and Community," funded by the Ford Foundation.

Dr. Rayman has also worked extensively in issues related to women and science. From 1991-1994, she was Director of the Pathways for Women in Sciences Project at Wellesley College. Since 1995, she has been principal investigator for a National Science Foundation study, "Women, the Economy, and Science Careers." She also helped plan the 1995 United Nations' Women and Development Conference in Beijing. Dr. Rayman is currently editor of the Temple University Press *Labor and Social Change* series. Her published works include *The Equity Equation* (1996, Jossey-Bass), *Pathways for Women in the Sciences* (1993, Alfred P. Sloan Foundation), *Out of Work: The Consequences of Unemployment in Hartford's Aircraft Industry* (1982, National Institute for Mental Health), *The Israeli Kibbutz: Community and Nation Building* (1981, Princeton University Press), and *Non-Violent Action and Social Change* (1979, Wiley Publishers).

Dr. Rayman is a member of the faculty at the Harvard Kennedy School of Government. She was associate professor of sociology at Wellesley College from 1990-1994 and assistant professor of sociology at Brandeis University from 1977-1984. She has also been a Bunting Fellow at Radcliffe College and a visiting lecturer in pediatrics at Harvard University Medical School. Rayman holds a joint doctorate in economics and sociology from Boston College and a bachelor of arts in political science from Hunter College.

Peter Syverson is Vice President for Research and Information Services at the Council of Graduate Schools. He has been involved in the higher education policy community in Washington for the past two decades. Peter is responsible for the research activities of the Council, which include directing the national CGS/GRE Survey of Graduate Enrollment, preparation of reports and articles that summarize CGS data and the research of others that bear on graduate education, and representing the Council on advisory committees involved in the conduct of national studies of U.S. higher education. His primary research interests involve the flow of individuals into and through graduate education and the labor market experiences of advanced-degree recipients.

He began his career in 1975 at the National Academy of Sciences where he directed the Survey of Earned Doctorates, the national survey of all new doctorate recipients. As Project Director, he led the project through the transition from a paper-based questionnaire processing system to a computer-based system and transformed the annual *Summary Report* to a policy-research document. He was appointed Director of Information Services at the Council of Graduate

Schools in 1985, where he established the Council's first office of research and set a research agenda for CGS. Working with the GRE Board, he developed a new Survey of Graduate Enrollment. That survey, now in its fourteenth year, has become a respected source of information on trends in graduate enrollment and application for graduate study.

Peter earned his B.S. in psychology from Duke University and a M.A. in economics from Virginia Tech.

Richard Alfred Tapia attended graduate school at the University of California at Los Angeles (UCLA), where he earned the master's and PhD degrees in mathematics.

Following graduation in 1967, he lectured in the Department of Mathematics at UCLA and then joined the Mathematics Research Center at the University of Wisconsin. In 1970 Tapia joined the Department of Computational and Applied Mathematics at Rice University. He became a professor of mathematical science in 1976 and served as chair of the Mathematical Science Department from 1978 to 1983. He assumed his present position as associate director for graduate studies in the Office of Graduate Studies in 1989 and serves as the director for the Center for Excellence and Equity in Education and as an adjunct faculty member of the Baylor College of Medicine. He has authored or co-authored two books and more than 80 technical papers.

Tapia has been nationally acclaimed for his success in producing minority Ph.D.s. Under his direction, minority students engage in educational outreach programs in inner-city schools working under the guidance of Rice researchers. Tapia also brings students, principals, and counselors to Rice during the summer to learn about opportunities in computational sciences, and shows teachers how to use computer technology in encouraging more young women to study mathematics and science.

In 1990 the National Research Council named Tapia one of the 20 most influential leaders in minority mathematics education. In 1991 Rice University honored him with the George R. Brown Award for Superior Teaching and named him the Noah Harding Professor of Computational and Applied Mathematics. He was elected to the National Academy of Engineering in 1992; received the Educator Achievement Award from the National Science Foundation in 1995; and received the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring Program in 1996. In 1998 the American Association for the Advancement of Science honored Tapia with the Lifetime Mentor Award. Tapia received the 1999 Giants in Science Award, Quality Education for Minorities from the QEM Network and was honored with the David Blackwell and Richard Tapia Distinguished Lecture Series in the Mathematical and Statistical Sciences by Cornell University in 2000. Tapia is a member of the Society for Industrial and Applied Mathematics, the Mathematical Association of America, the Mathematical Programming Society, and the Society for the Advancement of Chicanos and Native Americans in Science. Tapia was appointed to the National Science Board in 1996.

Michael S. Teitelbaum, a demographer at the Alfred P. Sloan Foundation in New York, was educated at Reed College and at Oxford University, where he was a Rhodes Scholar.

His past positions include: faculty member at Oxford University and Princeton University; staff director of the Select Committee on Population, U.S. House of Representatives; professional staff member of the Ford Foundation and the Carnegie Endowment for International Peace; one of 12 Commissioners of the U.S. Commission for the Study of International Migration and Cooperative Economic Development (1988-90); elected First Vice President of the Population Association of America, the scientific society of demographers; and served (via appointment by the Congressional leadership) as one of nine Commissioners of the U.S. Commission on Immigration Reform (known as the Jordan Commission after its late Chair, former Congresswoman Barbara Jordan) which completed its work in December 1997. He was elected Vice Chair by his fellow Commissioners, and served as Acting Chair for much of 1996.

Dr. Teitelbaum is a regular speaker on the subjects of immigration and demographic change, a frequent invited witness before Committees of the United States Congress, and publishes extensively in scientific and popular journals and in national op-ed pages. His books include: *A Question of Numbers: High Migration, Low Fertility, and the Politics of National Identity* (Hill and Wang, 1998, co-author); *Threatened Peoples, Threatened Borders* (W.W. Norton, 1995, co-editor); *Population and Resources in Western Intellectual Traditions* (Cambridge University Press, 1989, co-editor); *The Fear of Population Decline* (Academic Books, 1985, co-author); *Latin Migration North: The Problem for U.S. Foreign Policy* (Council on Foreign Relations, 1985); and *The British Fertility Decline: Demographic Transition in the Crucible of the Industrial Revolution* (Princeton University Press, 1984).

Virginia V. Van Horne is a Senior Associate with the Academy for Health Services Research and Health Policy (Academy). As a Senior Associate Ms. Van Horne serves as Project Manager for the Health Services Research in Progress (HSRProj) program as well as acts in various information services capacities.

Prior to joining the Academy, Ms. Van Horne worked in the American Association for the Advancement of Science's Directorate for Education and Human Resources (EHR) Programs as a Senior Research Associate. Her responsibilities spanned across several programs. Primarily, she worked on research assignments related to science and mathematics education and policy issues and worked with the Commission on Professionals in Science and Technology as a technical consultant. She has authored and co-authored various publications relating to science education, policy and diversity. She holds a B.A. in Journalism and History from Moravian College and an M.A. in Administrative Sciences from George Washington University.