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Keynote Presentation**:** *Who Will Do Science?* Revisited
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Discussant: Commentary on *Who Will Do Science?*
Changes in the Analysis of Participation
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Discussant: Commentary on *Who Will Do Science?*
Diversity Lessons Learned – One Research Uinversity, One State
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***Who Will Do Science?* Revisited**

Presented at CPST Annual Meeting, November 7, 2008

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Introduction

Fifteen years ago, the late Alan Fechter (1994) and I co-edited *Who Will Do Science? Educating the Next Generation* (hereafter, *Who Will Do Science?*). At the time, we noted that adequacy and equity had emerged as compelling issues for the science and engineering human resource policy agenda. The purpose of this paper is to revisit selective findings from *Who Will Do Science?* First, I present an overview of the origins of the book. Second, I present a brief chronology and summary of the authors' conclusions followed by an update on the state of the STEM talent pools in the U.S

Supply/Demand Debate

Then and now, there was a robust debate regarding whether the nation was facing an oversupply, undersupply or impending shortage of doctoral scientists and engineers (See NSF, 1989, NSF, 1990, Atkinson, 1990, Fechter 1990; Kuh, 2001, Teitlebaum, 2001, 2007, Butz et al. 2003, Greenberg, 2004, Jackson, 2004, Freidman, 2005, Freeman, 2006, Timmerman, 2007; Lowell and Salzman, 2007, Ellis, 2007, Guess, 2008; Jacobs and Spalter-Roth, 2008). In the *Foreword*, Linda Wilson (1994), then President of Radcliffe College, described the debate as a hardy perennial because of its frequent recurrence.

Critiques of the Shortage Argument

Research critiquing the shortage argument cites a number of contributing factors including unsubstantiated claims of shortages, inadequate forecasting models, the premise of oversupply, and labor market conditions..

Unsubstantiated Claims of Shortages

Some researchers (Freeman, 2006, Lowell and Salzman, 2007, Salzman and Lowell, 2009) argue that based on traditional economic evidence, such as substantial numbers of vacancies, robust employment growth, or rising wages, there is no labor market shortage (in the classic sense of the term) of scientists and engineers (Freeman, 2006, Lowell and Salzman, 20070. At the very time that the nation needs to make STEM careers more attractive, domestic job markets are soft because employers have tapped foreign sources of labor. There are signs, however, that access to foreign talent will not be unlimited. Multinational employers will need to compete with increasing intensive local development agendas, especially in Asia (Ellis, p. 5). According to Ellis (2007), what is in short supply are reasons to believe that technical careers will be worth the considerable investment in time and training required.

Inadequate Forecasting Models.

Fechter's (1990) critical analysis of the National Science Foundation (NSF) model that projected a gross underproduction of doctoral STEM professionals demonstrated that the model was seriously flawed. He concluded that NSF overstated its case for impending shortages. Ultimately, concerns were raised that NSF's projections may have been politically motivated in order to increase its budget.

In the intervening years, there appears to be consensus among researchers and policy analysts that forecasting models have not progressed significantly in the development of tools (i.e., models) that accurately assess the national needs for STEM skills and future needs (NRC, 2000, Finn, 2001). As a result, estimating future labor market conditions for STEM professionals as well as other economic indicators is not an exact science (See, also, Krugman's [2009] commentary on economists). In his chapter in *Who Will Do Science?,* Fechter (1994) advised policymakers to pursue a strategy that favors anticipating shortages because the costs of being wrong would be preferable to an erroneous assumption that markets will eventually be in balance (See, also Ehlers, 2007).

Some scholars were critical of researchers and analysts preoccupied with the validity of projected shortages or oversupply of STEM doctorates because they were ignoring two major issues—the composition of the extant STEM talent pool and the geographic distribution of STEM workers and jobs (Jackson, 2004; BEST, 2004, NSF, 2006, 2009b, NSB 2008, Mather, 2009). Once again, Wilson's (1994) comments continue to be both relevant and insightful: "I do not know whether we will experience overall shortages in the future. I do know that we currently face real shortages of talent from underrepresented groups—women and racial/ethnic minorities—and we will continue to face these talent deficits in the foreseeable future" (p. xiii). Despite the current perception of overproduction, the confluence of these expected supply and demand changes suggests that attracting and retaining talented students into the sciences and engineering will remain key policy issues.

Vetter (1994) and Leggon and Malcom (1994) argued that diversity of the STEM talent pool is a significant policy issue. The issue raised by these scholars as well as others was at the heart of the discourse in *Who Will Do Science?*

The Premise of Oversupply

Some critics of the shortage argument actually contend that there is an oversupply of STEM candidates. Supporters of the shortage argument disagree and point out a number of flaws. For example, Traiman (2009) criticizes the findings' generalizability because Lowell and Salzman employ a very broad definition of STEM occupations. In particular, she points out that by including data on outcomes for the life sciences, the study masks significant shortages of engineering graduates. Additionally, she argues that these findings of oversupply fail to align with the real life experiences of engineering deans. Traiman (2009) notes that Lowell and Salzman's study includes foreign-born students whose employability by U.S. companies may be subject to shifts in the political climate. Bell (2009) points out that it is likely that the unemployment rate of doctoral scientists and engineers will remain lower than for individuals with levels of educational attainment below the doctorate. Because of hiring freezes, he cautions that compared to past years, it will be considerably more challenging to secure an academic job (p. 4) .

Labor Market Conditions

Domestic markets are soft because employers have tapped foreign sources of labor. There are signs, however, that this is changing. LaFraniere (2010) reports that Chinese leaders are determined to reverse the current brain drain. They have implemented new policies to increase investment in research and development (R&D). In fact, the Chinese spend about 1.5 percent of its gross domestic product on R&D activities. In comparison, the U.S. spends about 2.7 percent. China's R&D investment far outpaces that of most developing countries, and has resulted in increased national wealth. Chinese leaders are investing more of their vast resources in science and technology.

The investment strategies are beginning to be noticed by STEM professionals in the West, especially the U.S. As a result, Chinese leaders have mounted recruitment efforts to entice Chinese naturalized citizens in the U.S. to return to their homeland to assume leadership roles in building a world class science and technology enterprise. So far, a number of internationally renowned Chinese American STEM professionals have returned to China. They believe that the status of science and technology in China will be attractive enough to retain their top STEM students for graduate school and the workforce. Ultimately, Chinese leaders see their country as a global leader in science and technology. Meanwhile, hundreds of thousands of talented Chinese continue to pursue STEM education and careers in the U.S.

The newly signed “America Competes Act” does not address the labor market conditions that are acting to discourage participation in U.S. science. Lowell and Salzman's research (2009) concludes that the U.S. is at risk of losing its global economic competitiveness--not because of an inadequately trained STEM workforce, but because of the lack of social and economic incentives to attract U.S. citizens to pursue science and technology careers.

For Traiman the situation is not limited to companies hiring STEM professionals. She asserts that it is highly unlikely that companies view themselves as the main problem because they are having difficulty finding U.S.-born STEM workers with doctorates. Rothkopf (2009) agrees and argues that Microsoft, Intel, and Texas Instruments report difficulties identifying a sufficient pool of talented U.S.-born STEM professionals. Nevertheless, to attract STEM graduates, employers need to be more competitive in terms of both salary and lifestyle.

Support for the Shortage Argument

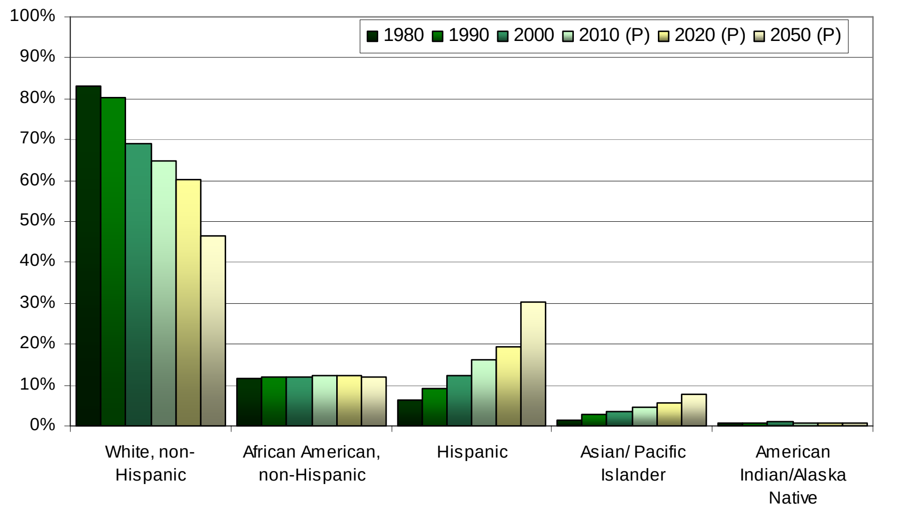
Research supporting the shortage argument cites a number of contributing factors including: demographic changes and declining student interest; geography and the digital divide; undergraduate and graduate education; the roles of Historically Black colleges and Universities (HBCUs) and for-profit institutions; and the effects of intervention programs.

Demographic Changes and Declining Student Interest

In her chapter, Vetter (1994) cautioned that two major trends were on a possible collision course: (1) significant demographic changes and (2) declines in student interest in STEM careers. She argued that demographic changes would profoundly affect the nation’s ability to produce the next generation of STEM professionals. Specifically, she pointed to a dramatic demographic shift due to annual increases in number of births among diverse racial and ethnic groups. It is important to emphasize that much of Vetter’s thinking on the potential impact of changing demographic on the production of scientists and engineering was greatly influenced by two reports from the Office of Technology Assessment (OTA). The first report, *Demographic Trends and the Scientific and Engineering Workforce: A Technical Memorandum*, was published in 1985; the late Eugene Frankel was Project Director for this study. A number of contributors (Alan Fechter, Shirley Malcom, Willie Pearson, Jr., and Betty Vetter) to *Who Will Do Science?* were also involved in the project. The second report, *Educating Scientists and Engineers: Grade School to Grad School*, was published in 1988 and continues to be highly cited. This report built, in part, on the 1985 report. Daryl Chubin had a hand in both projects, as Project Director for the latter, and contributor to the former. As a member of the Internal Editorial Board for *Who Will Do Science?*, Chubin's experience was indispensable in providing advice to Vetter on the relationship of the OTA work to the substantive content of her chapter.

Data in Figure 1 confirm Vetter's (1994) observations regarding the increasing racial and ethnic diversity of the U.S. population. In general, trend lines reveal a dramatic shift from the current to the projected demographic composition of the U.S. Perhaps the most dramatic of these changes were the steady declines in the proportion of the population that is White, non-Hispanic and the sharp increases in the proportions of the population that are Hispanic and Asian. Limited growth for African Americans and American Indian/Alaska Native fractions of the populations were projected over the next decades. Thompson (2009) notes that these demographic shifts are already impacting a number of K-12 systems. She reports that both legal and illegal immigrants have contributed to the greatest growth in public schools since the baby boom. Thompson estimates that approximately 10 percent of students enrolled in public schools are English learners (i.e., English as a second language). This represents a 60 percent increase since the publication of Vetter's chapter; this sudden and significant influx of new students has seriously strained many public school district budgets.

Figure 1. U.S. Population by Race/Ethnicity, 1980, 1990, 2000 (Actual) and 2010, 2020, 2050 (Projected)



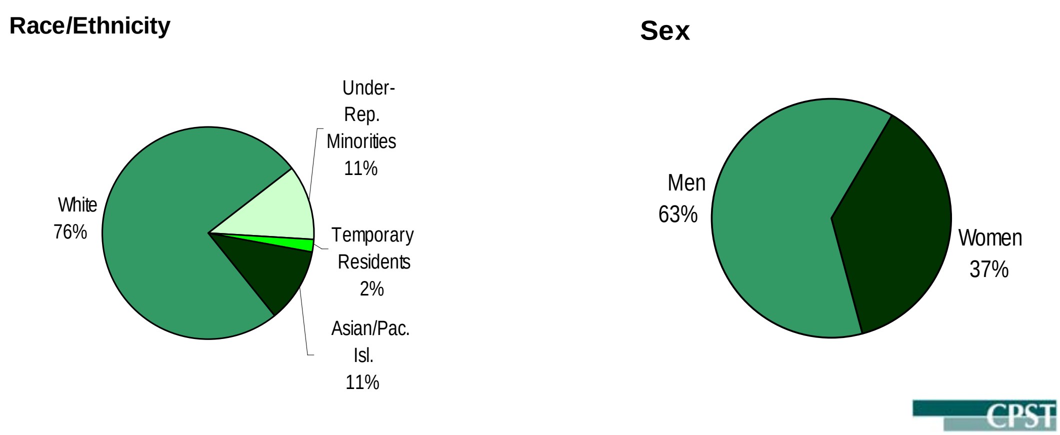
Note: For 2000, and the projections for 2010, 2020 and 2050, only includes those who reported one race.
Source: CPST, data derived from U.S. Census Bureau.

In 1994, Vetter observed that half of all high school graduates were women, and one in four was a racial/ethnic minority. She noted that the possible effect of these demographic trends on both the level and diversity of the U.S. STEM talent pool was exacerbated by trends in career interests of students. In particular, Vetter noted that the number of first-year college students planning to major in a STEM discipline decreased by nearly half, and at least half of the well-prepared students entering college with intentions to major in STEM disciplines switched to non-science majors. According to

Vetter, the number of students graduating from high school was at its lowest level in a quarter of century. Moreover, the proportion of students who were qualified to pursue STEM fields declined each year as they progressed through the Pre-K educational system. Also, Vetter noted the growing concern about the adequacy of science and mathematics training of U.S. students and expressed concern that children were increasingly limited by poverty, drugs, single parent homes, and an education system that was failing to prepare most of them to compete in an increasingly technological world. Vetter asserted that any significant effort to increase the number of students eligible to pursue college majors in STEM must take both sex and race/ethnicity into account. She warned that the U.S. could no longer afford to waste the talent of two-thirds of its increasingly diverse population.

Figure 2 depicts the STEM workforce that Vetter argued was misaligned with the growing demographic profile of the U.S. population (Jackson, 2004; Taningco, Mathew, and Pachon, 2008). In short, the U.S. STEM workforce did not mirror the general population.

Figure 2. Composition of the U.S. S&E Workforce, 2006
(n = 10,135,621)



Note: Underrepresented minorities include African Americans, Hispanics and American Indians.
Source: CPST analysis of National Science Foundation SESTAT data base. The use of NSF data does not imply NSF endorsement of the research, methods, results or conclusions presented here.

Moreover, many of the groups that Vetter claimed were growing the fastest were the very ones she argued were the least well served by the public education system, especially in science and mathematics.

Data in Figure 3 reveal that from the mid-1990s to 2006, all racial/ethnic groups experienced declines in high school non-completion rates. However, regardless of gender, underrepresented groups (especially Hispanics) are far more likely than Whites to have not completed high school.

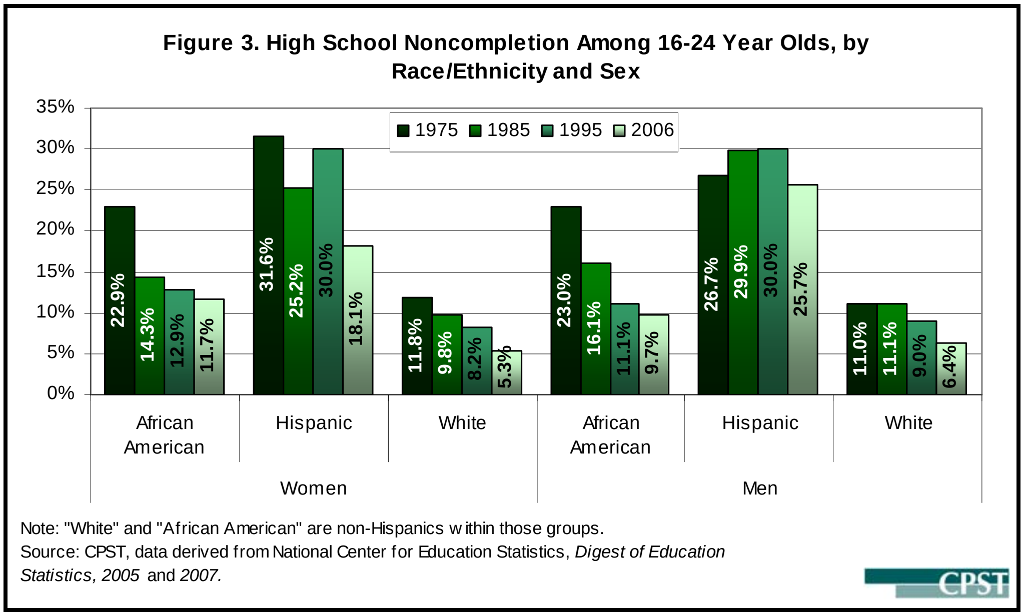
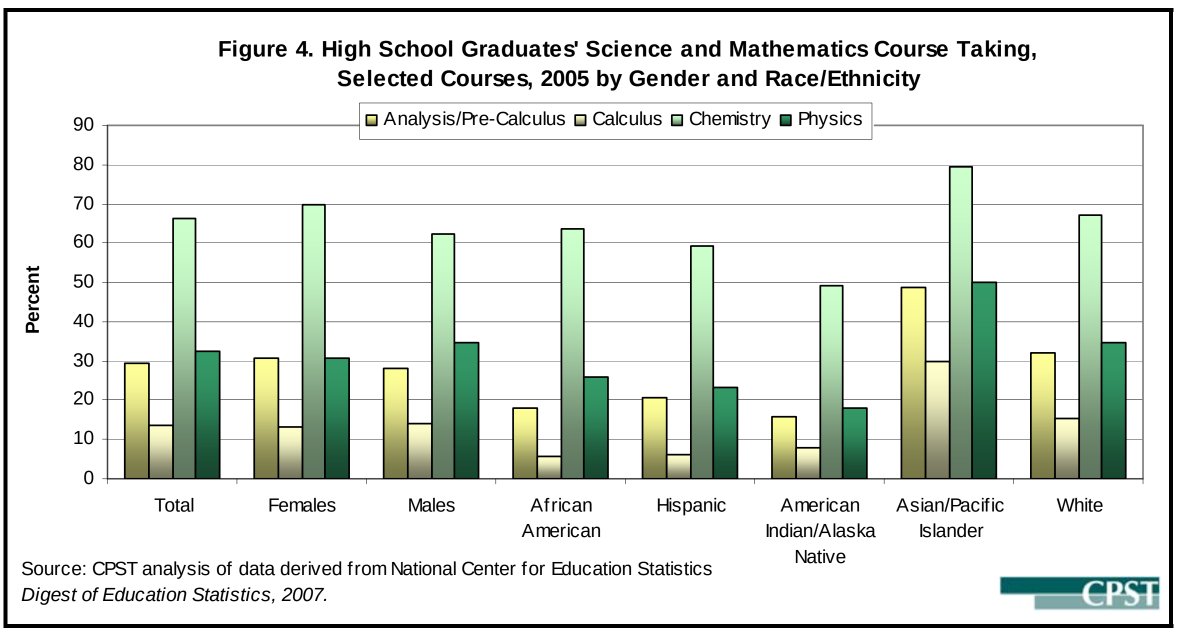
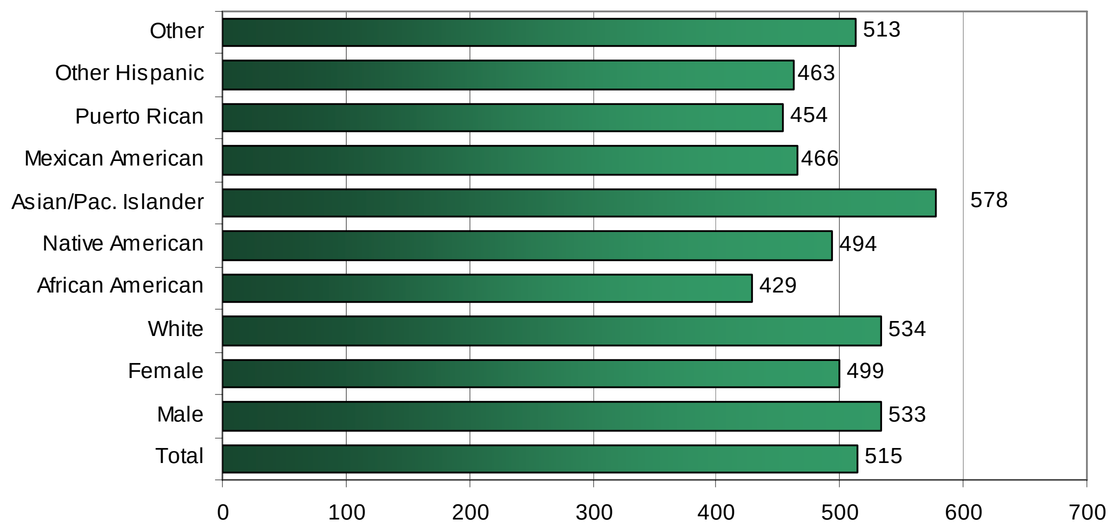


Figure 4 reveals that females are about as likely as males to take calculus courses and more likely to take chemistry courses; however, they are less likely than males to take physics courses.



In the case of racial/ethnic groups, underrepresented minorities are far less likely than Whites to take advanced mathematics and science courses (Kelly, 2009; NSB 2008). Asian/Pacific Islanders take more advanced math and science courses than any demographic group. While other factors are also in play (See Stroup, 2009), data on average Math SAT scores in Figure 5, track the course-taking patterns seen in Figure 4.

Figure 5. Average Math SAT Scores by Sex and Race/Ethnicity, 2007



Source: CPST analysis of data derived from The College Board.

These data underscore speculations that Vetter made nearly 15 years ago. However, there is considerable evidence that these disparities begin early in the educational pathway (CPST, 2009a, NSB 2008; Taningco, Mathew and Pachon, 2008). For example, performance disparities among racial/ethnic subgroups emerge at the earliest entry point in public schools. Although recent studies report performance gains in mathematics and science for all elementary school students, there were not only differential rates of growth but also some widening achievement gaps. Low performing students from underrepresented groups are more likely to attend schools with large proportions of students from racial minority groups, many students on free and reduced meal programs, and teachers who are least prepared to teach math and science courses (NSB, 2008; Dewan, 2009).

Declining interest in STEM careers among high ability students continues to be debated. In the 1990s declining numbers of students expressing an interest in STEM careers was associated with declines in the college-age population. However, declining interest is not the same as declining enrollments and degrees. In general, the numbers declined in the 1990s as the college-age population declined. The percentages of students expressing an interest in a STEM career have remained constant. Currently, the number of degrees is increasing as the college-age population is increasing (NSB, 2008). Similarly, Ellis contends that “there is no shortage whatever of interested people” (Ellis, 2007:5). Nearly a decade ago, Teitelbaum (2001) attributed the problem to a long period of training that resulted in few employment opportunities--especially those involving research--and relatively low wages compared to other professions (such as, for examples, medicine, law and business).

Geography and the Digital Divide

In addition to the race/ethnicity and gender arguments, support for the shortage argument also looks at geography and the digital divide as contributing factors. While rural areas did not receive much attention, Harmon (2003:57) contends that technology has connected many remote rural areas to the global community. Yet, he believes that the potential of technology for improving teaching and learning of mathematics and science in rural school settings is virtually unknown. Harmon claims that there is limited knowledge of whether "what works" in urban and suburban contexts will work in rural schools. However, Howley and Gunn (2003:92) found no evidence of a national rural/nonrural mathematics achievement gap in any form (such as, for example, rural versus suburban, and rural versus urban). At the state level, they found a rural/nonrural achievement gap in about 40 percent of the state. The gap favored nonrural students in 20 percent of states and rural students in the other 20 percent of states. About 70 percent of the variance associated with the rural/nonrural, state-level achievement gap was explained by conditions of schooling. The authors concluded that assumptions about rural deficiency in mathematics achievement in comparison to national averages are unwarranted.

According to Thompson (2009), educators estimate that it will take the average English learner from five to seven years to write essays or explain scientific processes at the level of their English-speaking peers. While more students from underrepresented racial/ethnic minority groups are attending 4-year colleges immediately after graduating from high school than in previous decades, they remain far less likely than Whites and Asian/Pacific Islanders to do so (Redd, May 2008; NSB, 2008). According to Glenn (2009), "students from low-income families are quite sensitive to tuition levels, even at relatively inexpensive public universities."

According to Gowen (2009), while the digital divide narrowed dramatically in the past decade, there continue to be disparities in terms of home access to the Internet. She reports that roughly two-thirds of U.S. households report having home access to the Internet. However, more than 90 percent of the households in affluent D.C. suburbs are believed to have home access to Internet. Some describe the digital divide as the participation gap where some students have ready access to the Internet at home, while others--many of whom are members of racial/ethnic minority and low income groups--struggle to work in public spaces. In addition, Taningco, Mathew and Pachon (2008) attribute the underrepresentation of Latinos in STEM careers to a number of factors such as poor retention and academic preparation, and limited exposure to career information.

Undergraduate Education

For those underrepresented racial/ethnic minorities who make it to college, challenges remain. For example, a recent report by the National Center for Education Statistics (NCES) (Knapp, Kelly-Reid, and Ginder, 2009) indicates that among all college students who began pursuing a 4-year bachelor's degree, slightly over one-third (36 percent) graduated from that institution within four years; 53 percent earned a degree within five years and 57 percent completed the degree in six years.

Among students beginning their careers in a 2-year college (where a disproportionate number of students from underrepresented groups begin their higher education), slightly less than one third (31 percent) earned a degree within three years. Graduation rates vary by both demographic group and type of institution. For instance, whether they began in a 2-year or 4-year institution, women are more likely than men to earn their degrees on time; however, White, non-Hispanic males, Hispanic males, and Asian/Pacific Islander males beginning in 4-year, private, for-profit institutions are the exceptions. For students beginning their careers at 4-year institutions, six-year graduation rates ranged from 39 percent for Native American students to 66 percent for Asian and Pacific Islander students. Generally, students beginning their careers at 4-year, private nonprofit institutions graduate at a higher rate than those beginning at public and for-profit institutions. It is noteworthy that underrepresented minorities are more likely to be enrolled in the latter (Knapp, Kelly-Reid, and Ginder, 2009).

Chen (2009) found no evidence of gender differences in persistence and attainment rates in STEM fields between 1995-96 and 2001. However, Chen did find some differences along racial/ethnic lines. Despite finding no measurable racial/ethnic differences in STEM entrance, Chen reported that Asian students had a higher STEM bachelor's degree completion rate (31.2 percent) than did White (29.5 percent), Black (15.5 percent) and Hispanic (16.3 percent) students.

Drawing on an extensive review of the literature, Taningco, Mathew, and Pachon (2008) conclude that many minority students choosing STEM majors have their origins in high schools where they are viewed as the most academically talented. Consequently, these students develop strong academic confidence without having taken any advanced placement classes. However, once in college, they are often overwhelmed by the course demands of STEM majors. This situation contributes to the students switching to less-challenging majors or dropping out of college altogether.

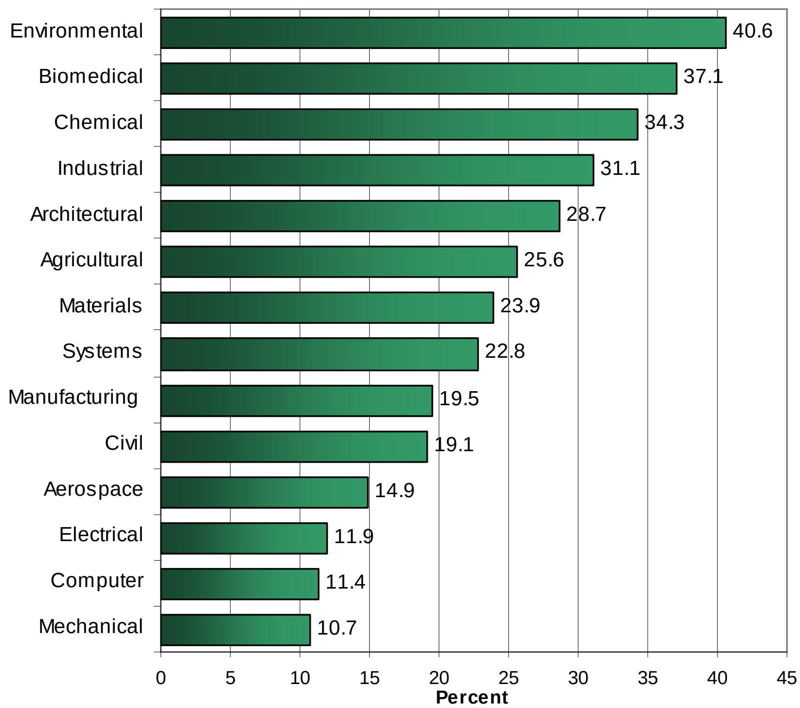
Since the mid-1990s, the demographic composition of students planning to major in STEM fields has become more diverse; this pattern is likely to continue because of demographic shifts in the population. By 2018, college enrollment is expected to grow by 38 percent, 26 percent and 4 percent, respectively among Hispanic, Black, and White students; in addition, college enrollment among is expected to be much higher for women (16 percent) than men ((9 percent) (Brainard, 2009).

Women as a percentage of first-year students planning a STEM major increased from 39 percent in 1985 to 47 percent in 2006. Comparable figures for racial/ethnic minorities also showed increases for the same period: Asians (4 to 12 percent), Hispanics (2 to 9 percent), Native Americans (1 to 2 percent) and African Americans (10 to 11 percent) As minorities increased as a percentage of freshmen planning STEM majors, the percentage who are White declined from 84 percent in 1985 to 72 percent in 2006 (NSB, 2008).

Approximately 60 percent of STEM majors earn their degrees within six years. Roughly one-third of students who began the first year of college with an intended STEM major switched to a non-STEM field over the next 6 years (Chen, 2009). To a large extent, field switching out of STEM majors is almost balanced by those entering STEM. Since 2000, women have earned half of all STEM bachelor's degrees. However, there are significant gender differences in the disciplinary distributions of these degrees (Leggon, 2006). In 2005, men earned a greater share of quantitativebased STEM bachelor's degrees. For example, men earned a substantial portion of bachelor's in engineering (80 percent), computer sciences (78 percent), and physics (79 percent). In sharp contrast, women received more than half of the bachelor's degrees in psychology (78 percent), agricultural sciences (51 percent), biological sciences (62 percent), chemistry (52 percent) and social sciences (54 percent). The computer sciences represent a special case for women. Women as a proportion of computer sciences bachelor's degrees awarded declined from 37 percent to 22 percent from 1985 to 2005 (NSB, 2008).

Data in Figure 6 reveal that women tend to be more highly represented in new and emergent engineering disciplines, such as environmental and biomedical engineering.

Figure 6. Women as a Proportion of Total Undergraduates in Selected Engineering Disciplines, Fall 2006



Source: CPST analysis of data derived from Engineering Workforce Commission, *Engineering & Technology Enrollments, Fall 2006.*

Traditionally, women have had relatively higher representations in chemical and industrial engineering than in mechanical, computer and electrical engineering.

Over the last 20 years, racial/ethnic minorities have made noticeable gains in their share of STEM bachelor's degrees. Between 1998 and 2007, the proportion of science bachelor's awarded to Asians/Pacific Islanders increased from 8.4 percent to 9.2 percent, comparable figures for Blacks, and Hispanics were 8.7 to 9.2 percent, and 6.8 percent to 8.3 percent, respectively. There was no change for American Indian/Alaska Natives (0.7 percent). The portion of science bachelor's degrees awarded to White students has been decreasing. In 1998, White students earned 72.6 percent of science bachelor's degrees; by 2007, they accounted for 66.4 percent of these degrees

(NSF, 2009b). For the same period, the proportion of engineering bachelors earned by Whites fell from 72.1 percent to 68.8 percent. Blacks also experienced a decline: 5.4 to 5.0 percent. Increases were experiences by Hispanics (7.3 to 7.8 percent), Asian/Pacific Islanders (12.4 to 13.3 percent). There was no change for American Indians/Alaska Natives (0.5 percent) (NSF, 2009b).

It is noteworthy that despite the increases in the proportion of underrepresented racial/ethnic minorities earning STEM bachelor's degrees, the gap between these groups and White students remains wide. In 2007, Whites earned the larger shares of bachelor degrees in agricultural sciences, math/statistics, and earth, atmospheric and ocean sciences than in other fields. Black earned larger shares of bachelor's degrees in computer sciences, psychology, and social sciences. Asians/Pacific Islanders earned their largest share of bachelor degrees in the biological sciences, physical sciences and engineering. Hispanics' degree share was concentrated in engineering, psychology and the social sciences, while American Indians' degree concentrations were in the agricultural sciences, biological sciences, physical sciences, psychology and the social sciences (NSF, 2009b, NSB, 2008).

Overall, parents' education levels were related to STEM degree attainment. For example, STEM bachelor's degree completion rates tend to be higher among students whose parent had at least a 4-year college degree than those whose parents did not. Students who took trigonometry, precalculus, or calculus in high school; earned a high school GPA of B or higher; obtained college entrance exam scores in the highest quarter; and expected to attain a graduate degree in the future were more likely than their peers without these characteristics to have higher rates of STEM bachelor's degrees (Chen, 2009).

Graduate Education

In their chapter on doctorate degree production, Smith and Tang (1994) reported that underrepresented racial/ethnic minorities and women were heavily underrepresented at the highest level of STEM education. They concluded that women made more gains in terms of both number and proportion than did minority groups. African Americans had the smallest growth in the minority doctoral population, whether measured in absolute or relative terms. Smith and Tang found that doctorate recipients with higher representation in STEM disciplines tended to have parents who held advanced degrees. Among racial/ethnic minorities, African American and Hispanic doctorate recipients were less likely than Asians to have a parent with an advanced degree. Smith and Tang attributed the increasing popularity of postdoctoral study among both women and minorities to a weak job market. They asserted that underrepresented racial/ethnic minorities and women were concentrated in academic employment settings, and that U.S. industry showed a penchant for recruiting foreign students educated in the U.S. The passage of the 1990 Immigration Act allowed employers to triple the number of immigrant STEM professionals entering the U.S. They speculated that a larger supply of foreign professionals in the labor market may affect the annual production of underrepresented racial/ethnic minorities and women doctorates. Vetter raised similar concerns about the potential impact of foreign STEM talent on underrepresented groups. She argued that one of the consequences of both the collision of the demographic shift and decline in student interests in STEM careers was a significant and increasing proportion of graduate students who are non-U.S. citizens.

According to Burns, Einaudi and Green (May 2009), in 2007, U.S. citizens and permanent residents from all racial/ethnic groups showed increased enrollment in S&E fields. They report that the largest change in the demographic composition of S&E graduate students in the United States has been more along racial/ethnic than gender lines. For example, in 2000 white, non-Hispanic students accounted for 71 percent of all U.S. citizens and permanent residents pursing graduate studies; by 2007, the comparable figure was 66 percent.

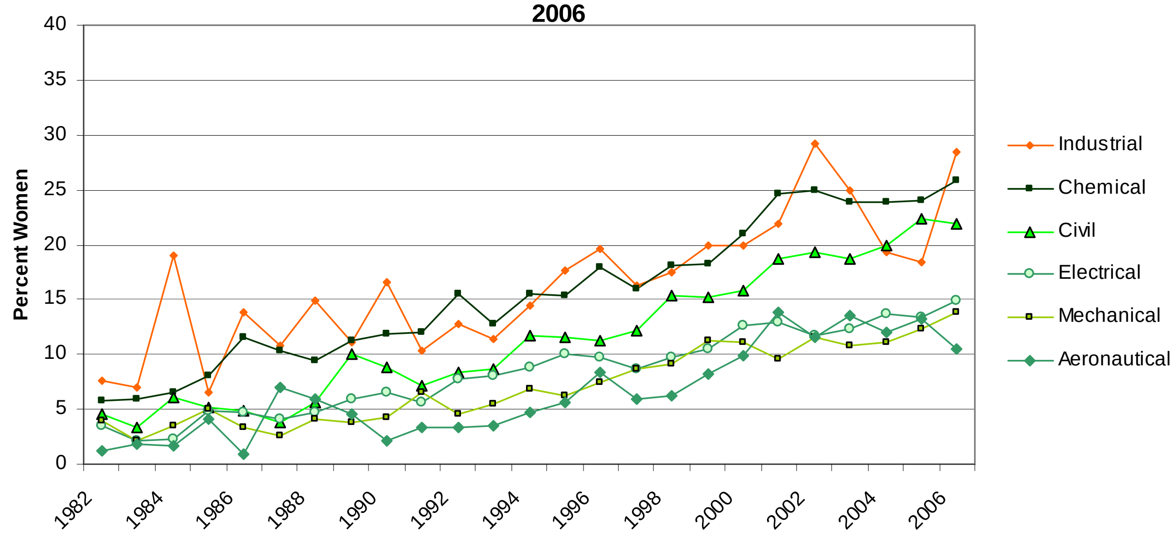
Bell (2008) pointed out that between 1987 and 2007, the average annual rate of S&E graduate enrollment increased by 2.7 percent, outpacing medicine (0.3 percent) and law (1 percent). In Fall 2007, the representation of women in graduate education is higher (59 percent) than in either medicine (49 percent) or law (47 percent). At the same time, citizen and permanent resident minorities comprised about 22 percent of all students enrolled in graduate school –the same representation of minorities in law programs. In contrast, more than one-third of all enrollees in medicine were minorities. This is due largely to the representation of Asians/Pacific Islanders, who accounted for 21 percent of all medical students. Based on recent enrollment trends in medicine and law, Bell concludes "that graduate schools will need to be more proactive in their efforts to attract the best and brightest students" (p. 4).

According to Redd (2008a), over the past decade, graduate enrollment for Latinos in the biological and physical sciences and engineering increased by five percent. In the same fields, both African Americans and Native Americans experienced a three percent increase, while White; non-Hispanics remained relatively unchanged. In 2006, engineering, physical sciences, and biological sciences, collectively accounted for only 8 percent of African Americans, 12 percent of Native Americans, 13 percent of Latino graduate students, 16 percent of White, non-Hispanics and 29 percent of Asian Americans. In another report, Redd (2008c) argued that the low representation of African Americans and Hispanics in graduate schools may be traced to parental educational attainment; this supports Smith and Tang's observation that doctorate recipients tended have a parent who held an advanced degree. Chen (2009) also found that parental education was related to STEM degree attainment. They indicated that STEM bachelor's degree completion rates were higher among students whose parents had at least a 4-year college degree compared to those did not. In a study of high school sophomores, Redd found that about 14 percent of Whites, 20 percent of Asians, 8 percent of African Americans and 5 percent of Latinos had fathers who held a graduate or professional degree. Fathers' occupation emerged as the most important contributor to publishing: the higher the fathers' occupation, the higher the publication rate (Nettles and Millett, 1999).

Although financing STEM graduate education is an increasing challenge for many U.S. citizens, it is especially challenging for many underrepresented racial/ethnic minorities. Typically, their families have lower incomes than other subpopulations and they are among the least willing of groups to take out loans for education. For these groups, grant and fellowship aid is vitally important for improving both access and persistence in graduate STEM education (Redd, 2006; John and Rochkind, 2009). Overall, racial/ethnic minorities who are underrepresented in STEM are also underrepresented among recipients of fellowship and assistantship aid. According to Redd (2006), one primary reason may be that they are much less likely to be enrolled in major research universities, which tend to have greater resources for fellowship and assistantship aid (Pearson, Ness, and Hoban, 1999, NSF, 2009b). At Research Extensive institutions, the percentage of doctoral candidates receiving fellowships and grants was similar for underrepresented racial/ethnic minorities and majority students (68 percent versus 66 percent).

Statistics on women awarded doctorates in selected engineering fields reveal patterns of upward trends since the publication of *Who Will Do Science?* (Figure 7). The pattern for industrial engineering tends to have more spikes than the other disciplines. As more women earning undergraduate degrees in the new or emergent engineering disciplines continue their education through the doctoral level, those trend lines will likely move upward.

Figure 7. Trend in Women's Doctoral Awards in Selected Engineering Fields, 1982-2006



Source: CPST analysis of data derived from National Science Foundation, *Science and Engineering Degrees, 1950-1980 and 1966-2006*.

In the past two decades, women have accounted for an increasing share of all STEM doctorates awarded to U.S. citizens. From 1989 to 2007, the number of doctorates awarded to female U.S. citizens and permanent residents grew 86 percent, while the number of doctorates earned by their male peers increased 3 percent over the same period. In 2007, women earned slightly less than half (47 percent) of STEM doctorates awarded to U.S. citizens and permanent residents (NSF, 2009b). However, considerable gender differences along disciplinary lines remain. While women accounted for half or more of doctorate recipients in the social sciences (including psychology) and biological sciences, they earned less than a third of the doctorates in physical sciences, math/statistics and engineering (NSF, 2009b).

As was the case for women, racial/ethnic minorities have increased their share of STEM doctorates. In 2008, approximately 4,423 (of whom 1,966 are underrepresented minorities) racial/ethnic minority U.S. citizens and permanent residents earned STEM doctoral degrees. This number is 10.8 percent greater than 2007. The proportion of racial/ethnic minority STEM doctorate recipients increased from 22.3 percent in 2003 to 24.1 percent in 2008. Asians (43 percent) accounted for the largest share of racial/ethnic minority STEM doctorate recipients, followed by Hispanics (24.5 percent), Blacks (18.6 percent), multiracial individuals (7.4 percent), other (5.1 percent) and American Indian/Alaska Native (1.4 percent).

Data in Table 1 reveal racial/ethnic variations by broad field for selected years. Relative to 1998, the number of science and engineering doctorates awarded to American Indians fell sharply in every broad field except the life sciences. A similar pattern (except for the social sciences) prevailed for Asian Americans. In the case of Whites, declines were shown for engineering and the physical sciences. In contrast, Hispanics and Blacks showed increases across all broad fields (Fiegener, 2009).

Table 1: US citizen and permanent resident doctorate recipients, by race/ethnicity and broad STEM field of study. Selected years, 1988-2008

Field of Study and Race/ethnicity	1988	1998	2008
Life Sciences			
American Indian	18	24	30
Asian	236	812	777
Black	104	201	327
Hispanic	111	244	398
White	4210	4696	5489
Physical Sciences			
American Indian	11	19	4
Asian	227	542	417
Black	41	91	130
Hispanic	75	113	166
White	2981	3286	3168
Social Sciences			
American Indian	13	43	23
Asian	147	325	347
Black	201	309	339
Hispanic	158	322	426
White	4065	4592	4106
Engineering			
American Indian	4	13	7
Asian	332	557	493
Black	31	81	111
Hispanic	63	110	133
White	1655	2171	2089

Source: Adapted from Table 8, NSF/SRS, Doctorate Recipients from US Universities; Summary Report 2007-2008. Special Report, Arlington, VA: NSF10-309, NSF/Division of Science Resources Statistics, p. 35.

Feigner (2009) confirms Smith and Tang's and Vetter's speculation regarding the growth of foreign STEM talent in U.S. graduate schools and the workforce. He reports that from 2003 to 2008, the number of doctorates awarded to temporary visa holders increased 50 percent, while the U.S. citizens and permanent visa holders experienced an 18 percent growth for the period. From 2003 to 2008, the temporary visa holders' share of total STEM doctorates awarded increased from 33 percent to 38 percent. (Feigener, 2009).

In 2008, students on temporary visas earned 57 percent of all doctorates awarded in engineering, 45 percent of physical sciences doctorates; however, they earned far fewer of the doctorates awarded in the life sciences (29 percent) and social sciences (21 percent) (NSF, 2009a). Many of these students prefer to remain in the U.S. upon receipt of their doctorates, especially those with definite commitments for employment or postdoctoral research/training. For example, the stay rates for foreign doctorate recipients in all fields increased from 46.8 percent in 1988 to 74.1 percent in 2008. From 1998 to 2008, the percentage with definite commitments for postdoctoral research or training in the U.S. remained relatively unchanged. Those earning engineering doctorates were most likely of all to express a preference to remain in the U.S. (Fiegener, 2009)

The vast majority of the S&E temporary visa holders have their origins in China. Marklein (2009) claims that Chinese students represent an economic boost to many U.S. colleges and universities by contributing nearly $18 billion last year in tuition and living expenses to the US economy. Temporary visa holders earned the majority of doctorates awarded in engineering (57 percent) and just under one-half (45 percent) of the doctorates awarded in physical sciences. In absolute numbers, U.S. citizens and permanent residents earned more doctorates in life sciences than in any of the other broad fields, whereas engineering was the most prevalent broad field of degree for those in the U.S. on temporary visas (NSF, 2009a).

In their chapter, Etzkowitz et al. (1994) found that women accumulate disadvantages at each stage in the pathway to a STEM career. They argued that many of the barriers encountered by women are toxic enough to discourage even the most highly motivated. For these authors, removal of these barriers at the doctoral and junior and senior faculty levels could contribute to an increase in women's participation in STEM disciplines. Etzkowitz et al. asserted that stakeholders were beginning to promote an alternative model for enhancing women's full participation in the scientific community. They noted that matters of gender and science were coming into the foreground in sociological theory, feminist research, and human resource policy. These authors believed that the norms of science that incorporated both traditional male and female perspectives into a broader nonsexist framework would free both experimentation and verification of knowledge from the exclusionary oppositions that defined feminine as antithetical to "good science."

Since the publication of Etzkowitz et al.'s chapter, women STEM doctorates have made steady progress in the numbers and percentages who are tenured, on tenure-track appointment and hold the rank of full professor (NRC, 2009). For the most part, the patterns hold across disciplines and institutions. While notable progress has been made, some of the barriers identified by Etzkowitz et al remain (See NRC, 2007). For example, women remain underrepresented among the tenured and full professors at major U.S. research universities. This is true even in disciplines in which women have been earning more than half of the doctorates for a considerable time (Burrelli, 2008; NSF 2009b).

Historically Black Colleges and Universities (HBCUs)

Trent and Hill's (1994) chapter focused on the status and contributions of historically black colleges and universities (HBCUs) to the STEM workforce. They concluded that HBCUs have served as traditional conduits for the education of African American students in STEM careers, and that HBCUs were more likely than traditional white colleges and universities (TWCUs) to not only admit students who are underprepared to pursue majors in the natural sciences, but also to graduate them. Trent and Hill found that TWCUs were more likely to graduate African American students in the social sciences. The authors concluded that HBCUs had their greatest impact at the baccalaureate level, both in terms of degrees awarded and the numbers going on to earn doctorates. Traditionally, HBCUs have contributed disproportionately to African Americans earning STEM doctorates (See Leggon and Pearson, 1997; Pearson, 2005, Burrelli and Rapoport, 2008).

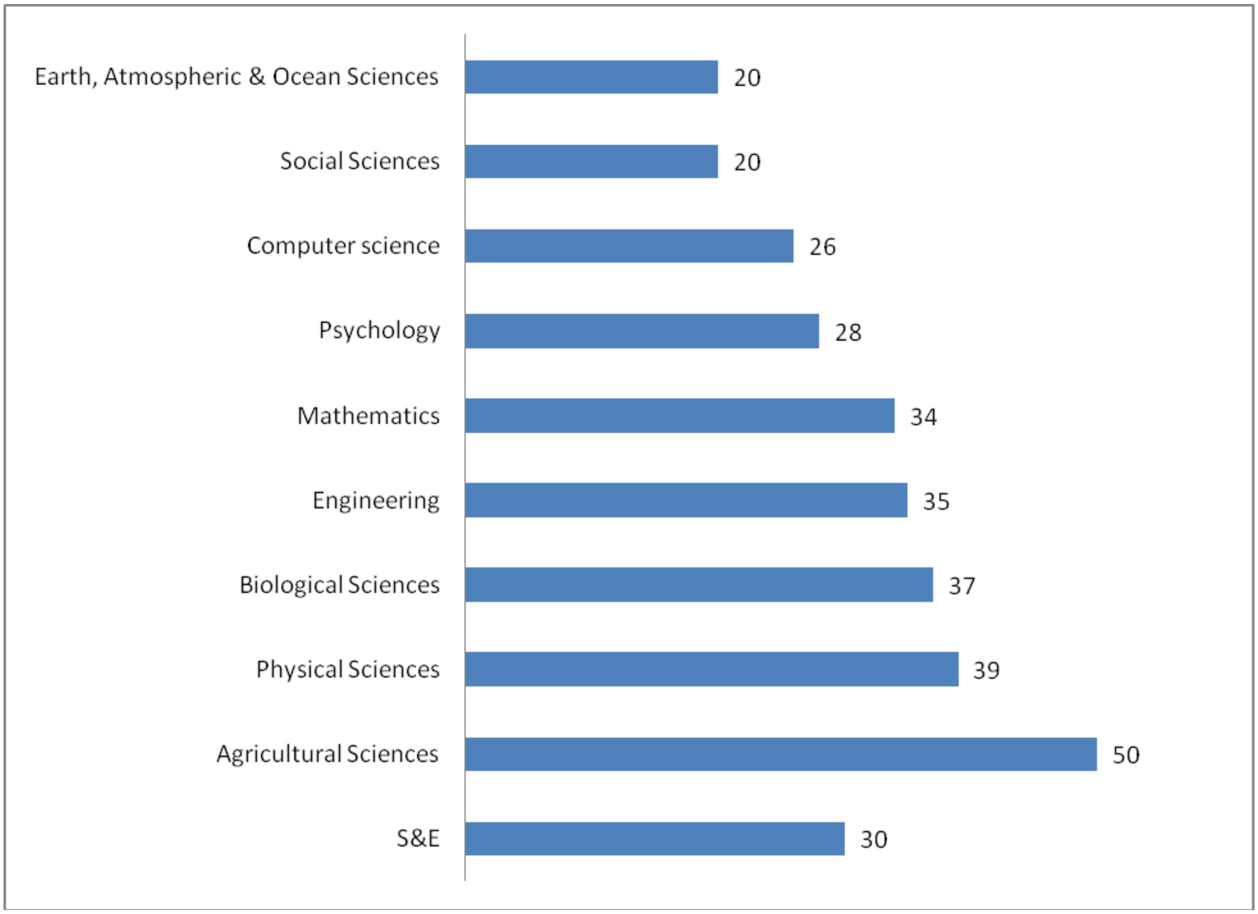
In 1994, Trent and Hill reported that HBCUs contributed one-third of the pool of STEM baccalaureates awarded to African Americans. They described HBCUs as vital national resources. Noting that these institutions are underfinanced, which contributed to their inadequate infrastructures, Trent and Hill called for more investments in HBCUs. They warned that failing to do so would threaten the viability of these institutions and their traditional student base. Ultimately, there would be a substantial reduction in the talent pool of African Americans for both the STEM workforce and graduate training. In 2009, U.S. Secretary of Education Duncan had this to say about HBCUs:

> ...for decades, HBCUs have made enduring, even staggering contributions to American life. And this is a story of educational triumph over adversity that is too little known or appreciated outside of the African American community. Forty percent or more of all African Americans who receive degrees today in physics, chemistry, mathematics, biology, and environmental sciences graduate from HBCUs…HBCUs cannot simply survive. They have to thrive (Pp. 1-2).

To some extent, Trent and Hill's warnings were prophetic. Consider that in 1997, HBCUs awarded 7,909 science bachelor's degrees to African American U.S. citizens and permanent residents. Of these, 4051 were in the social sciences, and 905 were in engineering. By 2006, HBCUs awarded 7,959 science bachelor's degrees (4177 of these were in the social sciences) and 639 bachelor's degrees in engineering. In terms of percentages of total science and engineering bachelor's degrees awarded to African American U.S. citizens and permanent residents in 1997, the figures were approximately 30 and 29, respectively. Comparable figures for 2006, however, were significantly lower with the sciences at 22 and engineering at 20 (NSB, 2009b, NSF, 2009c, Burrelli and Rapoport, 2008).

Burrelli and Rapoport (2008), report that in the early 1990s, 25 percent of African American STEM doctorates earned their bachelor's degrees from HBCUs; in 2006, this increased to around 33 percent. However, when the number of bachelor's degrees awarded was normalized, they concluded that only 5 of the top 50 baccalaureate origin institutions of 1997-2006 African American STEM doctorate recipients were HBCUs. Specifically, only Spelman College, a women's college, was in the top 25. These figures underscore Trent and Hill's point regarding the critical contributions of HBCUs in the natural sciences. Bachelor's recipients from HBCUs are as likely as their peers from other colleges and universities to be employed or to pursue graduate and professional school studies. Despite these declines, HBCUs continue to be baccalaureate origins and a significant source of talented African American U.S. citizens who earn STEM doctorates. For example, in the period 2003-2007, Howard University (105), Florida A&M University (76), Hampton University (69), Spelman College (68), and Morehouse College (63) were the top baccalaureate institutions of Black U.S. citizens and permanent residents earning doctorates (NSF, 2007). Furthermore, data in Figure 8 show that one third or more of Black U.S. citizens earning doctorates in mathematics, engineering, biological sciences, physical sciences and agricultural sciences from 2002 to 2006 earned their bachelor's degrees from HBCUs.

Figure 8: Percent of Black U.S. Citizen Doctorate Recipients with HBCU Baccalaureate Origins 2002-2006



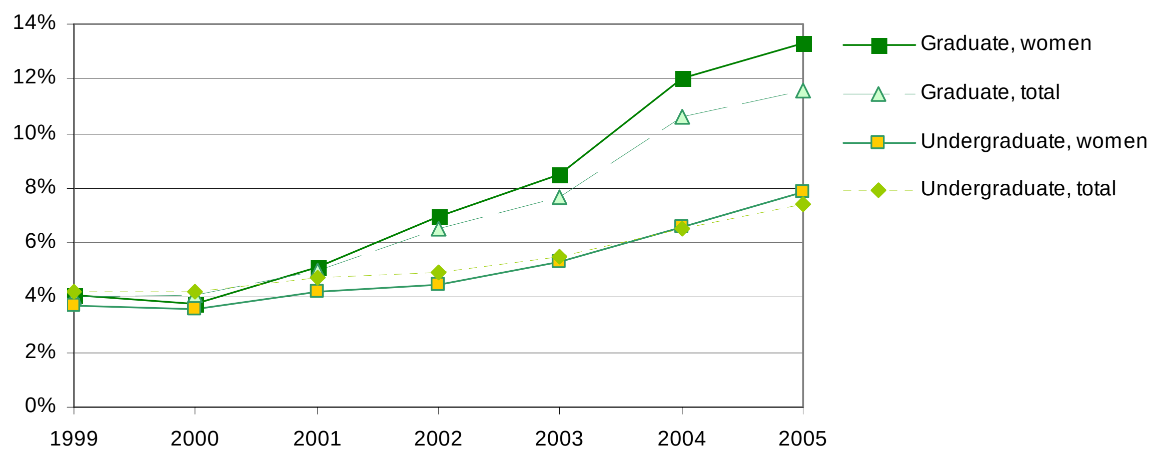
Source: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, 2007

Since 1996, more HBCUs have begun to offer doctoral programs; by 2006, the percentage of HBCUs with doctoral programs grew to 32 percent, with just under half of the 4-year public HBCUs offering such programs. Between 1996 and 2006, the number of graduate students enrolled at these institutions increased 17 percent. The combined increase in numbers of HBCUs offering doctorates and the number of graduate students attending these institutions has led to a rapid growth in the number of African Americans receiving PhDs and other doctorates (Redd, 2008b). Most of these degrees are awarded in non-STEM disciplines. While few of the earlier programs were in STEM disciplines, a number of the more recent ones are in STEM disciplines. As a result, the number of doctorates awarded to African Americans in physics, engineering, and environmental sciences has increased dramatically. Clearly, some of the new programs in physics and engineering have increased the number of African American doctorate recipients. Nevertheless, one could raise questions about the quality (as measured by prestige rankings) of some these programs.

For-Profit Institutions

Recently, another type of institution—for profit--has emerged and attracts increasing numbers of graduate students from groups underrepresented in STEM. Data in Figure 9 show these trends for women. Initially, these institutions offered doctorates in non-STEM disciplines, especially education. In fact, between 2003 and 2007, two for-profit institutions were among the nation's top-five leading producers of all doctorates awarded to African Americans. Specifically, Nova Southeastern University (264) ranked second to Howard University and Walden University (145) ranked fourth behind the University of Michigan (155) (Welch, 2008, CPST, 2009). In a recent public affairs announcement, Nova Southeastern University (NSU) (2009) reported that it ranks first nationally both in the number of doctoral degrees and first professional degrees awarded to Hispanics. According to the announcement, NSU ranked first in the number of doctorates awarded to African Americans in 2008.Today, these institutions are increasingly offering doctoral programs in some STEM disciplines. The implications of this trend are currently unknown.

Figure 8. Percent of All Full-Time College Students Enrolled in For-Profit Institutions by Level, 1999-2005



Source: CPST analysis of data derived from National Center for Education Statistics, *Digest of Education Statistics, 2007* and earlier editions.

Intervention Programs

Matyas' chapter focused primarily on programs designed to increase the participation of women and racial/ethnic minorities in STEM careers (1994). She found that a substantial proportion of the programs were segregated along racial/ethnic or gender lines. Matyas reported that most programs for women tended to have few women of color, and programs focusing on racial/ethnic groups tended to have few Hispanic females and Native American females and males.   Significantly, Matyas indicated that regardless of targeted group, few intervention programs had been or were being evaluated to determine their effectiveness. Moreover, among the few programs that had been or were being evaluated, frequently the evaluation was added on after the program ended. She argued that evaluation had to be an integral program component; as such, evaluators need to be involved from the inception of the program in order for the evaluation plan to capture both the formative and summative evidence. Matyas concluded that we need to know whether these programs work, for whom and under what conditions.

While there remains considerable room for improvement (Mervis, 2006; 2009a), progress has been made in the evaluation of STEM intervention programs. Today, most funders require program proposals to have an evaluation plan; many require that the evaluation be conducted by external evaluators. As a consequence, considerably more is known about effective programs aimed at increasing the representation of underrepresented groups in STEM (BEST, 2004, CEOSE, 2006, 2009; Clewell, DeCohen, Tsui, and Deterding, 2006; Howard Hughes Medical Institute, 2006, White, Atlschuld, and Lee, 2008; Leggon and Pearson, 2009).

In the final chapter, Leggon and Malcom (1994) argued that market forces alone would not increase the size and diversity of the STEM workforce. They concluded that policy intervention would continue to be required in order to increase the diversity of the STEM workforce. For STEM human resource policy to be effective, Leggon and Malcom asserted that intervention should be viewed as a system in which efforts targeted to one part of the system have consequences for other parts of it. They recommended that successful efforts resulting from such deliberate policy should be rewarded. While they recognized that systematic reform may proceed in increments, Leggon and Malcom emphasized that it must be sufficiently flexible. Flexibility is required in order to make adjustments based on the formative evaluations. Moreover, the authors recommended that the process be carefully monitored to ensure that programs are consistent with the policy that informs them. They concluded that a carefully crafted human resource policy, combined with flexible programs and practices, will generate the systematic reform necessary to increase the size and diversity of the U.S. STEM workforce.

Fechter (1994) agreed with Leggon and Malcom (1994) that some policy issues may be independent of any current or projected state of the labor market. He cited as examples, underrepresented groups in STEM such as women and African Americans, Hispanics, Native Americans, and Pacific Islanders/Alaska Natives. He asserted that underrepresentation reflects, in part, barriers that prevent qualified individuals from these groups from pursuing STEM careers. In short, Fechter argued that underrepresentation is an indicator of STEM talent that is not developed to its fullest potential. He contends that such underutilization, which can exist simultaneously with market conditions of oversupply, represents a cost to society as well as to the individuals in these groups (See Fechter, 1989; Bowen, Chingos, and McPherson, 2009). In sum, Fechter concluded that policy formulation aimed at reducing this underrepresentation should not be totally driven by market conditions. Indeed, Krugman (2009; 13) asserts that “economics, as a field, got in trouble because economists were seduced by the vision of a perfect, frictionless market system.”

Conclusions

Overall, the authors were remarkably prophetic. Many of the issues raised a generation ago have become central topics of today’s investigations and policies. Fechter (1994) advised policymakers to pursue a strategy that favors anticipating shortages because the costs of being wrong would be preferable to an erroneous assumption that markets will eventually be in balance. Vetter (1994) and Leggon and Malcom (1994) argued that diversity of the STEM talent pool is a significant policy issue, regardless of the state of the labor market. The issue raised by these authors as well as others was at the heart of the scholarly discourse in *Who Will Do Science?*

Vetter raised concerns about the potential impact of foreign STEM talent on underrepresented groups, and expressed concern about the increasing reliance on foreign STEM graduate students, post doctorates, and professionals to fill the void left by U.S. citizens. Recent studies and reports confirm the growth of foreign STEM talent in U.S. graduate schools and the workforce and express sentiments similar to Vetter. (Freeman, 2006; Finn, 2007). Like Vetter, Finn (2007) acknowledges that foreign students and STEM workers have made significant contributions to the U. S. workforce. The extent to which this talent source remains viable is a topic of considerable discussion

HBCUs have long played a major role in the development of African American STEM talent. Yet, the warning forecasted by Trent and Hill has become a reality as many HBCUs struggle for their very existence in a turbulent economy (See Pope, 2009). Although HBCUs are increasingly producing a smaller share of African Americans who earn STEM degrees and continue to pursue a STEM career, they continue to produce a disproportionate share of African American STEM talent. The racial/ethnic compositions of the STEM faculties of these institutions have been transformed since the publication of *Who Will Do Science?* The natural science and engineering faculties at many HBCUs consist of predominantly foreign born individuals. Many HBCUs continue to struggle to recruit U.S. born STEM doctorate holders to their faculties. In addition, many of these institutions continue to be challenged by decades of underfunding and inadequate STEM infrastructures. U.S. Department of Education Secretary Duncan acknowledged the significant contributions of HBCUs to STEM fields. He asserts that these institutions must not only survive but thrive. This will be a challenge without significant changes in the manner in which these institutions are managed. HBCUs will need substantially more public and private funding (especially from alums), if they are to build an infrastructure that facilitates and budgets that allow them to compete for well-prepared faculty members and students. In all likelihood, several HBCUs will close their doors because they will not be competitive. Others, however, will thrive, especially if they provide strong evidence of their research and educational effective.

Today, most funders require the programs they fund to have strong evaluation components. A review of both private and government funders' websites speak to this change (Howard Hughes Medical Institute, 2006, CEOSE, 2006, 2009). Moreover, many funders require that the evaluation be conducted by an external professional. At the time that *Who Will Do Science?* was published, Daryl Chubin was a division director at the National Science Foundation and played a major role in the agency's focus on program evaluation, warning that evaluations would not affect practice until negative consequences are visited upon those unconcerned about "impact."

At the time of this writing, the Obama Administration has placed a strong emphasis on both a high-quality STEM education system and STEM workforce (Nelson, 2010). They see this as a fundamental component of the U.S.'s position as a global leader in both innovation and standard of living. As was the case in the G. W. Bush Administration, the Obama Administration seeks to reduce the extant achievement gaps, in STEM education (especially K-12) along racial/ethnic, class and gender lines. The Obama Administration supports more rigorous evaluations of federal programs (See Orszag, 2009; Mervis, 2006, Mervis, 2009a).

Much has transpired in both the scientific community and the larger society since the publication of *Who Will Do Science*? Therefore, the time is long overdue for scholars to build on the contributions of these authors. Because of data limitations, we continue to know little about the intersection of citizenship, race/ethnicity, gender and disability in relation to developing STEM talent within and across disciplines (Mervis, 2009b). We have little understanding of why some women of color, compared to their male peers and to majority women, have higher rates of participation in disciplines where women have traditionally under participated (e.g., engineering, physics and computer science). While much focus has been on broadening the participation of all women in STEM fields (and rightfully so), less attention has focused on the under participation of some minority males in STEM education, especially in higher education (See Frierson, Pearson, and Wyche, 2009a; Frierson, Wyche and Pearson, 2009b; Hrabowski and Maton, 2009; Bowen, Chingos and McPherson, 2009). We know, too, that a number of diverse institutions have emerged as top producers of underrepresented groups (Li, 2007; NSF 2009). Yet, we continue to know little about the faculties of these institutions. While women and underrepresented minorities have made some progress, they continue to be underrepresented on major university faculties, especially departments at top-ranked institutions (Burrelli, 2006, Pearson, 2006). Moreno et al. (2006) assert that campus senior administrators often attribute the low representation and slow growth of underrepresented minorities on the faculties at majority institutions to few faculty vacancies. According to these researchers, their research provides evidence that even when a third of the faculty was being hired, the actual numbers of underrepresented minorities did not increase significantly. Luo (2009) supports this finding by arguing that race remains a serious obstacle in the job market for African Americans, including those with degrees from elite institutions (See, also, MacLachlan, 2004, Pearson, 2005). He points out that Black male college graduates are twice as likely as their white counterparts to be unemployed (8.4 percent versus 4.4 percent).

While the supply and demand debate continues, the composition of the STEM workforce has become the mantra for governmental and industrial policies and programs. Indeed, many stakeholders embrace the need for a diverse and globally competitive workforce to drive the U.S. innovation system (NSF, 2006).

To that end, a number of scholars call for a major shift in the current federal policy approach to funding graduate students in STEM fields (See Mervis, 2009c). Specifically, Freeman (2006) asserts that the current NSF fellowship policy serves as a disincentive for young citizens to pursue STEM careers. Like Teitelbaum (2001), Freeman contends that STEM careers must become more attractive in order to attract top performing students. In order to do so, Freeman believes that the NSF must increase its graduate fellowships. He argues for a change in federal policy with not only a significant increase in spending on basic research, but also of directing the spending toward young researchers. Ultimately, Freeman (2006) believes that this will attract women and minorities to STEM careers. Nearly a decade ago, Teitelbaum (2001) warned that STEM doctoral careers were becoming increasingly unattractive. He attributed the problem to a long period of training that resulted in few employment opportunities especially involving research and relatively low wages compared to other professions, such as medicine, law and business. (For a discussion of market and broadening participation issues in law and medicine, see Lewin, 2010, Weiss, 2010, Lamm, 2009, American Bar Association, 2008; Neill, 2010, AAMC, 2009a, AAMC, 2009b, AAMC, 2008a, AAMC 2008b).

Regardless of the market forces in the STEM labor market, the diversity of the STEM talent pool remains a significant policy issue-more than a generation after the publication of *Who Will Do Science?*

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Commentary on *Who Will Do Science?* Changes in the Analysis of Participation[*]

Presented at CPST Annual Meeting, November 7, 2008

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We are one generation removed from the collection, *Who Will Do Science?* As a reviewer of the original manuscript and the project director of a precursor federal report (OTA, 1988), I find it instructive indeed to weigh, with the benefit of hindsight provided by one of the book's coeditors, its impact and implications for scholars and practitioners in 2009. Dr. Pearson's reflections on what *was* in 1994 help us to calibrate what *is* today: what has changed in the way we approach and understand issues of participation in science?

I would suggest at least five changes. First is our *language*. STEM (science, technology, engineering, and mathematics) has become the acronym for a more expansive look at a set of disciplines and a workforce. For example, we have abandoned "pipeline" for "pathways," link career aspirations to "self-efficacy," and speak empirically (rather than ideologically) of "stereotype threat," "critical mass," and "chilly climate." Second is our growing *sophistication about relationships* at many levels—among analytical factors (individual, disciplinary, institutional), market variations (local, regional, national, and global), and professional pursuits (the demarcation of research, policy, and practice). Third is how CPST, the intellectual home of the Pearson-Fechter volume, has made *disaggregated analysis* more visible, yielding new insights and, perhaps more important, allowing us to pose better questions of the data. Fourth is the *legal climate* that constrains sponsors and performers alike due to fear, ignorance, or a lack of leadership (take your choice). Fifth is the *global context* in which countries, universities, and industries that produce or consume STEM workers must anticipate and respond to human resource development needs.
As Pearson reminds us, we must look back to assess where we have been and where we must go. This prompts both celebration and lamentation. As far as we have come—as researchers, evaluators, technical assistance providers, and policymaking staff—the sad reality is that STEM education and workforce, students and faculty, hardly look like America. Indeed, they hardly look like the rest of academe. At every degree level and every rung on every employment hierarchy, underrepresentation of women and persons of color persists (yes, a little better here, a little worse there).

So we may have improved *opportunities* to participate, but fallen short—collectively, despite our earnest efforts—to increase participation through degree

[*] My thanks go to Linda Blockus, Fellow of the AAAS Capacity Center (on leave from the University of Missouri-Columbia), for comments on an earlier draft.

attainment and skills acquisition. Regardless of denominator, US minority citizens lag their majority peers in STEM degrees earned, and the gap is even more glaring at the doctoral level when comparing US minorities to foreign citizens.

The data, in short, have *informed* us—but they have yet to compel the kinds of actions that dramatically change the numbers in various categories of participation. With all due respect to my academic colleagues, one's professional advancement doesn't induce change in the real world (Chubin, 2009). Aside from boosting the prospects for promotion and tenure, scholarship is supposed to be a vehicle for spreading knowledge and grounding behavior that will improve a well-documented, amply-hypothesized situation (Chubin and Ward, forthcoming).

This is where policy and practice must connect to the literature. If our knowledge base is so much more robust than a generation ago, how do we convince policymakers to act on it? The data *don't speak for themselves*: more than research and analysis, we need advocacy to amplify the numbers, underscore their significance, and convey their urgency. "Broadening participation" should be more than an NSF mantra; it should be operationally defined to influence peer reviews and competitive research decisions. If this does not happen, we face another generation of analysis that becomes sharper in its precision and duller in its impact.

What I am asking is nothing less than a re-examination of the paradigms in which we each were schooled. None captures the relationships at work here. And if we don't collaborate to enrich our approaches and traverse disciplinary boundaries, we will speak mainly to ourselves and not to well-intentioned but skeptical policymakers (DePass and Chubin, 2009).

Underrepresentation of soon-to-be majority groups—women are already at parity in the general population—has become a chronic condition. A good example of analytical blinders that ignore this reality is labor economics. Alan Fechter was an unusual labor economist. He saw flaws in supply-and-demand formulations, and recognized that what was *un*measured required explication. Collaborating with an unusual sociologist, Willie Pearson, who understands context and how it is shaped, he produced a finer sense of the pathways from precollege to undergraduate to graduate study and beyond. Today we know that these segments are adjoined, that one can intervene at various junctures, but that disadvantages, like advantages, accumulate.

This nuance, and Fechter's realization of it, remains utterly lost on economists fixated on supply and demand instead of the demographic composition of the workforce (e.g., Bound et al., 2009). If the paradigm decrees that markets operate consistently for all actors, and in a global configuration to boot, then it follows that equilibrium will occur *without* programmatic or policy intervention. But we hypothesize that the influx of foreign talent to US STEM programs does impact the domestic pool. The last two generations, as Pearson's data presentation attests, shows no substantial gain in STEM enrollments of and degree awards to domestic students, especially women and minorities, *despite* interventions.

From an activist perspective, research vigilance (i.e., continued documentation and analysis of complex relationships over time) is necessary. Vigilance alone, however, is not sufficient to change education and workforce participation rates. Although programs can save and salvage talent, they are still too dependent on soft money rather than hard institutional commitment.

At the time that *Who Will Do Science?* was published, I was a division director spreading the NSF gospel on education evaluation. Today education evaluation is an industry. I'm not sure, however, that it has improved outcomes. Sponsors' exhortations notwithstanding, evaluations will not affect practice until principal investigators take them seriously in executing their projects.

Finally, there is the law. What federal and state statutes allow does not always prevail in practice. The burden is on those who wish to go beyond the letter of the law to operate in the spirit of participation. That spirit is under assault, especially in public institutions of higher education (Malcom et al., 2004). Even programs that are deemed effective with years of data on positive educational outcomes may not be legally sustainable. Context matters. Actions matter.

So it is with pride and gratitude that I salute the prescience of the Pearson-Fechter volume. For now, we speak routinely of "climate" (Sandler, 2009), of institutions that are "minority-serving" (George et al., 2001), and of the soft expectations that reject the "mismatch" theory (Tapia, 2009). These are analytical advances that reflect well on a maturing community. In unison we can repeat with certainty what Linda Wilson observed 15 years ago: there is *no* shortage of PhDs in STEM. But there *is* a shortage of minorities in STEM, of women on university faculties, and on people from underrepresented groups in leadership positions in every sector of the economy (Chubin and Malcom, 2008).

Those are not opinions, but evidence-based generalizations. They are a tribute to data mined and "minding the data." What next? Let's hope that Pearson is correct: our nation in the Obama era may, in some significant ways, be turning the corner on equity and excellence.

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Commentary on *Who Will Do Science?*:
Diversity Lessons Learned—One Research University, One State

Presented at CPST Annual Meeting, November 7, 2008

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I am honored to respond to Professor Willie Pearson, Jr.'s reflections on the gains made in science, technology, engineering and mathematics (STEM) education since the publication of *Who Will Do Science?* in 1994. This book was very influential in my own career and it is appropriate to consider the changes we have seen in the past 14 years. My remarks will be based on my own experiences both at the University of Michigan and within the larger State of Michigan context. There have been several successes and a comparable number of challenges.

Enrollment of Diverse Students in STEM at the University of Michigan
The enrollment of women and historically underrepresented minority students in STEM fields significantly increased starting in the 1980's but leveled off in the 1990's to the present day. Since 1994, the College of Engineering (CoE) has averaged around 290 women first year students annually, out of a class that has ranged from 900 to 1200 incoming students. In some years women were as high as 35 percent of the incoming class. But as the college has grown overall in recent years, the absolute number of incoming women students has remained fairly constant. In 2008, 279 women, about 23 percent, were in the freshman class. Historically underrepresented minority students were 12 percent of CoE undergraduates in 1994. In 2008, they represent 8 percent of the undergraduate population.

Women are well represented in many of the science and mathematics concentrations at Michigan. About 60 percent of the undergraduate majors in Biology are female; 39 percent in Mathematics; and 30 percent in Chemistry. But only 11 percent of the physics majors are female.

The value of our diverse student population has been brought home to us in recent years by recruiters of our graduating seniors. These individuals tell us that there are two reasons they like to recruit Michigan grads. The first reason is for their technical expertise coupled with their communication skills – our students are simply good engineers, scientists, and mathematicians. The second is for their sense of multicultural competency. Increasingly scientists and engineers are working in a global marketplace. Michigan graduates are very diverse and this, combined with the Michigan experience, appears to have produced graduates who can easily fit into multinational companies. This feedback from our recruiters has helped bring home the importance of our diversity efforts for our University administration and faculty.

Challenges in the Past 14 Years

The University of Michigan faced two significant legal challenges since 1994. The first, of course, was the admissions policy lawsuit which went all the way to the Supreme Court in 2003. We had a very brief period of celebration after successfully defending our use of affirmative action. The court case was soon followed by Proposal 2 which was adopted by Michigan voters on November 7, 2006, and took effect in late December of that year. It amends the Michigan Constitution to ban public institutions from discriminating against or giving preferential treatment to groups or individuals based on their race, gender, color, ethnicity or national origin. We know that anecdotally from talking with prospective students and their families that this lengthy process, both the court cases and the subsequent ballot proposal, negatively impacted our enrollment of underrepresented students. Proposal 2 has taken away many of the tools that we have used in the past. But it has also forced us to think more creatively and I explain below.

The State of Michigan – Economy and Education

As a state institution, the University in many ways mirrors issues within the State of Michigan. James Duderstadt, University of Michigan President Emeritus and University Professor of Science and Engineering, in a 2004 publication entitled "A Roadmap to Michigan's Future" (http://milproj.ummu.umich.edu/publications/roadmap/) presented several disturbing statistics about the state of Michigan:

- The state is 50th in the nation in personal income growth
- The state is 50th in the nation in unemployment rate (highest unemployment rate)
- The state is 50th in the nation in employment growth (in fact the only state with a decline)
- The state is 50th in the index of economic momentum (e.g., population, personal income, and employment)
- The state is 50th in the change of support of higher education over the past 6 years
- ¼ of Michigan adults do not have a high school diploma
- 1/3 of Michigan high school graduates are college ready
- ¼ of Michigan citizens have college degrees

Christopher Swanson, in his report "Cities in Crisis," found that the Detroit City School District ranked last in the graduation rates of the school districts serving the nation's 50 largest cities. Only 24.9% of our Detroit City high school students graduate (http://www.americaspromise.org/APAPage.aspx?id=9172).

Those of us who work in STEM educational outreach throughout the state are often frustrated by the belief of many Michigan high school students and their families that individuals do not need a college degree to obtain a well-paying job. This is a legacy of 100 years of the automotive industry, but is no longer true. In addition, within the state engineering as a career has a bad reputation due to the perception that all of the engineering jobs are being outsourced to other countries.

Some Recent Strategies Developed at the University of Michigan

The University of Michigan is committed to the education of highly qualified diverse STEM graduates and recognizes its role in the creation of an educated high-tech citizenry within the state. To that end, the University has implemented several new initiatives in recent years. I would like to highlight four of these efforts, though there are many more. They include:

- The Center for Research on Learning and Teaching (CRLT) at the University of Michigan, founded in 1962, was the first teaching center in the country. CRLT partners with U-M faculty, graduate students, and administrators to promote a university culture that values and rewards teaching, respects and supports individual differences among learners, and encourages the creation of learning environments in which diverse students can learn and excel. In 2004, CRLT and the College of Engineering collaboratively opened a dedicated office on north campus to serve engineering faculty, staff, and students. The office is directed by a Ph.D. engineer with expertise in engineering education.
- The Instructional Development & Education Assessment (IDEA) Institute, a joint venture of the College of Literature, Science, and the Arts and the School of Education was launched in October 2008. The Institute will bring together faculty and students from science, mathematics, and education to design, implement and assess new teaching methods and materials to advance learning in science and mathematics from middle school through graduate school.
- The College of Engineering launched the Office of Educational Outreach and Engagement (OE^2) in 2004. OE^2 serves to link College of Engineering faculty, students, scholars and staff with local communities. It addresses issues related to diversity, serves as a resource for potential students and their parents, and contributes in meaningful ways to our community. Office staff encourages and helps faculty to engage the community's school children and their parents, teachers and educators, and public citizens to help raise academic achievement and increase understanding and interest in science, technology, engineering, and mathematics.
- The Michigan STEM (M-STEM) Academy is a high school-to-college transition program based on the highly successful Meyerhoff Scholars Program at the University of Maryland Baltimore County. M-STEM supports diverse students with a pre-freshman year summer program, intense academic coaching, some financial incentives, research opportunities, and professional development activities. The pilot program commenced in 2008 with 47 College of Engineering students.

Conclusion

While some things have improved since the publication of *Who Will Do Science?* in 1994, much remains the same. There have been significant challenges, particularly in the legal arena and the economic landscape that the authors could not have anticipated. Yet the necessity of a well-educated technologically literate citizenry is as critically important in 2008 as it was in 1994 – perhaps more so. We continue to work on these issues, often showing great creativity and energy, using the foundation established by this important document.