# Skills for the Innovation Economy:

## *What the 21st Century Workforce Needs and How to Provide It*

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## What the 21st Century Workforce Needs and How to Provide It


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The innovation economy is based on intellectual capital and the ability to translate ideas into new technologies, products and services faster and better than the competition. In the last half century, the United States enjoyed the benefits of being the world's leader in innovation, in large part due to the quality of its workforce. The education and training infrastructure of the U.S. has allowed it to produce a substantial workforce of specialists – individuals who are highly trained and well versed in the latest techniques relative to a single field of pursuit. This has been particularly true for science and engineering. It has been these workers who have provided the ingenuity needed to produce America's robust system of innovation, but clouds are forming. How can we ensure that America's workforce of the 21st century will continue to be a global leader in economic competitiveness and overall quality of life?

First, it will be necessary to ensure that the workforce of the 21st century includes adequate numbers of these knowledge discoverers, applications designers, and innovation drivers. Among these will be workers in such critical fields as science, technology, engineering and mathematics (STEM) at all levels. Although these workers currently comprise only about five percent of our nation's 138 million person workforce, in the past 50 years, more than half of America's sustained economic growth came from this small segment of the workforce. From microchips embedded in hand-held computers and cell phones to curing polio and other diseases, the innovation of these workers has made our lives richer, more productive and more promising.[1]

But, the reservoir from which America has traditionally drawn STEM talent is changing dramatically and in important ways. Attention must be paid to both the internal and external drivers that propel that change if we are to sustain global leadership. These include demographic, educational, economic and cultural forces at play, domestically and abroad.

All of these forces lead to concern that insufficient supplies of our scientists and engineers will hamper our ability to continue to create new technologies, make scientific breakthroughs and thus slow down our innovation, just when America's competitors are beefing up their numbers. There is reason for concern. Although about a third of the school-age population consists of U.S. underrepresented minority students, over three-quarters (77 percent) of the working population in STEM occupations is white, with a fair representation of Asians (about 12 percent), but only about 11 percent African American, Latino, and American Indian participants. While women comprise about half of the school-age population, they represent only about a quarter of the STEM workforce.

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[1] BEST, *The Talent Imperative: Meeting America's Challenge in Science and Engineering, ASA,* 2004.

The demographics are shifting. The traditional talent pool – white, non-Hispanics – from which our nation has drawn heavily for its scientists and engineers, is projected to stop growing completely by 2030 and then slowly decrease. In contrast, the African-American, Asian, American Indian and Hispanic populations are projected to increase at varying speeds. By far, the greatest population change will be among the Hispanic population, which is projected to contribute 44 percent of the population growth from 2000 to 2020, and 62 percent from 2020 to 2050.[2] These demographics clearly point out that the talent base is changing and suggest that the nation must work to make its domestic workforce more inclusive.

Historically, about one third of all bachelor's degrees are awarded in science and engineering (S&E). In 2001, 1,257,648 baccalaureates were awarded, of which 400,206 (or 31.8 percent) were in science and engineering. Since 1970, the number of bachelor's degrees in science and engineering to men has fluctuated around 200,000, while the number of S&E bachelor's degrees earned by women has been steadily increasing reaching majority status in 2000. In 2001, women earned 50.6 percent of the baccalaureates in science and engineering. Underrepresented minorities earned 16.9 percent of the degrees in science and engineering, exactly the same percentage that they did of the non-science and engineering bachelor's degrees – 16.9 percent.[3]

In computer science, as in other STEM fields, the number of bachelor's degrees awarded is very cyclical. From 1981 to 1985, the total number increased 157 percent, only to go into a decline from 1985 to 1997. However, because of the high tech boom of the late 1990s, more and more people started again to pursue studies in computer science and related disciplines and the number of CS/IT degrees increased by 60 percent from 1998 to 2001 reaching 43,184, and data from the National Center for Education Statistics indicate that bachelor's degrees in CS/IT increased another 14 percent from 2001 to 2002 reaching 49,404.

Despite the fact that women have emerged as the most educated segment of our society over the past 25 years, large numbers still shy away from technical careers as is evidenced in computer science. From 1985 to 1987, the number of degrees in CS/IT earned by women dropped more than twice as much as the number earned by men – over 52 percent for women – 25 percent for men. As a result, their proportion declined substantially from 37 percent in 1985 to 27.5 percent in 2002, as shown in the chart on the following page.

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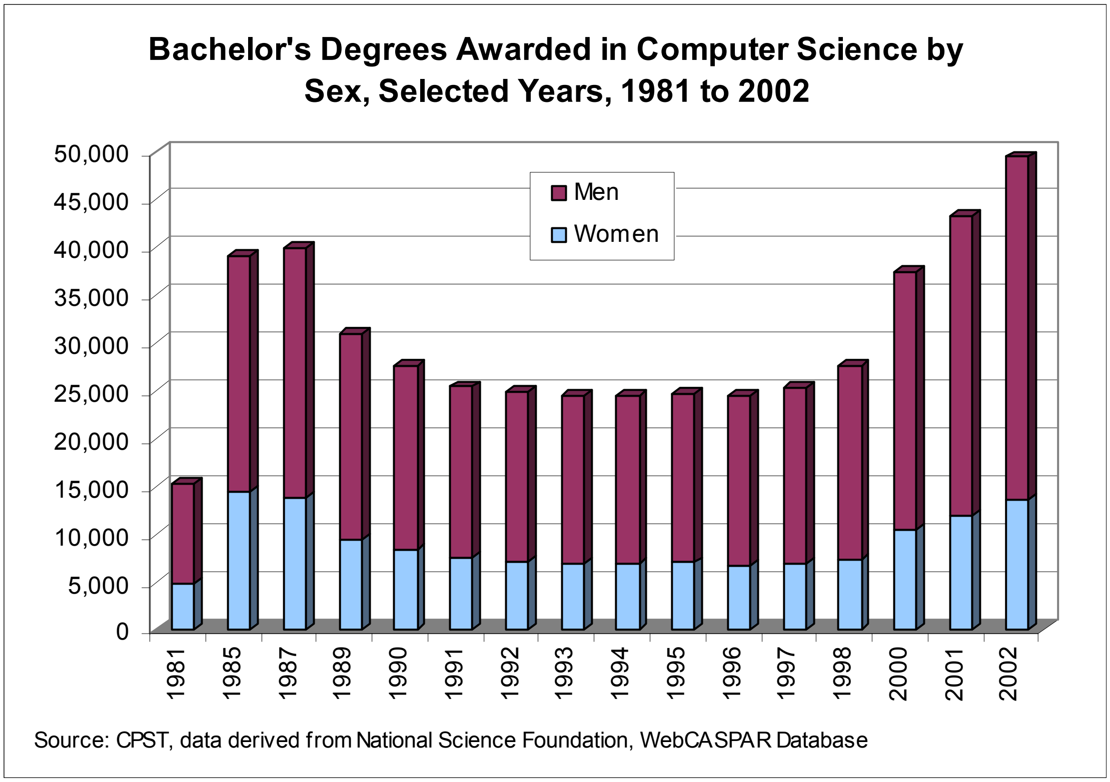
[2] Day, Jennifer Cheeseman, ***Population Projections of the United States by Age, Sex, Race, and Hispanic Origin: 1995 to 2050***, U.S. Bureau of the Census, Current Population Reports, P-25-1130, U.S. Government Printing Office, Washington, DC.
[3] National Science Foundation, WebCASPAR Database system.

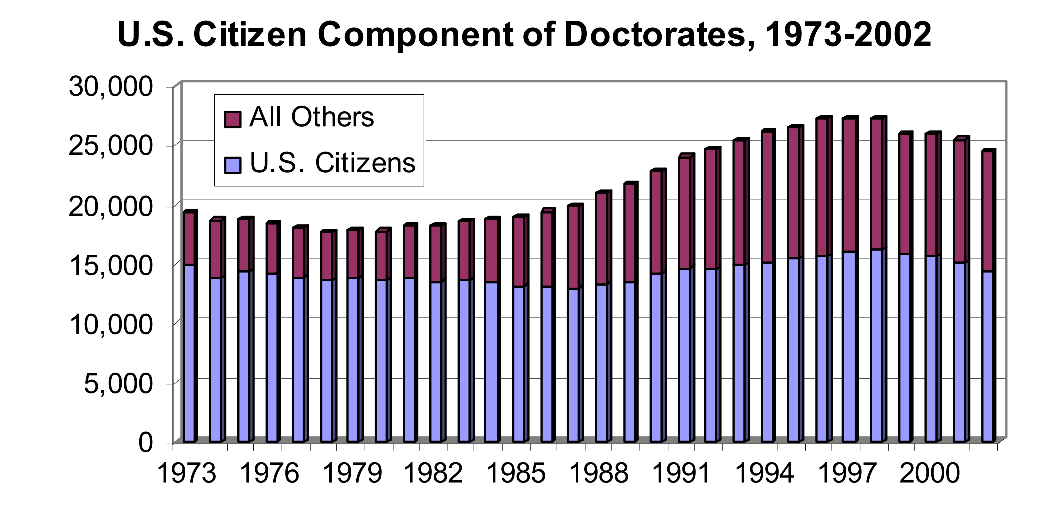



And again, there is evidence from a survey by the Computing Research Association (CRA) that the period of explosive growth in undergraduate enrollment in computer science experienced for the last several years is clearly over. CRA reported that the number of new undergraduate majors plummeted 23 percent to 17,706 in 2002-03, from 23,033 the previous year. Total undergraduate enrollment fell 19 percent in 2002-03, following an 11 percent increase in 2001-02. This dramatic decline should affect BS degree production in about 2006.

Similar ups and downs occurred in engineering. Although the number of bachelor's degrees in engineering more than doubled (38,210 to 78,178) from 1973 to 1986, the peak year of production, the number dropped 20 percent reaching 62,500 in 1999 before starting back up. Over the past four years, the numbers have again increased, including an incredible 9.3 percent jump from 2002 to 2003 to 75,031, but still shy of the record in 1986. During the period from 1975 to 2003, women increased their numbers substantially. In 1975, they earned 878 or 2.3 percent of the 43,429 bachelor's degrees awarded in engineering. In 2003, they earned 15,114 or 20.1 percent of the 75,031 engineering baccalaureates. Underrepresented minorities earned 1,569 or 4.8 percent of the engineering bachelor's degrees in 1975. In 2003, they earned 8,469 or 11.3 percent.

Despite this overall progress in baccalaureate degree production in engineering for women and underrepresented minorities, the proportion of women and minority freshmen in engineering has been declining since 1995. Although the absolute numbers have been increasing for both women and underrepresented minority engineering freshmen, the numbers for men and non-minority freshmen have been increasing at a faster pace. In 1995, women represented 19.9 percent of the freshman class; in 2002, they represented 17.2 percent. Even more disturbing is a considerable decline of 5.4 percent in the absolute number of women engineering freshman in 2002 (19,509) from 2001 (18,447) and new data from the Engineering Workforce Commission reports further declines in fall 2003. Total freshmen enrollment dropped by 3 percent to 103,834; African Americans declined to 7.3 percent of engineering freshmen, down from 7.6 percent, while women engineering freshmen decreased by another 1,400 to only 16.2 percent of the freshmen class, after reaching a 19.9 percent peak in 1995. Underrepresented minorities constituted 17.4 percent of the freshman engineering class in 1995; in 2002, they represented 15.6 percent. These declines in the proportion of women and underrepresented minorities enrolled at the undergraduate level in engineering will translate into continued declines in the proportion of degrees earned by women and underrepresented minorities in the coming years. Again, fewer degrees from the populations that are growing the fastest.

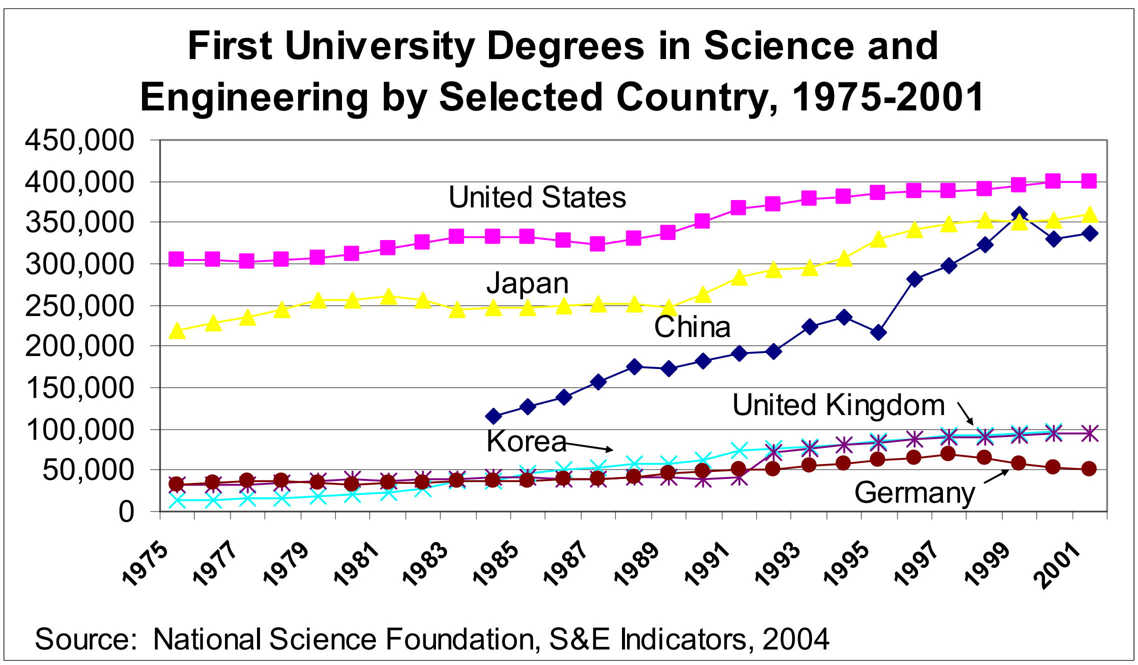
Perhaps even more disturbing is the decline in the share of science and engineering doctorates earned by U.S. citizens. In 1973, U.S. citizens earned 77.5 percent of all S&E PhDs. In 2002, they earned 58.3 percent. As shown in the chart below, the number of U.S. citizens over the past 20 years has not changed much – all the growth in total S&E PhDs awarded can be attributed to non-U.S. citizens. The primary reason for this proportional drop is the decline of men, who earned 86 percent of all the doctorates awarded to U.S. citizens in 1973 dropping to 57 percent in 2002. Even more disturbing is the fact that over the past five years (1998 to 2002), the number of white men earning PhDs in science and engineering who are U.S. citizens dropped 24 percent. Who will take up this decline? Underrepresented minorities over the 30 year period 1973-2002 only increased their proportion of the science and engineering doctorates minimally – from 1.3 percent to 5.5 percent.



Source: CPST, data derived from NSF, WebCASPAR Database

It is therefore not surprising that we find that women and minorities comprise a much smaller proportion of the STEM workforce than they do the general workforce. Women are nearly half of the general workforce (47 percent in 2003), but only about a quarter of the STEM workforce. Under-represented minorities comprised over 23 percent of the general workforce, but only about 12 percent of the STEM workforce. And if we look specifically in academe at the top research institutions, we find few women and underrepresented minorities. There are few female full professors in S&E; across all fields the percentage of women among full professors ranges from 3 percent to 15 percent. In a survey of diversity among S&E faculty in research institutions, in all but one discipline surveyed, the highest percentage of female faculty is at the level of assistant professors. And underrepresented minority women are virtually nonexistent among the faculties of the top S&E departments. In the top five computer science departments in FY 2002, there were no African American, Hispanic, or Native American tenured or tenure-track women faculty.[4]

The rest of the world has taken notice of the U.S. successes in innovation. While the U.S. may still be ahead of the curve, many of our chief competitors are catching up. Looking at first university degrees awarded in science and engineering by various countries, we find that the United States is still leading, but both Japan and China are quickly closing the gap. In 2001, the U.S. awarded 400,206 degrees in S&E, while Japan awarded 359,019 and China awarded 377,352. However, over the last decade (1992-2001), China increased its production of first university degrees in S&E by 75 percent (from 193,088 to 337,352), Japan increased its production by 23 percent (from 292,085 to 359,019), while production in the U.S. increased only 8 percent (from 372,092 to 400,206). If one only looks at first university engineering degrees, both China (at 219,563) and Japan (at 104,478) lead the U.S. (59,258).[5]

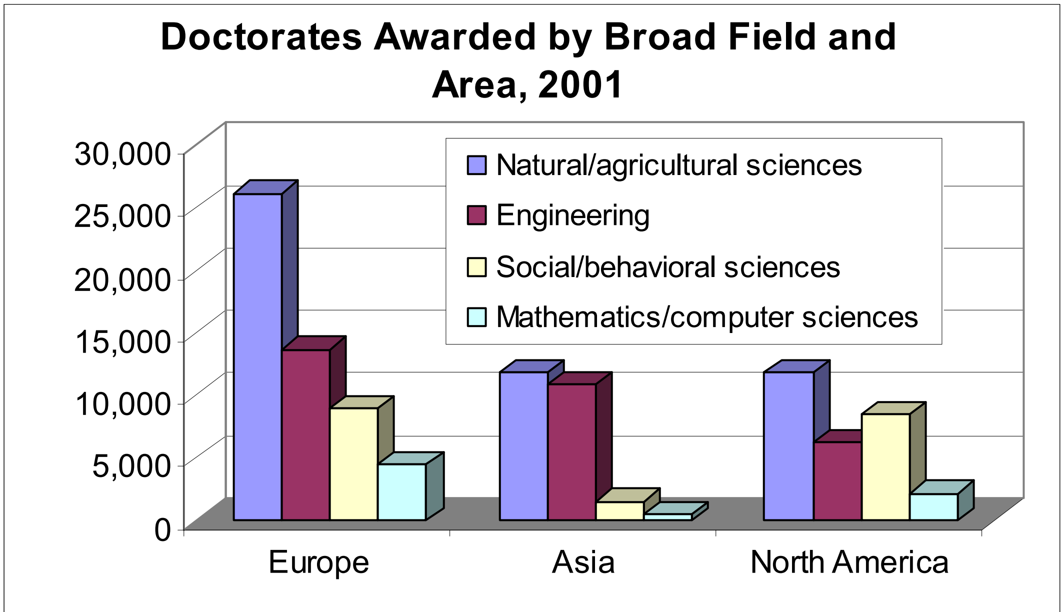



At the doctorate level, Europe awards about twice as many natural science doctorates as both North America (U.S., Canada and Mexico) and Asia. In addition, Europe awards over twice as many doctorates in engineering as does North America and twice as many doctorates in

[4] Nelson, D. J. and D. Rogers, *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities*, 2003.

[5] National Science Foundation, *Science and Engineering Indicators*, 2004.

mathematics and computer science. The only broad field in which North America competes equally is in the social sciences. However, North America still leads Asia considerably in the award of doctorates in mathematics and computer sciences and in the social and behavioral sciences. However, it trails Asia in the production of engineering doctorates. It is important to remember that these are total production figures – not just production figures for citizens of the home countries.



Source: National Science Foundation, S&E Indicators, 2004

Added to this concern of a decreasing supply of U.S. citizens entering the STEM fields, particularly at the doctorate level, is the fact that about a quarter of our current scientists and engineers will reach retirement age by 2010. How will we replace those workers? Can we continue to rely on international talent to fuel our economy? That prospect becomes more of a concern as the home countries of this international talent raise their own standards of living and place greater value on their own technical innovation, and as our nation institutes policies that decrease the flow of foreign talent. Other countries are happy to take up the slack and are aggressively recruiting international students. This surely leads to the conclusion that we must figure out how to again interest our youth in science and engineering, and we must involve all our citizens and create many pathways to technology-based employment.

The U.S. has relied on coping with short-term labor shortages in select fields by its visa policy – i.e. the H-1B visa for workers in information technology, nursing and some teaching fields. In IT, for example, foreign-born persons accounted for over a fifth of our core IT workers in 2001, and despite the fact that IT employment dropped between 2001 and 2002, the number of immigrants in IT did not drop as much as the number of natives, so the immigrant share of IT jobs continued to rise even during the recent economic decline. But, should we continue to rely on this method of labor force fixes or should we take the longer-view to our STEM workforce challenge and expand our own talent base, since these short-time fixes have been disrupted by unexpected external events, such as September $11^{th}$?

It will continue to be in the national interest to maintain open doors. International students, scholars and researchers are important to our universities, our research enterprises and our overall prosperity. There are signs that the United States is no longer welcoming or perceived as welcoming those from outside its shores due to increased security concerns after September 11th. This situation must be reversed with the U.S. establishing new visa policies while bolstering security. Our visa processing system not only must provide genuine security against those who might do us harm, but also keep our borders open to the stream of scientific and technical talent that fuels our progress. Science and security are not at odds with each other – they go hand-in-hand.

We face similar challenges with outsourcing considerations. This issue has become the lightning rod issue of our times and much has been written in the media about this growing workforce trend, particularly in fields such as information technology. U.S. technical workers are now and must continue to be the best in the world, but "best" and "cheapest" are not synonymous concepts. The U.S. must compete on the basis of "better jobs," not just "jobs." Its technical workers will have to compete on value-added quality and productivity and will have to increase their skills base. The future prosperity of the U.S. will depend on the availability of a deep pool of talented STEM workers.

Another reason to keep our intellectual borders open is because other countries are courting the world's best students to attend graduate school outside the U.S. and due to the very short supply of PhD's in certain science and engineering fields some U.S. companies may be forced to open research centers elsewhere where there is a talent supply. Signs are growing that off-shoring and outsourcing will continue to grow. Add to this the fact that scientific papers by Americans peaked in 1992 and have since fallen roughly 10 percent according to the National Science Foundation, and the U.S. share of its own industrial patents has fallen steadily over the decades and now stands at only 52 percent.

The nature of innovation is changing. A large body of evidence suggests that raw production of ideas alone is no longer sufficient for accomplishing innovation. As an example, consider that most patents produced in the U.S. today are not commercialized and produce little direct economic impact.[6] Generating ideas in bulk and leaving commercialization to chance, a strategy which worked so well for the U.S. in the last half century, will not continue to provide a competitive advantage for America in the 21st century.

The innovators of the future will need to be equipped with more than just specialization skills. Specifically, innovations in the future will come from teams of *collaborators* who can bring together multiple skills and perspectives.[7] Note that this collaboration includes not only joint

[6] Christensen and Raynor, *The Innovator's Solution*, Harvard University Press, 2002, pp. 73.
[7] Collaboration is a process that aligns multiple parties to solve a related set of issues. The constituents may retain their own perspectives and goals but jointly benefit from solving a common constraint. A practical example is innovation in recycling. There were different stakeholder needs: natural resources scarcity, a limited ability to process garbage, social responsible corporate and personal images, and reduce production costs. However, for recycling to become adopted, standards needed to be adopted, infrastructure built, new raw material recovery process,

activities among scientists and engineers but also with business and industry specialists, including specialists in the services sector. This is particularly true for the U.S. where estimates are that 60 percent of the economy is services-based. Unfortunately, too little *formal* infrastructure exists in the U.S. to support collaborative innovation. Pockets of outstanding collaborative culture do exist, such as the unique relationships between research organizations (e.g. universities, the National Science Foundation, etc.) and businesses in Boston or Silicon Valley. But little of this culture has been institutionalized, and almost no formal educational structure exists to train scientists, engineers, MBAs, or service specialists on collaborative techniques.

The ideal U.S. workforce for the 21$^{st}$ century would be well equipped to leverage innovation as an ongoing mechanism for promoting new business development and the job growth that goes with it. Such a workforce would exhibit three main characteristics:

- Depth (strong disciplinary base). Everyone should “know something” that they can bring to a collaborative effort. Depth of understanding and expertise remains a fundamental component of innovation.
- Breadth (ability to team and collaborate and understand the nature and context of innovation). Great collaboration arises among individuals who know a great deal about differing subjects, and yet are able to bring their knowledge to bear outside of their given area of expertise.
- Width (inclusiveness of a diversity of perspectives). To be as effective as possible, the innovation workforce should be intellectually diverse, drawing upon specialists from across multiple disciplines and individuals with multiple perspectives, and demographically diverse, drawing fully upon the entire population.

The workforce of the 21$^{st}$ century must be composed of workers at many levels. Some of these knowledge workers will have associate degrees, others will have doctorates. Still others will have the Professional Science Masters (PSM) degree – a new type of master’s degree in the sciences that equips people for work outside academia, integrating study in the natural sciences and mathematics with knowledge and training in management, law, or other professional domains. Leading universities have created PSM programs to better align student training in the sciences with market needs.

The innovation economy is dependent on access to the most innovative research institutions, the best-educated employees, the most reliable high-speed telecommunications services, and the most responsive and efficient government. In order to continue to spawn new technology companies, retain and expand the ones we have, attract still others from elsewhere and harness technology through the economy, government (federal, state, local), education, private (business/industry and foundations) and non-profit sectors must forge strategic alignments, broaden

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biodegradable inks and a good deal of cooperation. For this study, collaboration will be defined to be: "A process through which parties who see different aspects of a problem can explore constructively their differences and search for (and implement) solutions that go beyond their own limited vision of what is possible (Taylor-Powell et al., 1998, see citinews.unl.edu/TOP/english/dictionarywhole.html)."

partnerships, and provide systematic, continuous and adequate funding for underrepresented students and faculty in proven research and education opportunities.

We must ensure that every U.S. citizen be provided an equal opportunity to gain the skills and knowledge necessary to compete in the STEM workforce. By so doing, America not only broadens the participation of her citizenry, but the nation also enriches the quality of scientific discoveries and technological advances made by infusing intellectual diversity of perspective throughout the scientific enterprise. But without specific policies and programs that aggressively support greater participation and advancement by all members of the U.S. talent pool, this goal will not be achieved.

Our nation's system of innovation and our people are what drive us forward. Our 21st century STEM knowledge workforce will continue to span several sectors, including the instructional workforce at the preK-12 and higher education levels (i.e., teachers and faculty), scientists and engineers, informed legislators and policy-makers, as well as an educated citizenry more broadly. With all these groups working together, our creativity and innovation efforts will continue to propel us to global leadership in the 21st century.