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Center on Education and the Workforce

STEM

SCIENCE
TECHNOLOGY
ENGINEERING
MATHEMATICS

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We undertook this report to help advance the discussion and understanding of many contentious issues surrounding STEM. The STEM debate has and will continue to stir controversy amongst interested groups. We invited many experts on various sides of this debate to critique this report. Though they sometimes held positions that were diametrically opposed and philosophically divergent from ours, we wish to thank them for their esteemed input. This process of evaluation contributed enormously to our understanding of the environment and forced us to address many methodologically difficult questions much more clearly. That said, all errors, omissions and provocative viewpoints remain the responsibility of the authors.

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Introduction

The generative economic power and social influence of Science, Technology, Engineering, and Mathematics (STEM) has made the production of a capable science and engineering workforce a priority among business and policy leaders.[1] They are rightly concerned that without a robust STEM workforce, we will become less competitive in the global economy.

What is really at stake in the current debate over the existence of quantifiable STEM shortages is an important question regarding a national strategy for sustaining economic innovation in the United States at a time when science, technology, innovation, and related work in STEM occupations have become more integrated globally.

Many among these leaders have argued that there is a shortage of STEM workers.[2] They cite disturbing trends in the STEM pipeline, such as the fact that although the raw number of Doctoral and Master's degrees in STEM has increased, those disciplines have declined as a proportion of all degrees awarded.[3]

Other respected authorities have vigorously contested the claims of shortage, arguing that we produce enough STEM degrees to fill all the STEM openings (Lowell and Salzman 2007; Freeman 2008; Teitelbaum 2003). These critics continue to argue that the language of crisis surrounding much of the dialogue is misleading, and they suggest that we are actually overproducing STEM talent at home, especially at the graduate level in academia. They conclude that despite increased funding for STEM education and research, tenure-track academic jobs for people who invest more than a decade of their lives in postsecondary STEM education are becoming scarcer. Therefore, these critics argue, promoting STEM is leading gifted students down a path of limited career prospects and wasted talent.

Both the oversupply and the undersupply arguments have merit, depending on which STEM workers, which education level, and which STEM competencies are being discussed. For the most part, the debate over whether we have too many or too few STEM workers has focused on the portion of the STEM workforce engaged in research and development (R&D)

1 Our definition of STEM occupations is far more encompassing than traditional definitions in that we allow for workers at the sub-baccalaureate level and include Architects and Technicians – (6% of the STEM workforce where 88% of them have Bachelor's degrees or better). Technicians and other technical workers that use STEM skills are often excluded from STEM discussions and definitions despite the use of highly technical skills by the sub-baccalaureate STEM workforce. We also exclude social scientists and further analyze STEM majors who may work in fields outside of STEM.

2 The National Academy of Sciences (2007, 2010), the National Association of Manufacturers (2005), the Council on Competitiveness (2005), the Association of American Universities (2006), and many others have argued that the United States faces a shortage of elite STEM workers.

3 Based on authors' analysis of Integrated Postsecondary Education Data System.

activities, as many believe that R&D is the part of the STEM workforce that most contributes to innovation.[4]

However, R&D workers represent a small share of the STEM workforce. We are concerned not only with the 21 percent of the STEM workforce in R&D, but also with the STEM workforce as a whole, STEM competencies as a whole, and the demand for them both within *and outside of* traditional STEM occupations.

What is really at stake in the current debate over the existence of quantifiable STEM shortages is an important question regarding a national strategy for sustaining economic innovation in the United States at a time when science, technology, innovation, and the related work in STEM occupations have become more integrated globally.

SOLVING THE SHORTAGE VERSUS SURPLUS PUZZLE: DIVERSION

To some extent, the reported shortage of STEM workers outlined in reports such as the National Academies' *The Gathering Storm* is puzzling (National Academy of Sciences 2007; Members of the 2005 "Rising Above the Gathering Storm" Committee 2010; National Academy of Sciences 2010).[5] The supply of STEM workers should be heavily influenced by the pull of demand incentives—principally, the relative differences in earnings, job security, and working conditions between STEM occupations and other occupations. STEM occupations are already among the nation's most highly paid—earnings in STEM are only matched or exceeded by a small slice of Managerial and Professional and Healthcare Professional occupations.[6] But the pull of higher earnings for STEM workers appears insufficient to draw a commensurate flow of students into STEM and keep them there over a working lifetime (Toner 2011).

We find that the disagreement between those who argue that STEM workers are undersupplied or oversupplied can be resolved by the fact that large numbers of people with STEM talent or degrees are diverted away from STEM careers either in school or later in their careers.

Given persistently high STEM wages, we would expect a stronger supply-side response as students and workers react to career prospects. This is especially true because we know that the education system produces more STEM talent and more STEM graduates than those who ultimately end up in STEM careers.

We find that the disagreement between those who argue that STEM workers are undersupplied and those who argue they are oversupplied can be resolved by the fact that large numbers of people with STEM talent or degrees divert from STEM occupations either in school or later in their careers.

We find that the diversion of STEM talent and STEM workers into other occupations results from the increasing value of the competencies—the set of core cognitive knowledge, skills, and

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[4] The direct relationship between R&D and innovation is often obvious. New drugs, new chemicals, or new biotechnology discovered in R&D have direct and immediate payoff in markets. But incremental innovations are spread across a much larger share of the workforce outside the traditional R&D sector. In addition, apart from the more spectacular examples, it is hard to find a strong correlation between the size of R&D staffs and innovation. Researchers do find a relationship between the size of R&D staffs and innovation in manufacturing, but the complexity of the innovation process and the lack of detailed, firm-level data makes it impossible to trace these relationships into other industries or innovation networks (Toner 2011).

[5] Shortages are difficult to measure in labor markets because markets find substitutes for what is not available or shift economic activity elsewhere. The best indicator of labor shortages are prices. When particular kinds of workers are abundant, the salary offerings for those workers decline. When a particular kind of worker is scarce but in demand beyond the available supply (undersupplied), employers compete for them by bidding up their salary offerings. Therefore, we conclude that rising wage offerings for STEM workers suggest a continuing scarcity.

[6] Many analysts argue that the only proper comparison with STEM occupational wages are those that compete directly with STEM—that is, Managerial and Professional and Healthcare Professional fields. We disagree. While it is true that an apples-for-apples comparison by education level in these STEM competitor fields leaves STEM wages in the dust, there are many other occupations that require high levels of education (comparable to these definitions of STEM that require a Bachelor's and better) that do not pay as well as STEM occupations. For example, editors (81% Bachelor's and better), educators (90% Bachelor's and better), and social workers (76% Bachelor's and better) all get paid wages that are much lower than STEM workers with comparable attainment levels.

O*NET COMPETENCIES ASSOCIATED WITH STEM

Cognitive

STEM Knowledge	STEM Skills	STEM Abilities
Production and Processing	Mathematics	Problem Sensitivity
Computers and Electronics	Science	Deductive Reasoning
Engineering and Technology	Critical Thinking	Inductive Reasoning
Design	Active Learning	Mathematical Reasoning
Building and Construction	Complex Problem Solving	Number Facility
Mechanical	Operations Analysis	Perceptual Speed
Mathematics	Technology Design	Control Precision
Physics	Equipment Selection	
Chemistry	Programming	
Biology	Quality Control Analysis	
	Operations Monitoring	
	Operation and Control	
	Equipment Maintenance	
	Troubleshooting	
	Repairing	
	Systems Analysis	
	Systems Evaluation	

Non-Cognitive

STEM Work Interests	STEM Work Values
Realistic	Achievement
Investigative	Independence
	Recognition

abilities—that are associated with STEM occupations, and the noncognitive work interests and work values associated with STEM occupations. In fact, since 1980, the number of workers with high levels of core STEM competencies has increased by almost 60 percent. Further, in all but two occupational clusters in the national economy, the rate of growth in demand for these core STEM competencies has increased at far greater rates than the growth in employment.[7]

Ultimately, the demand for STEM certificates, certifications, and degrees is a proxy for the demand for underlying competencies.[8] It is these competencies that reflect the knowledge, skills, and abilities of STEM workers. In order to understand the dynamic process of diversion of STEM talent, we drilled down below the number of degrees conferred and STEM jobs to these core STEM competencies.

Based on a detailed occupational database of incumbent workers called the Occupational Information Network (O*NET), we've done an empirical analysis to determine which competencies are highly associated with STEM occupations.[9] These competencies are listed in the adjacent box. As we describe later in the paper, O*NET is a unique database that has detailed information on over 965 occupations and the cognitive and noncognitive competencies of incumbent workers in these occupations.

We break STEM competencies into cognitive and noncognitive domains. The cognitive domain includes STEM knowledge, skills, and abilities (KSAs). Knowledge is "an organized set of mental structures (content) and procedures (procedural knowledge)" (Morgan, Ponticell, and Gordon 1998, 213). In simplest terms, knowledge is information, such as the knowledge of calculus, chemistry, or history. Skill is the use of knowledge to learn more or solve problems.[10] Skills include capabilities like Complex Problem Solving or Active Learning. Skills are most easily learned and most useful when they are learned and used in particular knowledge domains. The application of problem-solving skills by a lawyer is substantially different than the application of problem-solving skills by scientists, teachers, and managers, for example.

Abilities are more generic and transferable competencies, such as Mathematical Reasoning or Creativity, and are considered "relatively enduring attributes of an individual's capability for performing a particular range of different tasks" (Fleishman, Costanza, and Marshall-Mies 1999, 175). While there is an innate dimension to abilities, the lion's share of abilities are developed through schooling and experience on and off the job.[11] Abilities are also best learned and most effectively used in the context of particular knowledge domains but are enduring and somewhat more transferable among knowledge domains.

The noncognitive competencies include work values and work interests that are personal markers for success in particular occupations or occupational clusters like STEM.[12] The inclusion of work interests and work values enables us to understand an individual's potential motivations in choosing and persisting in careers. Job performance and job satisfaction are partially dependent on the extent to which jobs match an individual's work interests and work values. For example, someone who enjoys working with others might find being a

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[7] Sales and Office Support and Community Services and Arts are the exceptions. The U.S. labor force grew by 44 percent, while high-level core STEM employment in Managerial and Professional, STEM, and Healthcare Professionals increased by 73 percent, 175 percent, and 79 percent, respectively, between 1980 and 2008.

[8] We posit that STEM education both develops cognitive human capital (knowledge, skills, and abilities) and reveals noncognitive characteristics (work values and work interests) that make some people more successful in STEM occupations than others.

[9] To identify STEM competencies, we isolated STEM occupations in O*NET and identified the knowledge, skills, and abilities (also work interests and work values) that yielded the highest importance (five levels on a Likert scale) and highest levels (seven levels on a Likert scale) to those STEM occupations. To determine prevalence of STEM competencies, we connected O*NET to Current Population Survey (CPS) data via occupational codes.

[10] Skill is "a repertoire of routines which the workers can do accurately and fast, as well as a selection of principles among routines" (Stinchcombe 1990, 21).

[11] The psychometric literature on innate and developed abilities shows that schooling and life experience develops the innate abilities of affluent students but fails to develop the innate abilities of low-income students (Nisbett 2007; Turkheimer et al. 2003).

[12] These constructs were adopted from the O*NET content model.

desk-bound mathematician unsatisfying, even if he or she is highly skilled at math.

As defined by O*NET, work values are individual preferences that connect to success in particular occupations but also connect to what people want to get from their work such as Recognition, Achievement, Autonomy, Advancement, Independence, and Social Service. The traditional work values linked to persistence and satisfaction in STEM occupations are Achievement, Independence, and Recognition. But there are other work values, such as the desire for authority and structure or social service, that are less central in STEM occupations. STEM talent can divert into other occupations when STEM jobs, as traditionally constructed, do not satisfy, or are perceived to not satisfy, particular work values or when the breadth of work values served in alternative occupations reach beyond the traditional organization of STEM work.

Like work values, work interests are characteristics of individuals who are successful in particular occupations. Work interests associated with occupations are diverse but, as measured by modern psychological instruments, fall into six summary categories: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional. The traditional core work interests linked to success in STEM occupations are Realistic and Investigative. While STEM jobs satisfy Realistic and Investigative work interests, they are less likely to satisfy Social or Artistic work interests.

We conclude that our education system is not producing enough STEM-capable students to keep up with demand both in traditional STEM occupations and other sectors across the economy that demand similar competencies.

We find that the diversion of STEM talent—which ultimately results in its overall scarcity—owes to the transferability of some STEM competencies into other academic disciplines or the diversion of STEM students into other careers that satisfy alternative personal and work interests and values. In the education system, for example, STEM-related curricula in math and science can lead to a variety of occupations ranging from architecture to business and finance to medicine. What's more, some of these occupations pay better wages than STEM, increasing incentives for some STEM students and workers to leave the field.

We conclude that our education system is not producing enough STEM-capable students to keep up with demand both in traditional STEM occupations and other sectors across the economy that demand similar competencies. The demand for STEM competencies outside STEM occupations is strong and growing. While STEM earnings are high, the earnings of comparably skilled workers in many other high-skill occupations are higher and increasing faster.[13] As a result, traditional STEM occupations oftentimes cannot compete in terms of pay and working conditions.

In other words, even when the numbers indicate that we are producing enough STEM graduates for STEM occupations, we do face STEM scarcity in some occupations because STEM-capable workers divert from STEM into non-STEM occupations, particularly Managerial and Professional and Healthcare Professional occupations.

[13] To some extent this is an artifact of the complex role of knowledge in our economic system. Advances in knowledge are valuable intellectual property that bring high returns to owners. But the extent of individual or institutional ownership and use of new knowledge is time limited and tightly circumscribed. Most innovation is incremental and collective and rarely fully captured privately (Baumol 2002; Mokyr 1990, 2002). As a result government interventions are required to optimize investments.

Part 1: *STEM and the Changing Structure of Innovation*

THE SCOPE OF STEM OCCUPATIONS AND STEM COMPETENCIES GROWS IN TANDEM WITH THE SCOPE OF INNOVATION

STEM professionals touch virtually every facet of our lives at work, at home, and in our complex routines everywhere else. STEM workers design our bridges, invent our medicines and our phones, and create the architecture of our buildings and our Internet. Moreover, because of the key role they play in inventing and making technologies available for commercial use, STEM workers are a significant source of technological changes that ultimately result in up-skilling across the full range of occupations.

There is broad acceptance that STEM professionals are essential for innovation and economic growth. President Obama acknowledged as much when he addressed the National Academy of Sciences: "At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury at moments defined by necessities. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before."

But the role that STEM workers play in innovation is rapidly changing. The "Cold War" model—where the government invested heavily in R&D, and a small cadre of elite scientists made important discoveries, mostly related to national security and weaponry—has been superseded by a much more complex innovation process tied to the global economy.

Although it is still emerging, the structure of innovation is no longer a one-way street from the university labs and corporate campuses to markets. The process of innovation is becoming more collaborative and socially engaged. Our former "linear conception of the relationship between science and innovation . . . needs to be replaced by an inter-active, dynamic, networked . . . understanding that emphasizes learning" (Hansson, Husted, and Vestergaard 2005, 1041).

The new realities create a fundamental divide between innovation and economic value based on major scientific breakthroughs to innovation that use science and technology in innovative networks. The industrial era was driven by major inventions brought to market by firms like General Electric, General Motors, IBM, Kodak, and Xerox. While bringing breakthroughs to market is still characteristic of many industries—pharmaceuticals and chemicals, for example—postindustrial expansion is notable for using existing science and technology in ever more complicated networks. Google, for example, creates new wealth by developing networks made from available technology in collaboration with its users. These new, networked innovation systems require a whole new set of soft skills among STEM professionals who work outside of traditional research environments (Fountain and Atkinson 1998).

Christopher Hill points to the rise of networked firms like Google, Federal Express, Wal-Mart, and Amazon as examples of the growing reach of innovation beyond traditional R&D.[14] Hill argues that these firms are fundamentally different from the industrial-era firms dominated by direct application of

[14] Hill is a professor of Public Policy and Technology at George Mason University.

basic research. These newer, networked organizations have learned to meet human needs in new ways without making advances in basic science. In Hill's view, the cutting edge of technology-based economic innovation—and where the most value is added—is in making the interface with cultures, communities, and individuals more seamless and customizable (Hill 2007).[15]

At its core, innovation still depends on a solid foundation of basic research in the physical, biological, and mathematical sciences as well as in engineering. But the economic value of innovation has shifted toward applications customized to meet critical individual and social needs.

American STEM workers are becoming part of an increasingly global innovation system and workforce.

The iPod exemplifies these trends. Its success is based on diverse foundations in science, math, and engineering, but the majority of its value-added comes from Apple's creative, marketing, and business innovations in response to consumer demand—and it is produced in a global market, for an increasingly global consumer (Linden, Kraemer, and Dedrick 2007).

In this context, the boundaries between STEM occupations and the broader process of innovation blur. Lines are also blurring between the policy domains of science and technology, higher education, workforce development, and economic development (Goddard 2005). Integrating these policy domains is the cutting edge in policy formation and is essential for remaining competitive in a global, knowledge-based economy.

In this emerging innovation system, the United States is an important hub—but not the sole source of innovation (Hill 2007; Freeman 2009). In part, the diversion of domestic STEM talent reflects the broader reach of innovation beyond the traditional specialization of bench scientists and engineers toward integrated networks of manufacturers, producers, and customers across a wide array of industries.

The changing nature of innovation also helps explain the diversion of STEM talent. The nation's STEM talent is chasing exciting innovation opportunities beyond the traditional environs of STEM work into the burgeoning social and economic networks that define the modern postindustrial economy. Moving away from the labs also allows STEM talent to explore and develop a broader range of work values and work interests outside traditional STEM occupations.

INNOVATION IS NOW GLOBAL AND STEM JOBS ARE FOLLOWING

The American STEM workforce is becoming part of an increasingly global system of innovation and STEM workforce development. The growing global system has also helped create a global labor market. As with other jobs, firms are going to continue to shift some STEM jobs offshore. This is in part because it is cheaper to use labor in, for example, India and China, and in part because firms are trying to get a foothold into new markets. To remain competitive, these firms need to engage with diverse global markets and global R&D.

Still, the offshoring of American STEM jobs and the onshoring of foreign-born STEM workers do not mean that the creation of STEM jobs is a zero-sum game. The old hand-me-down system of trade, in which we gave up our less-skilled,

STEM is already one of America's more global workforces and likely to become more so as innovation continues to expand globally.

[15] We are not arguing that there are no longer industries that translate basic research directly into standardized products. Chemicals and pharmaceuticals are examples of sectors where discovery leads relatively directly to commercialization. Instead, the point is that value-added chains have become longer and more complex with the synergy between information technology and globalization.

low-wage, low-technology jobs to developing countries while we focused on occupations, like STEM, that need more skill and command higher wages, is changing in subtle ways. Countries like China, India, and many others are able to "leapfrog" over the traditional developmental path by concentrating human and financial capital in competitive, high-tech industries (Freeman 2005).

The global economy is becoming flatter, but not "flat" (Friedman 2005). Concentrations of infrastructure and human capital are still geographically bounded (Leamer 2006; Goddard 2005; Porter 1998; Trefler 1995). Ironically, competitive advantage in the global economy remains remarkably tied to local, regional, and national clusters of industry and human capital, especially human capital in STEM occupations and competencies.

The United States also relies heavily on foreign-born STEM talent, especially highly educated foreign-born STEM talent. Foreign-born workers already make up about 17 percent of the domestic STEM workforce, with levels reaching 18 percent in Computer occupations and 25 percent in Life and Physical Science occupations. Moreover, there is substantial evidence to suggest that foreign-born STEM workers provide a net benefit to the American economy because they appear to be unusually innovative and create more jobs than they take from native-born Americans (Kerr 2008; Hunt and Gauthier-Loiselle 2008).

The globalization of the STEM workforce and the relatively open U.S. labor market ensure that Americans compete on a global scale for STEM workers and give the United States access to transnational networks of innovation as well as access to foreign markets. Our relatively open economy, our superior economic and technological infrastructure, and our relatively higher salaries for STEM workers have given the United States a competitive advantage in attracting global STEM talent (Freeman 2005).

Arguably, shifting domestic demand makes foreign-born STEM workers effective complements rather than substitutes for the most highly skilled American workers (Kerr 2008; Hunt and Gauthier-Loiselle 2008). Still, we may not be able to successfully acquire the world's STEM talent forever, especially as wages in other parts of the world begin to catch up with wages in the United States.

CURRENT ISSUES IN THE STEM WORKFORCE

The STEM workforce is being affected by a wide range of factors, from a shifting policy environment to technological change to the gloomy economic conditions of the last several years. Although our projections take into account longer-term trends, it is not a barometer of what's currently happening in the workforce. This box is a supplement for readers interested in a more timely account of STEM workforce trends. While anecdotal, these stories provide examples of recent business decisions among industry leaders and their likely impact on employment prospects for workers in the field.

POLICY SHIFTS

Some industries that employ large numbers of STEM workers are dependent on government support and spending, especially the aerospace and defense industries. Significant government spending cutbacks in these areas are likely to have a serious impact on these industries and the STEM workers employed in them.

For example, the recent government decision to end the space shuttle program has resulted in about 8,000 job losses thus far in Florida among both federal workers and contractors. The job losses are rooted where the space program has its hubs; Huntsville, Alabama, for example, recently lost about 280 workers at the Marshall Space Flight Center due to the cancellation of the Constellation Rocket program.[A] Major contractors connected with the Johnson Space Center have lost 900 jobs this year, on top of 1,400 jobs lost last year. The Kennedy Space Center laid off 2,800 employees in late July 2011.[B]

Moreover, due to the budgetary climate, defense spending is being eyed more closely than ever before to improve efficiencies and reduce waste, and STEM workers in this industry have become vulnerable. Lockheed Martin is expected to lay off 6,500 workers, including some engineers who have completed designs of the F-35 Joint Strike Fighter.

The defense and aerospace industry is increasingly hoping to rely on foreign sales for continued growth, although these opportunities are also heavily dependent upon domestic and international politics and are subject to regular change.[C]

TECH HEATING UP

Silicon Valley has been described as on a "hiring spree" and numerous commentators are making comparisons to the dot-com bubble that popped in 2000.[D] Layoffs are down, and both new upstarts and Valley mainstays have been hiring thousands of new workers in Northern California.

[A] Lee Roop, "Nearly 300 More Aerospace Jobs Threatened in Huntsville," *Al.com*, August 8, 2011, http://blog.al.com/breaking/2011/08/nearly_300_more_aerospace_jobs.html.

[B] Gina Sunseri, "Space Shuttle Atlantis: Now, the Layoffs," *ABC News.com*, http://abcnews.go.com/Technology/space-shuttle-atlantis-layoffs-follow-florida-texas/story?id=14119413.

[C] Greg Allen, "End of Shuttle Program Leaves Thousands Jobless," *NPR.org*, July 11, 2011, http://www.npr.org/2011/07/11/137677198/end-of-shuttle-program-leaves-thousands-jobless. Bob Cox, "Fort Worth Plant May Take Hit as Lockheed Martin Cuts 1,500 Jobs," *Fort Worth Star-Telegram*, June 30, 2011, http://www.star-telegram.com/2011/06/30/v-print/3192534/fort-worth-plant-may-take-hit.html. Margerie Censer, "Lockheed Martin Offers Buyouts to 6,500 Employees," *The Washington Post*, July 19, 2011, http://www.washingtonpost.com/business/capitalbusiness/shedding-jobs-lockheed-martin-launches-another-buyout-program/2011/07/19/gIQAVQVMOI_story.html. "The Last Manned Fighter," *The Economist*, July 14, 2011, http://www.economist.com/node/18958487.

[D] STEM is an occupational cluster, but here we often discuss industry. Industries and firms almost never employ exclusively STEM workers, so when discussing Silicon Valley, for example, there may be large numbers of STEM employees, but it is also likely that other occupational clusters—like Sales and Office Support occupations—are also represented.

CURRENT ISSUES IN THE STEM WORKFORCE (continued)

Furthermore, salaries, bonuses, and perks are rising in order to compete for top talent and to retain skilled workers. Tech layoffs decreased in June 2011, while the workforce experienced net growth. High-tech firms in computer, electronics, and telecommunications industries planned to hire over 25,000 workers this year. In fact, it appears that the job market for computer workers is booming.[E]

CONTINUING GLOBALIZATION OF THE STEM WORKFORCE

Globalization is affecting the STEM workforce in complex ways. American companies continue to hire STEM talent abroad. Though they are often offshoring to save labor, they are also increasingly following the market. U.S. manufacturers are hiring engineers abroad (sometimes while cutting payrolls at home), but they report doing so because that is where demand is growing fastest for their products, from elevators and air conditioners to broadband equipment.[F] For example, Intel is recruiting for positions in Shanghai and India, from which they get 75 percent of their revenues; IBM is hiring in Asia; and Microsoft is hiring 100 software engineers, mostly in China, and almost as many in India.[G]

But it is not only American companies that go abroad—in fact, companies from abroad are also interested in the American workforce and are increasingly "in-sourcing" STEM work. Tata Technologies, an Indian company, announced in late 2010 that they would hire 400 engineers by January to work with their car-manufacturing clients in Detroit, nearly doubling their U.S. employment. In 2011, Tata Consultancy Services announced it is adding 1,200 people between March of 2011 and March of 2012 to its U.S. workforce. Likewise, Infosys Technologies, another Indian firm, plans to hire 1,000 workers over the course of the year.[H]

OPEN JOBS, UNEMPLOYED WORKERS (MISMATCH)

Especially in the context of the recession, stories of companies with job openings which are unable to find workers with the necessary technical skills have become popular, both with journalists and with policymakers encouraging investment in education and training. Siemens has reported 3,200 open (but seemingly unfillable) jobs, and in Michigan, Nexteer Automotive is looking for 100 engineers but is having a hard time finding qualified workers. Many others report similar inabilities to hire highly skilled manufacturing workers and engineers.[I]

[E] Brian Burnseed, "Navigate the Booming Computer Science Market," *U.S. News and World Report*, August 8, 2011, http://www.usnews.com/education/best-colleges/articles/2011/08/08/navigate-the-booming-computer-science-market. Dan Simon, "Silicon Valley Experiencing New Hiring Boom," *CNN.com*, April 5, 2011, http://articles.cnn.com/2011-04-05/tech/silicon.valley.job.market_1_software-engineers-job-market-simplyhired?_s=PM:TECH. "Despite Cisco's Layoff Plans, 2011 Good Year for High-Tech Workers," *International Business Times*, July 12, 2011, http://www.ibtimes.com/articles/178788/20110712/cisco-layoffs-high-tech-workers.htm.

[F] Agence France-Presse, "Tata Plans Hiring Spree in Detroit," *Industry Week*, December 6, 2010, http://www.industryweek.com/articles/tata_plans_hiring_spree_in_detroit_23356.aspx. "Google to Go on Big Hiring Spree in 2011," *CBSNews.com*, January 26, 2011, http://www.cbsnews.com/stories/2011/01/25/business/main7282750.shtml. Scott Malone and Nick Zieminski, "Strong Foreign Demand Drives U.S. Manufacturers," Reuters, July 20, 2011, http://www.reuters.com/article/2011/07/20/us-usa-manufacturing-results-idUSTRE76J5MY20110720.

[G] Ron Schneiderman, "Job Market Becoming More Competitive for Engineers in Asia Pacific Region," *IEEE Magazine*, August 10, 2011, http://www.newswise.com/articles/job-market-becoming-more-competitive-for-engineers-in-asia-pacific-region.

[H] John Boudreau, "Indian outsourcers now 'insourcing' jobs to Silicon Valley," *MercuryNews.com*, August 5, 2011, http://www.mercurynews.com/breaking-news/ci_18625774.

[I] Harry Bradford, "Siemens CEO: 'Mismatch' Between U.S. Jobs Available, Skills Needed," *The Huffington Post*, June 21, 2011, http://www.huffingtonpost.com/2011/06/21/siemens-ceo-there-is-mismatch-jobs-unemployed_n_881257.html?view=screen. Kathryn Lynch-Morin, "Wanted: Qualified Engineers," *The Saginaw News*, June 27, 2011, http://www.mlive.com/business/index.ssf/2011/06/wanted_qualified_engineers.html.

Part 2: *What is STEM?*

THERE IS GREAT VARIETY AMONG STEM OCCUPATIONS

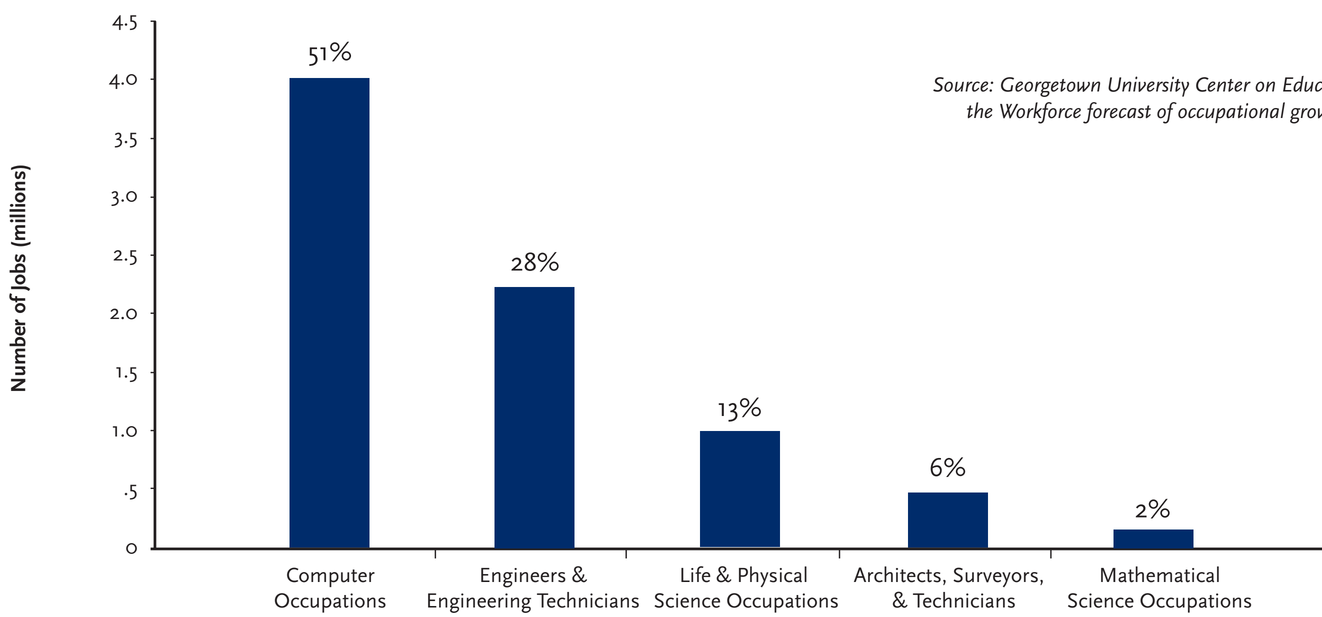
STEM occupations include five major subgroups:[16]

- Computer occupations[17]
- Mathematical Science occupations
- Architects, Surveyors, and Technicians
- Engineers and Engineering Technicians
- Life and Physical Science occupations.[18]

Jobs in these occupations include computer scientists, network and computer systems administrators, database administrators, architects, architectural drafters, nuclear technicians, various kinds of engineers, hydrologists, materials scientists, geneticists, microbiologists, biochemists, and many others.

Although we discuss STEM as a unitary set of occupations, there is much diversity under the broader STEM umbrella.

Figure 1: Computer occupations dominate STEM: 2018



Source: Georgetown University Center on Education and the Workforce forecast of occupational growth, 2018.

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[16] Computers (SOC 15-1111–SOC 15-1199); Mathematical Science (SOC 15-2011–SOC 15-2099); Architects, Surveyors, and Technicians (SOC 17-1011–SOC 17-1022; SOC 17-3011–SOC 17-3019; SOC 17-3031); Engineers and Engineering Technicians (SOC 17-2011–SOC 17-2199; SOC 17-3021–SOC 17-3031); Life and Physical Science (SOC 19-1011–SOC 19-2099; SOC 19-4011–SOC 19-4099).

[17] We use "Computer occupations" and "Computer workers" throughout the report as shorthand for Computer Technicians, Computer Programmers, and Computer Scientists.

[18] Our definition of STEM excludes social scientists. In a separate analysis, we provide education and training information for the social scientists (see Carnevale, Smith, and Strohl 2010).

The rapid growth of STEM occupations as a group masks marked differences in growth among particular STEM occupations.

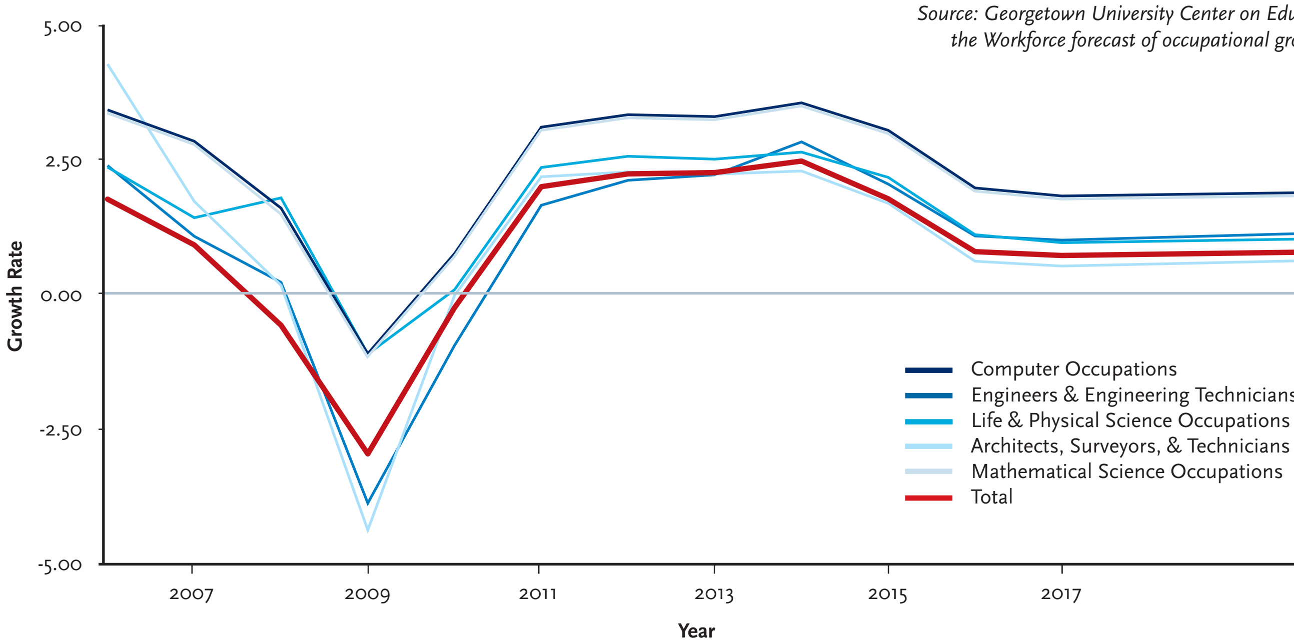
The relative importance of each occupation within STEM varies significantly. Figure 1 shows that Computer occupations are forecast to continue leading STEM occupations in 2018, increasing its share to 51 percent.[19] The share of Engineering and Engineering Technician occupations, meanwhile, are forecast to decline, going from 31 percent in 2005 to 28 percent in 2018. This reduction is associated with the overall employment decline of the Manufacturing industry.[20] Mathematical Science occupations are a very small portion of STEM jobs (2%) as are Architects, Surveyors, and Technicians (6%).

Figure 2 shows the annual growth rates for each of the STEM occupations and total U.S. employment between 2006 and 2018 (inclusive). The impact of the recent recession on the growth rates of all jobs, including those in the STEM sector, is clearly demonstrated by the sharp drop of almost 5 percent in 2009. Through 2011 and 2012, however, STEM occupations will climb out of the trough and begin creating new and replacement opportunities and attracting new candidates. These opportunities will continue to grow through 2015, when they are projected to level off at a more stable growth rate after 2016.

Growth rates are also forecast to vary widely within STEM. The sector's fastest-growing occupations are in Computer occupations (forecast growth rate of 23% between 2008 and 2018), while the slowest growing are Architects, Surveyors, and Technicians occupations (forecast growth rate of 8%).

Figure 2: Employment growth dropped during the recession but will come back by 2018

Source: Georgetown University Center on Education and the Workforce forecast of occupational growth, 2018.



[19] For a detailed description of our methodology, please see the Technical Appendix. These are derived from our projections of the entire economy and educational requirements (see Carnevale, Smith, and Strohl 2010).

[20] Manufacturing is still the nation's largest industry as measured by total output. While Manufacturing jobs will decline overall, there will still be more than 2 million job openings in Manufacturing due to retirements. Our own projections show Manufacturing output growing from almost $4 trillion in 2008 to almost $5 trillion by 2018. Manufacturing was once the nation's largest industry as measured by jobs, although it peaked in 1979. Productivity in this industry means that it is able to increase output with fewer employees, thus resulting in slack demand for new workers (Carnevale, Smith, and Strohl 2010).

There will be 2.4 million job vacancies for STEM workers between 2008 and 2018.

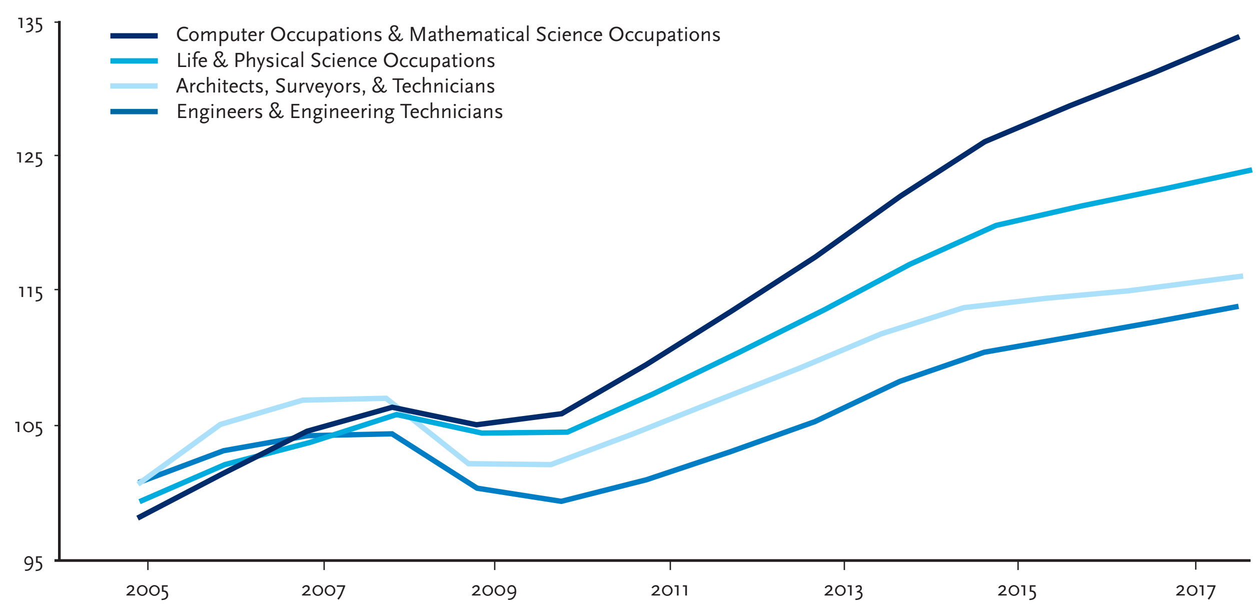
Still, as Figure 3 shows, some STEM occupations will rebound from the recession faster than others. Computer occupations and Life and Physical Science occupations are more resilient and will recover faster than the rest of the STEM group, and in fact they will grow faster than U.S. employment as a whole. Their resiliency is attributable to the fact that these occupations are mostly concentrated in the industries that are growing fastest, especially the Professional and Business Services industry.

Among STEM jobs, Architects, Surveyors, and Technicians have suffered the largest losses during the recession. At the beginning of the period, those jobs showed the fastest growth rates of the group, but when the recession hit and the real estate market collapsed, Architects, Surveyors, and Technicians were quickly left without much work. Recovery for those jobs will lag behind the rest of the economy, again due to the dragging housing market.[21]

STEM IS PROJECTED TO GROW AT 17 PERCENT THROUGH 2018.

In spite of the variation in growth rates, STEM occupations as a whole will have gained ground compared with the rest of the economy by the time the United States fully emerges from the recession. While the total number of jobs in the United States will grow 10 percent between 2008 and 2018, from 148 million to 162 million, the number of STEM jobs is projected to grow by 17 percent, making it one of the most dynamic occupation clusters in the economy. It will be surpassed in growth rates only by Healthcare occupations.[22]

Figure 3: STEM job projections normalized (2005 = 100)

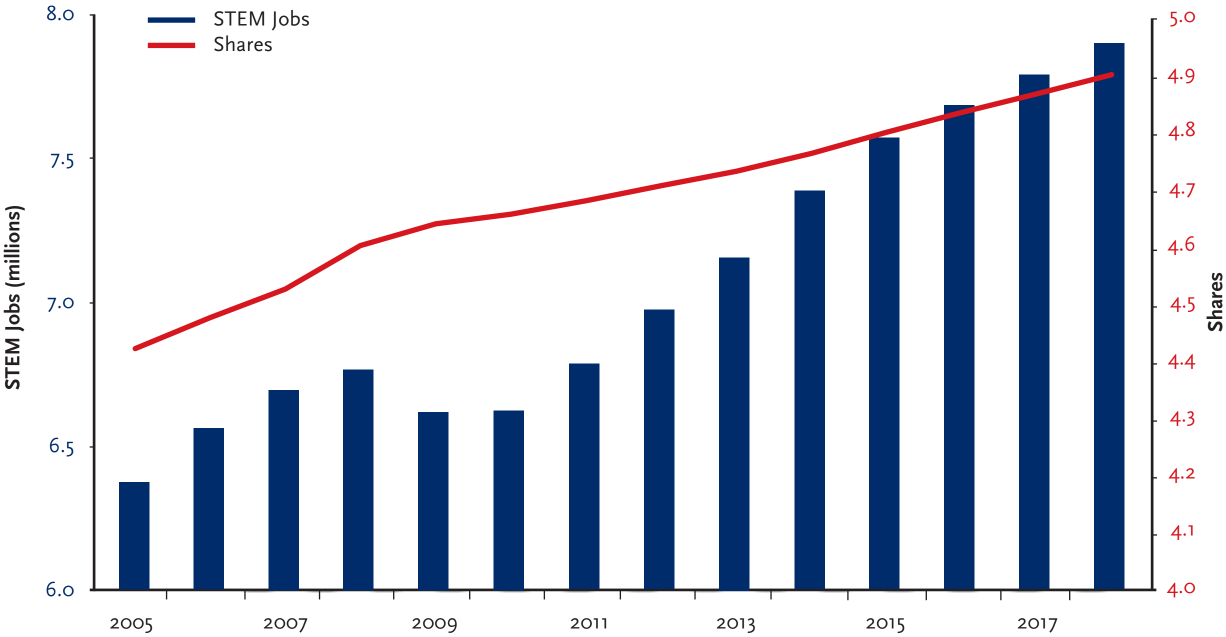


Source: Georgetown University Center on Education and the Workforce forecast of occupational growth, 2018.

[21] These projections are based on relative continuity and do not take into account outlier events or extremely unpredictable future instability. They are based on very specific assumptions about the behavior of the macroeconomy and captured by 134 estimated equations in Macroeconomic Adviser's Washington University Macro Model (WUMM), which forms the basis of our macro estimates.

[22] Healthcare includes Healthcare Professional occupations as well as Healthcare Support occupations.

Figure 4: STEM Jobs are an increasing share of all jobs in the U.S. economy.

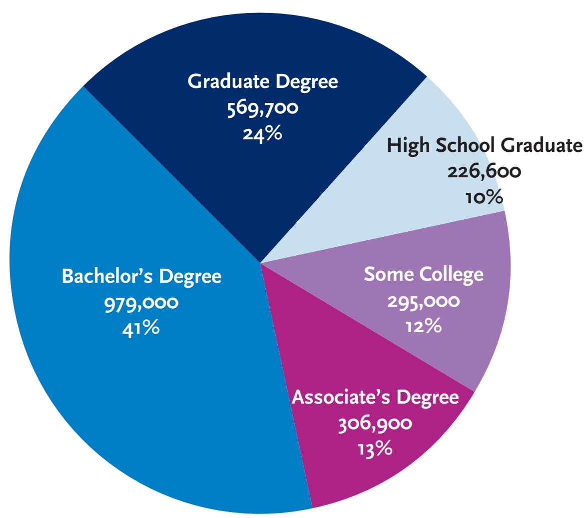


Source: Georgetown University Center on Education and the Workforce forecast of occupational growth, 2018.

Figure 4 shows projected STEM occupations (bars) and their share of the total U.S. economy (line). As with many other occupations during the recession, STEM lost a substantial number of jobs in 2009 and 2010. It will regain those—and more—once the recovery is fully under way. We project steady expansion for the sector through 2018, when the number of STEM jobs will have grown from 6.8 million to nearly 8 million—from 4.4 percent to 4.9 percent of all jobs in the U.S. economy.

Coupled with the rapid creation of new STEM jobs will be significant job openings due to baby-boomer retirements. Job openings arise when new jobs have been created or when replacement positions have become available due to incumbent workers retiring or moving to other sectors of the economy. We project 2.4 million job vacancies for STEM occupations between 2008 and 2018. Figure 5 shows the education levels those jobs will require. As with STEM jobs in general, a substantial portion of the projected vacancies (65%) will require Bachelor's and graduate degrees. Despite the educational intensity of the field, however, there will also be over 799,000 job openings available in STEM occupations for workers with less than a Bachelor's degree (see Table 1).

Figure 5: Distribution of STEM new and replacement occupations by level of education in 2018: The majority of new and replacement occupations in STEM will require at least some postsecondary education



Employment projections of STEM new and replacement jobs through 2018: 2.4 million

Source: Georgetown University Center on Education and the Workforce forecast of occupational growth through 2018.

Table 1: Education distribution of job growth due to new and replacement STEM jobs 2018

LEVEL OF EDUCATION	COMPUTER OCCUPATIONS	ENGINEERS & ENGINEERING TECHNICIANS	LIFE & PHYSICAL SCIENCE OCCUPATIONS	ARCHITECTS SURVEYORS & TECHNICIANS	MATHEMATICAL SCIENCE OCCUPATIONS	TOTAL STEM
High School Dropout	10,100	1,600	-	300	-	**12,000**
High School Graduate	85,000	130,800	6,100	4,000	700	**226,600**
Some College	184,600	98,100	3,300	4,600	4,400	**295,000**
Associate's Degree	121,400	175,500	-	8,300	1,700	**306,900**
Bachelor's Degree	563,400	182,400	129,900	79,400	23,900	**979,000**
Master's Degree	221,900	72,600	85,000	40,100	11,600	**431,200**
Professional Degree	8,700	5,300	8,700	2,300	1,900	**26,900**
Doctorate	24,600	9,500	69,200	3,700	4,600	**111,600**
Total	**1,219,700**	**675,800**	**302,200**	**142,700**	**48,800**	**2,389,200**[1]

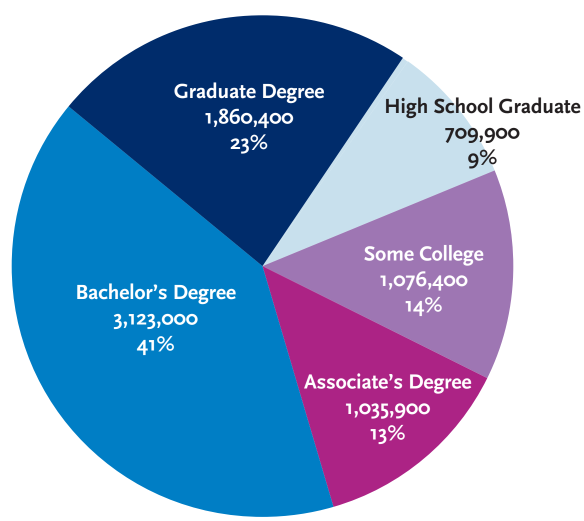
Source: Georgetown University Center on Education and the Workforce forecast of occupational growth through 2018.
[1] Numbers may differ slightly due to rounding.

Additionally, while on the whole, STEM occupations require high educational attainment, there is significant variation within different STEM occupations, as shown in Table 2. For example, Life and Physical Science occupations rely heavily on the highest levels of education, with almost half of the demand in these occupations being for workers with Master's and Doctoral degrees. Computer workers and Mathematical Science occupations, as well as Architects, Surveyors, and Technicians, mostly demand Bachelor's degrees. In contrast, many Engineering occupations require Associate's degrees and/or some college, including postsecondary vocational certificates.

MOST, BUT NOT ALL, STEM JOBS REQUIRE AT LEAST A BACHELOR'S DEGREE

Close to two-thirds (65%) of STEM jobs will require a Bachelor's degree or better by 2018. Overall, STEM is the third-most education-intensive occupational cluster, exceeded only by Healthcare Professional occupations and Education occupations.

Figure 6: Distribution of all STEM occupations by level of education in 2018



Employment projections of STEM jobs in 2018: 8 million

Source: Georgetown University Center on Education and the Workforce forecast of occupational growth through 2018.

Close to a quarter (23%) of STEM jobs in 2018 will be for workers with graduate degrees (PhDs and Master's degrees)—more than half a million jobs in 2018. Fifty-one percent of the demand for workers with Master's degrees in STEM will be for Computer workers; while 62 percent of demand for Doctoral degrees in STEM will be in Life and Physical Science occupations.

However, our projections also show that there are many opportunities for STEM workers at the sub-baccalaureate level. Thirty-five percent of all STEM jobs in 2018 will be open to people with less than a Bachelor's degree.

At present, just over 1 million workers in STEM occupations—14 percent of the STEM workforce—have some college education and training (including postsecondary certificates) but no degree.[23] In a separate analysis using O*NET data, we find that 576,000 Computer jobs (about 14% of all Computer jobs) will require a postsecondary vocational certificate in 2018. About 6 percent (169,000) of all Engineering and Engineering Technician occupations will require a certificate in 2018. Life and Physical Science occupations do not require certificates. A more detailed table providing distributions of these certificates across STEM occupations can be found in Appendix B.[24]

In addition to certificates, industry-based certifications are common in STEM occupations. Unfortunately, there is no comprehensive data source on industry-based certifications. What data we do have come from Payscale.com, which relies on a self-reported survey.[25] Of the approximately 200 different certifications that an individual is able to obtain which are listed on the site, about 35 of them are STEM-related. These are mostly IT related and include "Certified Professional Engineer," "CompTIA A+ Service Technician Certification," and "Microsoft Office Specialist, Excel Certification." For a complete list of STEM-related certifications reported by Payscale.com, see Appendix C.

The same survey reports about 760,000 individuals holding industry-based certifications, of which about a quarter are in STEM. While the survey is unscientific, STEM certifications—especially IT-related certifications—are clearly a significant part of the certifications market.[26] Of the top 10 most-listed certifications on the survey, half are STEM-related. The most frequently reported STEM certifications are "Microsoft Certified Professional," "Engineer in Training," "CompTIA A+ Service Technician," "Certified Professional Engineer," and "Cisco Certified Network Associate."

STEM JOBS BY INDUSTRY

STEM JOBS ARE CONCENTRATED IN PROFESSIONAL AND BUSINESS SERVICES AND MANUFACTURING

Engineers and Engineering Technicians are concentrated in the Manufacturing industry (46%), as well as the Professional and Business Services industry (26%), with the next highest concentration in the Government and Public Education Services (6%) and Natural Resources and Mining industries (5%).

Engineers and Engineering Technicians also comprise over 10 percent of all STEM workers in four industries. Mathematical Science occupations are dispersed across industries, being concentrated in Financial Services (33%), Professional and Business Services (21%), Government and Public Education Services (22%), and Manufacturing (8%).

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[23] Computer workers will also have significant numbers of test-based certifications and are likely to be included in this some college/no degree grouping.

[24] Many of these certificates will be obtained by individuals who already have another degree, while some will be counted as part of "some college/no degree" category of workers. Therefore, we cannot just add the number of certificates to the number of degrees and find the number of postsecondary credentials in STEM including certificates.

[25] Although there are numerous problems with the Payscale.com database, it is the best data available on industry-based certifications. However, the database also lists licenses and, in a few rare cases, certificates as industry-based certifications. The main problem with the Payscale data is that they are self-reported, thus contributing to possible selection bias.

[26] Certifications are test-based credentials earned for the purpose of proving competency in a particular field or job function. Many employers require them also for insurance purposes as proof that employees have passed industry standards of performance set for the occupation in question. Unlike certificates, certifications are test-based and must be re-validated after an established period of time.

Table 2: Industrial Distribution of STEM jobs

Industry	STEM
Natural Resources and Mining	4%
Construction	2%
Manufacturing	19%
Wholesale and Retail Trade	3%
Transportation and Utility services	3%
Information services	3%
Financial services	9%
Professional and business services	37%
Private Education Services	4%
Healthcare Services	3%
Leisure and Hospitality	1%
Personal Services	1%
Government and Public Education Services	13%

Source: American Community Survey (2009)

Life and Physical Scientists are highly concentrated in Professional and Business Services (30%), Manufacturing (26%), Government and Public Education Services (16%), Natural Resources and Mining (12%), Private Education Services (8%), and Healthcare Services (6%).

Computer occupations are the most widely represented across industries. For example, 9 percent are in Information Services, 12 percent are in Financial Services, 36 percent are in Professional and Business Services, 7 percent are in Government and Public Education Services, and 12 percent are in Manufacturing.

PROFESSIONAL AND BUSINESS SERVICES

The Professional and Business Services industry employs workers who provide consulting, temporary help, technical support, and network computing and communications support to the complex organizational networks that typify the postindustrial economy. In the top-down, vertically integrated older industrial economy, many of these same workers would have been hired on staff. General Motors, for example, had its own printing press and cafeteria workers on staff. But the complex institutional networks of the postindustrial era have replaced the top-down hierarchies. In these new organizational formats, only core competitive competencies are retained. Everything else, from architecture to computing to human resource functions, has been contracted out to businesses in the Professional and Business Services industry.

Professional and Business Services is the nation's third-largest industry by output (behind Manufacturing and Financial Services), producing more than $2.5 trillion in economic output in 2008 and projected to increase by another $1 trillion by 2018 (Woods 2009). Growth in this industry is a result of the increasing pace of change and complexity of institutional environments as employers struggle to retain and expand market shares in rapidly shifting environments.

The Professional and Business Services industry employed 19.7 million workers in 2008—13 percent of the U.S. workforce. We project it will add 1.4 million new jobs by 2018, making it second only to Wholesale and Retail Trade Services as the industry with the greatest growth.

Each occupational group within the STEM cluster, from actuaries to chemists, is heavily represented in the large, diverse Professional and Business Services industry. More than a quarter of Engineers and Engineering Technicians (26%), 30 percent of Life and Physical Science occupations, more than a third of Computer workers (36%), 21 percent of Mathematical Science occupations, and more than 70 percent of Architects, Surveyors, and Technicians are concentrated in the Professional and Business Services industry.

However, some occupations are more heavily concentrated in Professional and Business Services than others. For example, 84 percent of all architects, 73 percent of all surveying and mapping technicians, and 59 percent of all civil engineers are found in this industry.

MANUFACTURING

A high proportion of STEM occupations also reside in the Manufacturing industry, even as the industry continues to shrink as a percentage of all jobs in the economy. Manufacturing includes the makers of nondurable goods that are quickly used up, such as cosmetics or office supplies, as well as the makers of durable goods that are used for several years, such as cars. For many years, Manufacturing was the nation's largest employer, peaking in 1979. By 2008, Manufacturing was still our largest industry as measured by the value of its output, but it ranked sixth in terms of employment, with 13.6 million workers or about 9 percent of the nation's workforce. Manufacturing is expected to remain our largest industry as measured by output, but employment is projected to decline by 4 percent between 2008 and 2018. Increased productivity is the primary cause of declining employment shares. Therefore, in spite of increasing output by almost $1 trillion by 2018, Manufacturing's share of total output, its *share* of total employment, and its actual employment level all are expected to decline over the next decade.

Despite its declining shares of employment, there will be substantial job openings in Manufacturing due to retirements in the existing workforce. There will be 2 million job openings between 2008 and 2018 in the Manufacturing industry as a result of retirement.[27] The industry will rank eighth in total jobs openings, all from replacement of retiring workers.

Despite its declining shares of employment, there will be substantial job openings in Manufacturing due to retirements in the existing workforce. There will be 2 million job openings between 2008 and 2018 in Manufacturing as a result of retirement.

Output growth in Manufacturing will be led by the manufacture of computer and information technologies—the technologies at the heart of the structural change that demands increasing postsecondary education throughout the economy. Ironically, like all sectors of the Manufacturing industry, information technology (IT) manufacturing employment is the victim of its own successful technological revolution.[28] They have experienced the most intense productivity increases from automation, which has contributed to falling employment. As a case in point, the computer and peripheral equipment manufacturing sector will grow by almost $800 billion in output—while its employment is expected to decline by almost 60 percent (Carnevale, Smith, and Strohl 2010).

Engineers and Engineering Technicians are heavily concentrated in the Manufacturing industry, although some occupations more so than others. In particular, 85 percent of aerospace engineers, 89 percent of chemical engineers, 91 percent of materials engineers, 75 percent of industrial engineers, and 75 percent of chemical technicians are in Manufacturing. Moreover, over half of chemists, materials scientists, and biomedical and agricultural engineers are also concentrated in Manufacturing. The STEM jobs concentrated here are shrinking relative to those located in other industries.

GOVERNMENT AND PUBLIC EDUCATION SERVICES

The Government and Public Education Services industry, meanwhile, has been growing steadily, even throughout the recession. Government and Public Education Services encompasses a wide range of occupations, STEM among them. Of all STEM occupations, computer scientists, systems analysts, and operations research analysts are most prevalent in Government and Public Education Services (comprising 12% and 10%, respectively). Miscellaneous engineers, including nuclear

[27] Although we project that the industry will have some 2.6 million openings to replace retiring workers, about 565,000 of those jobs will be lost permanently, shrinking the number of actual openings.

[28] IT jobs that require limited local knowledge or innovation are liable to be outsourced because jobs such as computer programming is not place-specific and the transportation costs are close to zero. However, the impending retirement of many baby boomers in this occupation guarantees a significant amount of job openings—at least temporarily—to those with IT qualifications. Close to 40 percent of workers in IT were between 45 and 63 years of age in 2009. Career opportunities in the IT industry will be best for workers with experience in information protection and security, as sensitive information—bank records, health records, and corporate and national secrets—increasingly shift online and need to be protected.

engineers, comprise 9 percent of STEM workers in Government and Public Education Services, followed by computer software engineers (7%), computer support specialists (5%), network and computer systems administrators (4%), environmental scientists and geoscientists (4%), and biological scientists (4%), among others.

INFORMATION SERVICES

About 11 percent of the Information Services industry is comprised of STEM workers. The Information Services industry includes Internet service providers as well as newspaper publishers, libraries and archives, the motion picture and video industry, plus all other broadcast industries. It is the signature service industry of the postindustrial economy.

Because it sits at the heart of the economy's computer and communications technology change, the Information Services industry is a mixed bag of rapid growth and decline. Industry employment boomed in the 1990s as part of the start of the computer revolution, went bust when the dot-com bubble burst, but has grown at a slow and steady pace ever since.

While output in the Information Services industry will grow more than any other industry, employment growth will not keep up. Output will grow by 69 percent, while employment will grow by only 10 percent between 2008 and 2018. Information Services accounted for 3.1 million jobs in 2008, and we forecast that it will employ 3.4 million workers in 2018—an increase of about 290,000. The industry will create 985,000 total job openings due to retirement by 2018 and will rank 12th out of 13 industries in job openings. The strongest employment growth in this sector will come from software publishing, Internet publishing, the development of web search and service portals, and associated customer services as electronic media capture market shares from more traditional media.

Part 3: *Wages for STEM Workers*

STEM MAJORS VERSUS STEM WORKERS

In the STEM wages section we discuss two broad categories: those who majored in STEM fields when obtaining a Bachelor's degree, regardless of whether or not they work in a STEM occupation, and those who work in STEM occupations, irrespective of their initial undergraduate majors. As discussed in the introduction, there are many circumstances where STEM-trained workers have chosen not to work in a STEM field, and where workers without direct STEM training are employed in STEM occupations. In this initial analysis, we focus on workers engaged in an occupation in the physical sciences, computers and technology, engineering, or mathematical occupations or who have studied these fields as undergraduates. We use the following terms to distinguish when we are talking about each:

- STEM **majors** are of prime age (25–54), have a Bachelor's degree in a STEM field, and work in any occupation.
- STEM **workers** are of prime age (25–54) and work in a STEM occupation at any education level.

WAGES SUMMARY

There has been much debate over STEM wages. We find that while educational attainment matters in determining earnings, so does occupational choice. People with the same certificates and degrees have different earnings depending on the occupation (and to some extent the industry) in which they work.[29]

In addition, when comparing the growth in STEM wages to growth of non-STEM wages over the last several decades, we find that STEM wages have kept up with wages in general.[30] However, STEM wages have not grown as fast as wages for Healthcare Professional and Managerial and Professional occupations.[31]

We provide a breakdown of average earnings by disaggregated STEM occupations, education level, race/ethnicity, age-cohort, and sex.

We find that:

- Although some STEM jobs, such as those for certain PhD-holders in academia, are over-supplied, the rising wage advantages of STEM occupations at many other levels of educational attainment confirm relative shortages of

[29] See Carnevale, Rose, and Cheah (2011) for more on lifetime earnings by occupation and education.

[30] It is important to recognize that although STEM wages do not grow as fast as those for Healthcare Professional or Managerial and Professional workers, they grow at faster rates than any other occupation *with comparable years of schooling*. Social workers, teachers, and many other occupations require Bachelor's degrees to enter the profession and are not paid as well as STEM workers (even after adjusting for the work-year differences among teachers). In addition, although the growth rate of some STEM occupational earnings is slower than some other occupations, the initial earnings level is also higher. Entry-level engineers with a Bachelor's degree are able to command almost $20,000 more per year than entry-level educators with comparable levels of education.

[31] There is some amount of consensus in the STEM establishment surrounding the exclusion of "nonelite" occupations with which we compare STEM. This view is supported by the notion that a STEM job that adds innovative value can only begin at the Bachelor's degree level. We disagree. The appropriate comparison for STEM jobs are with other occupations with comparable years of schooling and preparation. There are many non-Bachelor's degree-level STEM jobs that are valuable to innovation and pay reasonably good wages.

workers for those in-demand STEM competencies.

- STEM occupations pay well at all education levels—and they pay more than all other occupations for those with high school or less, some college/no degree, certifications, and Associate's degrees. People in STEM occupations who have a high school diploma or less have higher lifetime earnings than people in other occupations with similar education levels (approximately $500,000 more).[32]
- People in STEM occupations earn an average of $14,000 extra per year *at every education level* over other occupations, except at the Master's and better level. At the Master's and better level, non-STEM Managerial and Profession and Healthcare Professional occupations earn more substantial wage premiums.
- No matter what their occupation, STEM majors make substantially more over their lifetimes than non-STEM majors, by about $300,000 ($2.1 million versus $2.4 million). STEM majors also earn considerably more over their lifetimes in some non-STEM occupations than in STEM occupations.
- Less-educated STEM workers can also earn more than non-STEM workers with higher education levels. For example, a worker with some college or a postsecondary vocational certificate who works in an Engineering and Engineering Technicians occupation earns $29,000 per year more than a worker with a Bachelor's degree who works as a high school teacher.
- Wages for Engineers and Engineering Technicians and Computer workers have grown slowly compared with the wages of all other workers, but this is primarily due to the fact that their base earnings are so high.[33] Even with slow growth, workers in these occupations do well financially.[34]

STEM EARNINGS ADVANTAGES ARE HIGH AND GROWING FASTER THAN WAGES FOR SIMILARLY-EDUCATED WORKERS—EXCEPT WORKERS IN HEALTHCARE PROFESSIONAL AND MANAGERIAL AND PROFESSIONAL OCCUPATIONS

STEM workers earn family-sustaining earnings at all levels of educational attainment and have enjoyed a consistent premium over non-STEM workers as a whole. STEM workers fare significantly better than non-STEM workers, both in terms of higher annual earnings and relatively lower unemployment rates. Depending on the subgroup occupation, some STEM workers can even earn as much as $35,000 more than the average worker at similar education levels in other occupations.

Several studies have noted that wages for STEM workers have been slow-growing in recent years (Lowell and Salzman 2007). Our analysis does not support this view when STEM workers are compared with all workers with similar education levels. Although we agree with other researchers that STEM earnings have been growing more slowly relative to the highest-earning individuals in our society (i.e., Healthcare Professional and Managerial and Professional occupations), these people represent a small slice of elite workers and STEM wages have not been growing slowly compared with a general baseline.

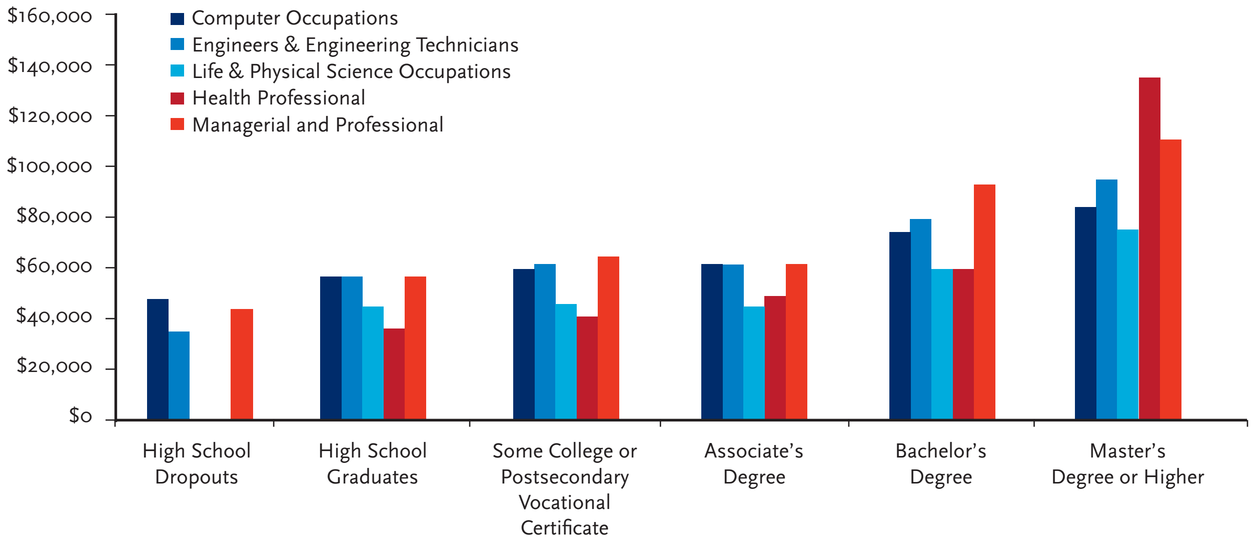
We find that real STEM wages have risen for every level of educational attainment over the 30-year time frame of this study (pooled data 1980–1984, and 2005–2009). Indeed, the growth rate for wages in all STEM occupations as a whole was

[32] It is important to recognize that although STEM wages do not grow as fast as those for Healthcare Professional or Managerial and Professional workers, they grow at faster rates than any other occupation *with comparable years of schooling*. Social workers, teachers, and many other occupations require Bachelor's degrees to enter the profession and are not paid as well as STEM workers (even after adjusting for the work-year differences among teachers). In addition, although the growth rate of some STEM occupational earnings is slower than some other occupations, the initial earnings level is also higher. Entry-level engineers with a Bachelor's degree are able to command almost $20,000 more per year than entry-level educators with comparable levels of education.

[33] There is also consensus in the STEM establishment that wages of STEM workers grow more slowly than others. This is true. What is also true is the fact that STEM workers start off higher than many others. For example, the average engineer today earns at least $80,000, placing these workers at the top end of the earnings distribution for the country.

[34] In a perfectly competitive labor market, wages are the equilibrium between the demand and supply of labor. There are many reasons, however, why wages rise that might have less to do with demand and supply and are more tightly linked to institutional factors. For example, in tight labor markets, wages above equilibrium (efficiency wages) may also be paid to workers to guarantee their tenure or as a premium for a special skill or attribute. Strong unions and minimum wage legislation also result in wages above equilibrium.

Figure 7: At the highest levels of educational attainment, STEM wages are not competitive. Degree matters: Graduate degrees confer real advantages to both management and healthcare (2009$)



Source: ACS, 2005–2009

31 percent, compared with 23 percent for all non-STEM occupations (combined). What's more, wages for STEM workers rose faster than wages for non-STEM workers as a whole. Disaggregating the non-STEM group, however, reveals that wages for Healthcare Professional and Managerial and Professional occupations have risen faster than wages for STEM.

High and rising STEM wage premiums indicate a relative shortage of STEM workers.[35] Rising wages can indicate excess demand or a short-term inability of supply to meet demand for a particular skill. This is because wages reflect the interaction between relative supply and demand for labor, and rising pay means that employers are paying higher wages to guarantee a worker's tenure or as a premium for special skills or training in tight labor markets.

Measuring by relative wage gains over the past 30 years, Healthcare Professional and Managerial and Professional workers are the biggest winners. We've separated these two occupational categories from the rest of the non-STEM group because, as we detail below, these occupations are competing for and diverting STEM talent both in the education system and in the labor market.

WAGES FOR STEM WORKERS ARE HIGH AT ALL LEVELS OF EDUCATIONAL ATTAINMENT

WAGES PAID TO SUB-BACCALAUREATE STEM WORKERS ARE ALSO BETTER THAN WAGES PAID TO THEIR NON-STEM COUNTERPARTS[36]

STEM occupations are dominated by workers with Bachelor's degrees and better, and STEM is one of the most postsecondary-concentrated occupational clusters. However, over 25 percent of STEM workers hold an Associate's degree, postsecondary vocational certificate, industry-led, test-based certification or license, or some college credit courses beyond a

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35 "Premium" refers to the percentage by which the annual earnings achieved by STEM workers exceed that achieved by individuals who are not employed in a STEM occupation.

36 To be clear, we are not advocating stopping school below the Bachelor's level. To the contrary, workers with a Bachelor's degree in STEM, on average, enjoy greater wage opportunities than those without a Bachelor's degree. However, the fact remains that even for sub-baccalaureate workers, STEM earnings are above average.

high school diploma. These credentials have value in the labor market—a value that is reflected in the relatively higher wages that employers pay these workers.

WAGES FOR STEM WORKERS WITH ASSOCIATE'S DEGREES ARE HIGH

Ten percent of all STEM workers possess an Associate's degree. Of all STEM workers with Associate's degrees, 44 percent are in Computers and 35 percent are in Engineering and Engineering Technician occupations. Wage opportunities for workers with this level of education are also good. For example, those with an Associate's degree who work in Engineering and Engineering Technician or Computer occupations earn $63,000, on average—which is $21,000 more than the average earnings for non-STEM Associate's degree-holders. STEM workers with Associate's degrees also earn more than Healthcare workers ($50,000 for Associate's) with the same qualification but have earnings similar to those with an Associate's who work in Managerial and Professional occupations.

SOME COLLEGE, POSTSECONDARY VOCATIONAL CERTIFICATES, AND INDUSTRY-LED, TEST-BASED CERTIFICATIONS

STEM workers with some college or a postsecondary vocational certificate make up 11 percent of the STEM workforce and earn, on average, $53,000 per year. Of all STEM workers with some college, or a postsecondary vocational certificate, 53 percent work in Computers and 27 percent in the Engineering and Engineering Technician professions. For some college workers in STEM, those in Engineering Technician occupations have the highest average annual wages, earning $63,000 (same as some college or a postsecondary vocational certificate), followed by those in Computers ($61,000) while workers in Healthcare with similar levels of educational attainment earn only $42,000 on average—mostly due to the fact that advancement in these occupations requires further education.

Figure 8

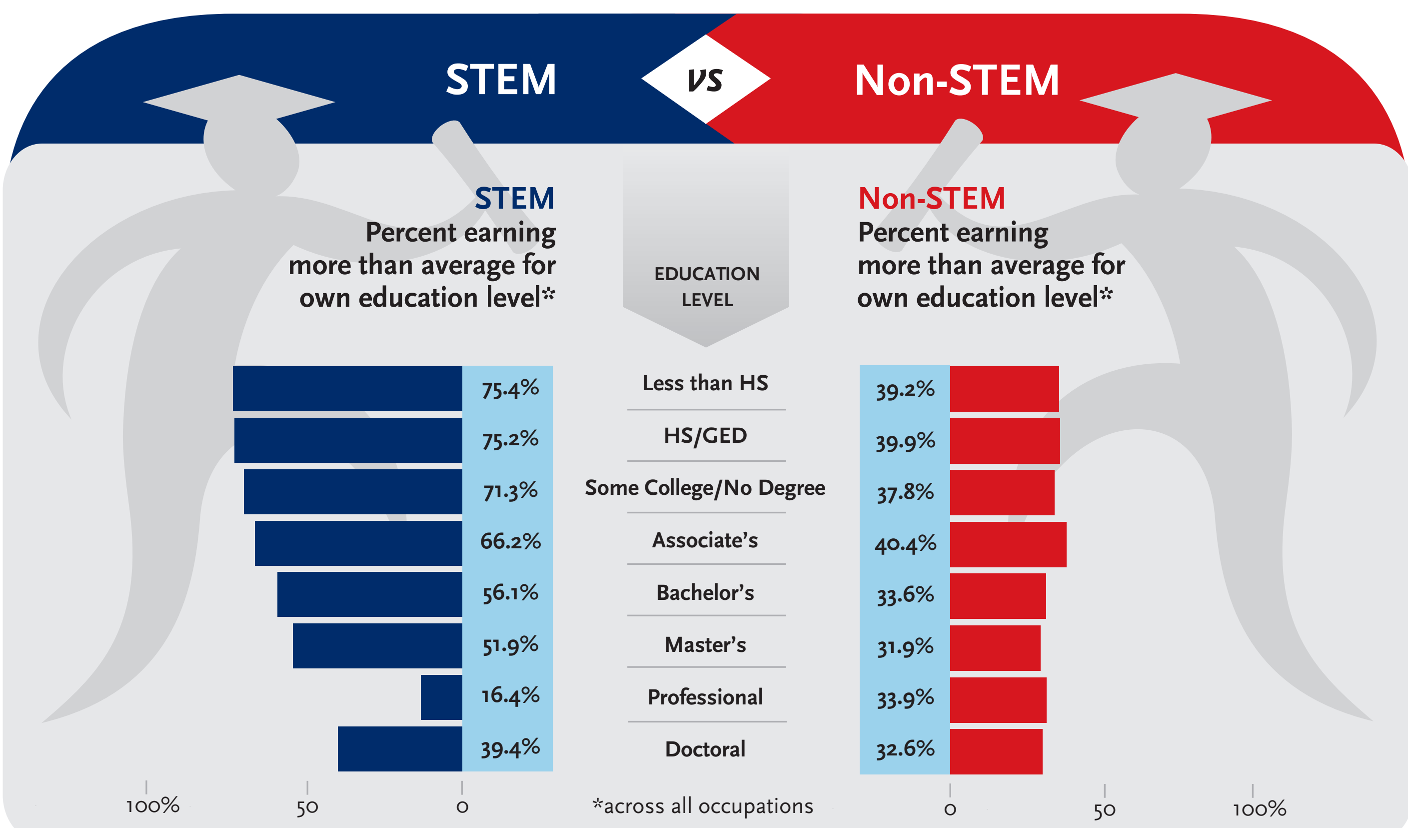
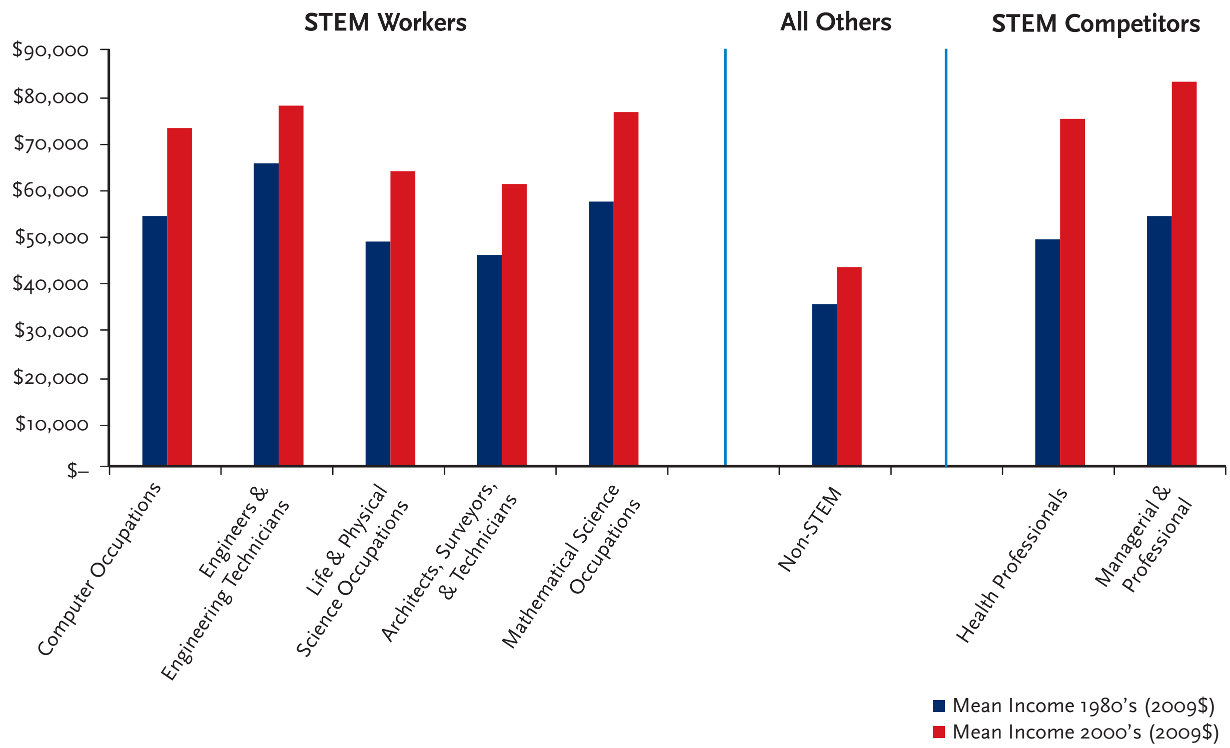


Figure 9: Wages for STEM workers rose faster than for non-STEM workers. However, Healthcare Professionals and Managerial and Professional occupations received the greatest increase.



Source: Authors' analysis of March CPS data, various years

EVEN WORKERS WITH ONLY A HIGH SCHOOL DIPLOMA AND ON-THE-JOB TRAINING CAN EARN MORE IN STEM OCCUPATIONS

Computer and Engineering and Engineering Technician occupations also offer excellent wage opportunities for workers have only a high school diploma or less.[37] For Computer workers with a high school diploma, the average annual wage is $59,000, and for Engineers and Engineering Technicians, the average annual wage is $58,000. This compares favorably with workers with only a high school diploma in non-STEM occupations, who earn $38,000.

However, these Computer and Engineers and Engineering Technicians tend to be relatively older, so their observed pay differentials also reflect years of accumulated work experience.

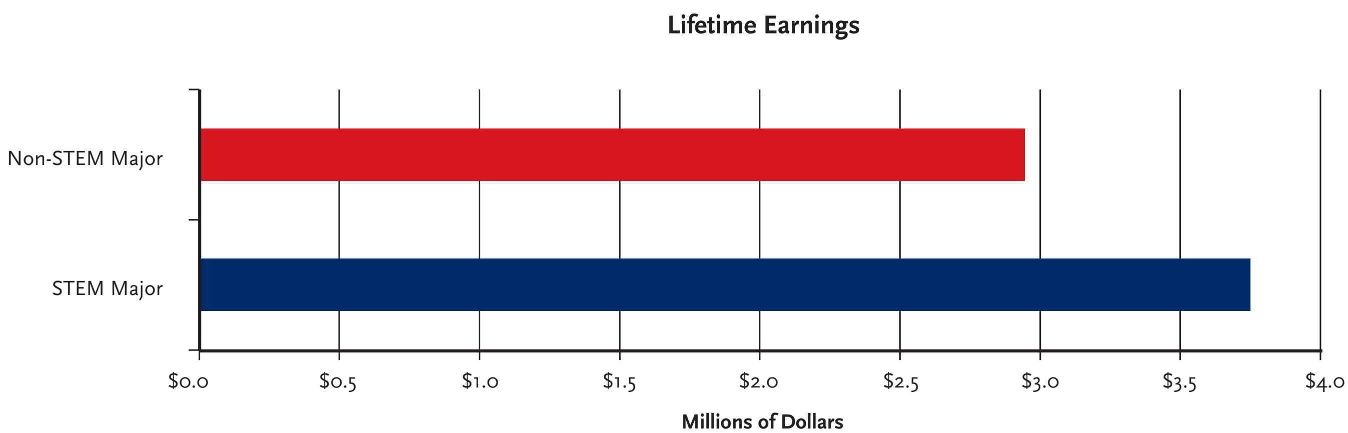
[37] Of course, we are not advocating that students drop out. What is clear from these comparisons is that for those workers—who, for whatever reason, do not get a postsecondary education—STEM occupations are a good bet.

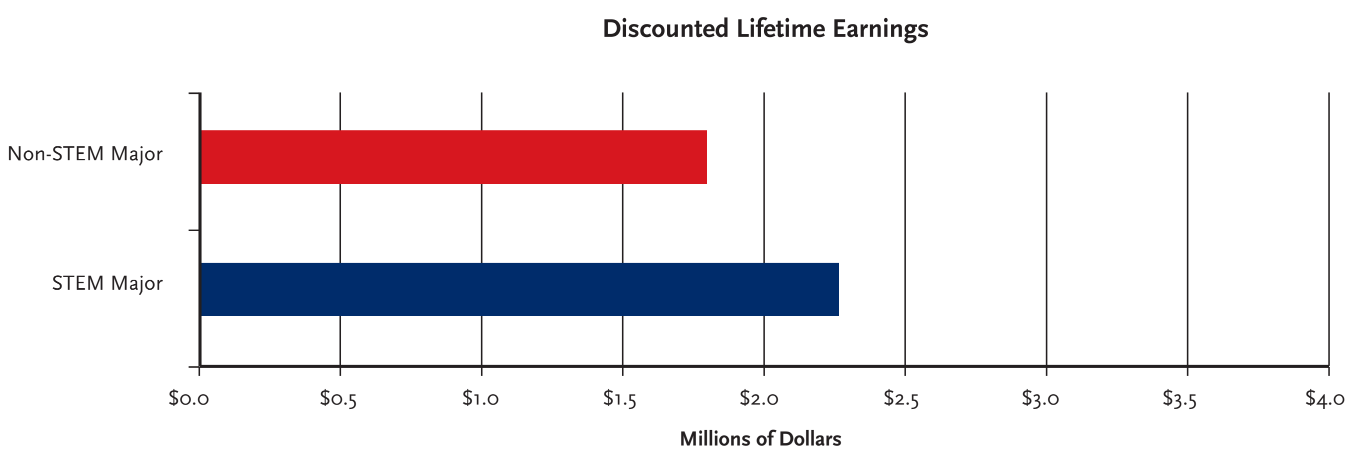
STEM MAJORS WITH A BACHELOR'S OR BETTER EARN MORE, BOTH ANNUALLY AND OVER A LIFETIME

When compared with all other majors, STEM majors (with at least a Bachelor's degree) do relatively well and have the potential to earn over $500,000 more than other majors over a lifetime (see Figure 10). Moreover, the earnings premium holds for STEM majors *even if they are not in a STEM occupation* (with the exception of Food and Personal Services occupations) (see Figure 11).

In addition, STEM workers with at least a Bachelor's degree also make a considerable amount over a lifetime. As Figure 12 shows, Mathematical Science workers, Engineers and Engineering Technicians, and Computer workers all earn more than $3 million over a lifetime. Architects, Surveyors, and Technicians have lower earnings potential, with expected mean lifetime earnings of $1.9 million and an average annual income of $61,000. Engineers and Engineering Technicians, however, are at the top of the list with average lifetime earnings of $2.3 million and an average annual income of $78,000.

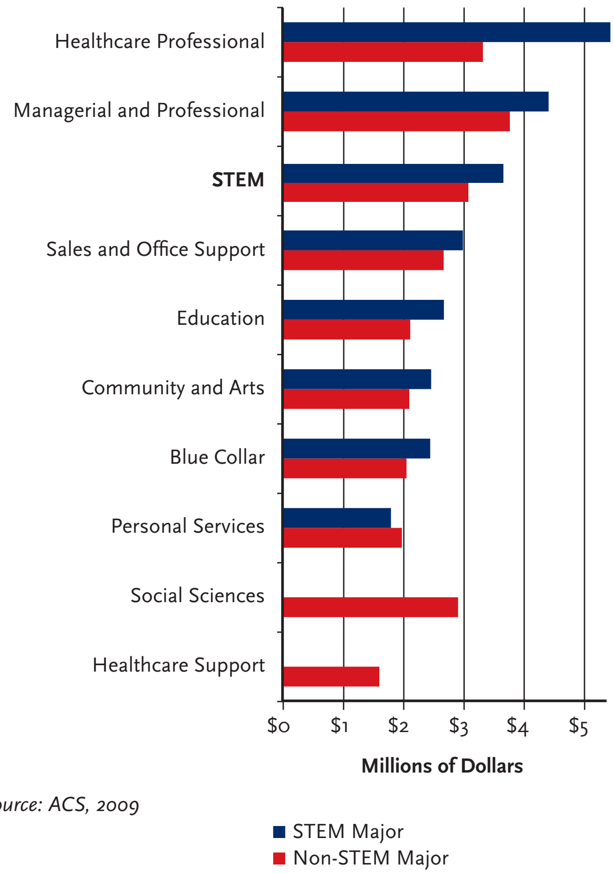
Figure 10: STEM majors earn $500,000 more than non-STEM majors over a lifetime (2009$)





Source: ACS, 2009

Figure 11: STEM lifetime earnings: those who major in STEM make more than those who don't, no matter what occupation they enter (2009$)



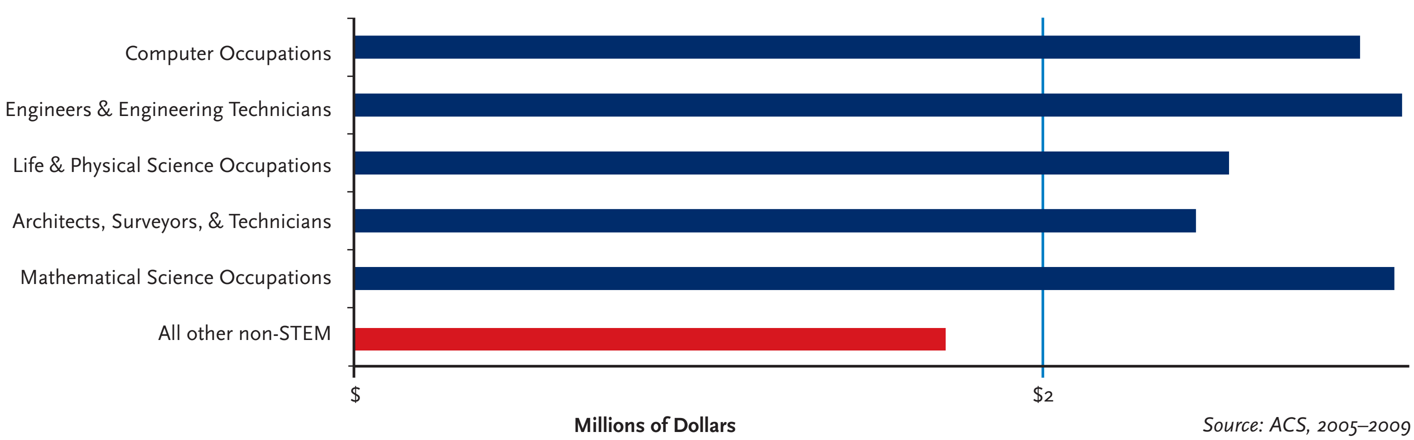
Source: ACS, 2009

The *average* earnings of STEM workers are, of course, highly related to the *lifetime* earnings of people in these occupations. The table embedded in Figure 12 also provides the average annual salaries for STEM workers. As it shows, STEM occupations pay much better than non-STEM occupations in the aggregate.

Figure 12: When disaggregated, the lifetime earnings of Mathematicians, Engineers and Computer specialists exceed all others. On average, STEM workers tend to have higher wages than All other non-STEM occupations.

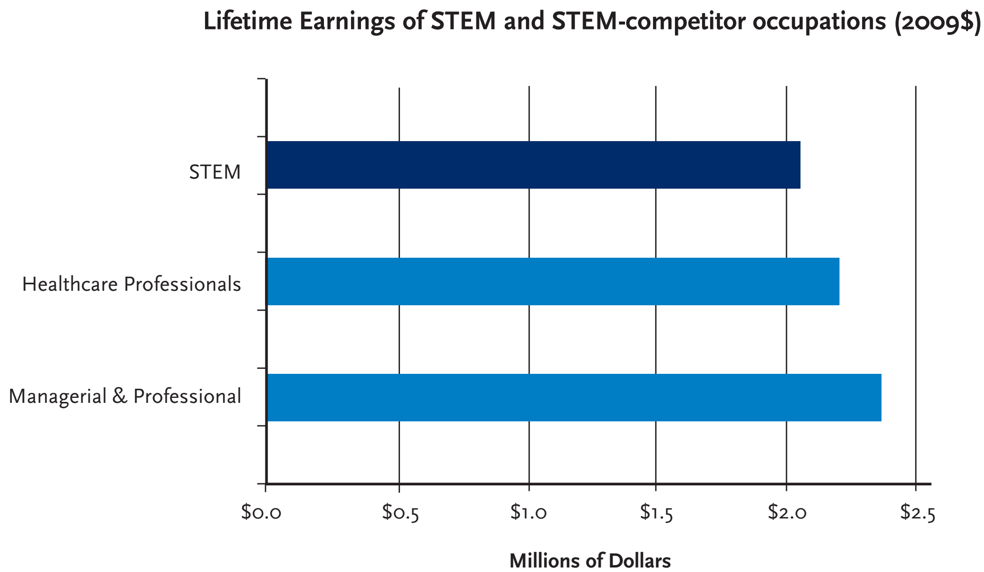
AVERAGE ANNUAL EARNINGS	
Architects, Surveyors, and Technicians	$61,000
Life and Physical Science Occupations	$64,000
Computer Occupations	$73,000
Mathematical Science Occupations	$77,000
Engineering and Engineering Technician Occupations	$78,000
All other non-STEM	$65,000

Lifetime Earnings of STEM workers–Disaggregated (2009$)



Source: ACS, 2005–2009

Figure 13: Wages of direct STEM competitors—such as Healthcare Professional occupations and Managerial and Professional occupations—divert STEM talent



Source: ACS, 2005–2009

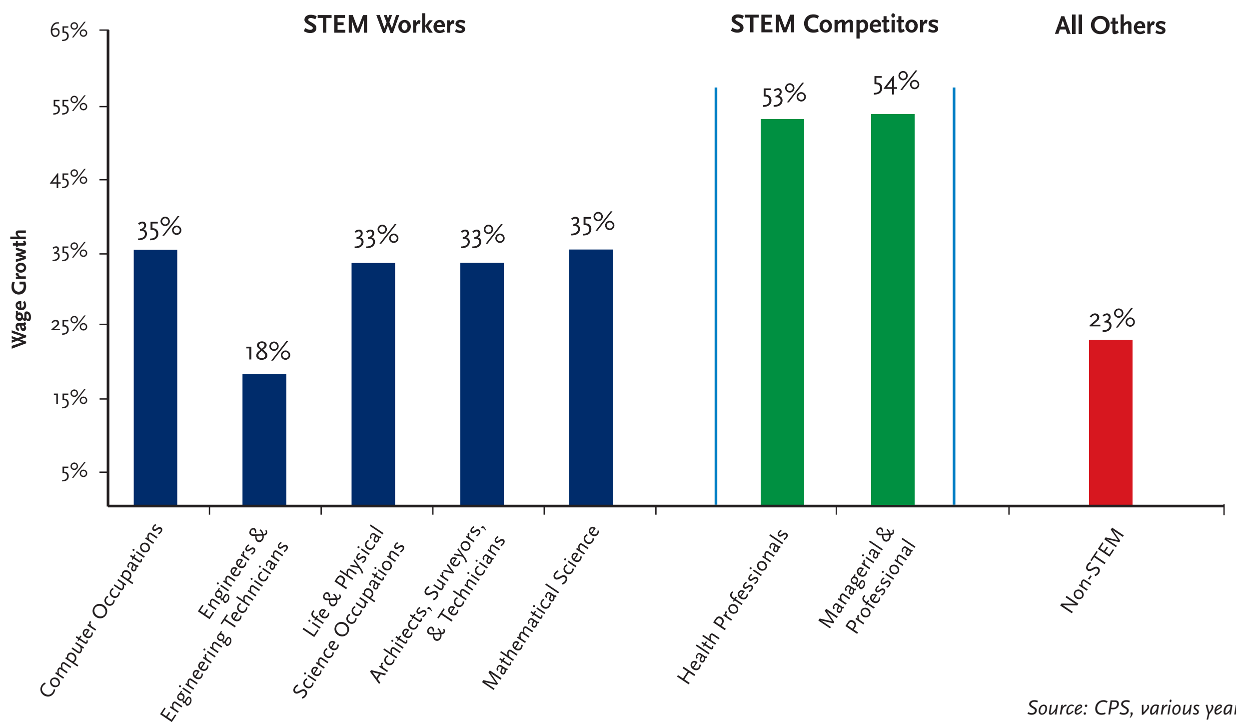
However, while STEM workers enjoy earnings advantages in general, two occupational clusters consistently beat STEM in terms of pay. Workers in Healthcare Professional occupations can expect to earn, on average, $6,250 more per year than STEM workers, while Managerial and Professional workers can expect to earn, on average, $14,250 more per year than STEM workers.

To the extent individuals are motivated by the compensation potential of a job or occupation, these two “competitor” occupations are a superior option—they pay more to use similar competencies found in STEM (as we demonstrate below).

THE STEM WAGE PREMIUM INCREASES WITH AGE

For all occupations, experience is positively correlated with wages. However, what is most remarkable about STEM is that the STEM wage premium increases with age and experience, suggesting that experience in STEM occupations is more valuable than experience in other occupations. Non-STEM occupations average $36,000 at the entry level (ages 25 to 29), while STEM occupations have a much higher starting average of $51,000. Age forward fifteen years, non-STEM occupations have increased average earnings by 50 percent to $54,000, while STEM occupations increase 52 percent over the same period, to $77,600. Life and Physical Science occupations and Architects, Surveyors, and Technicians drive the growth in STEM wages across the life cycle, as these subgroups increased an average of 67 percent and 64 percent, respectively. At 42 percent, the growth in the wages of Computer workers and Engineers and Engineering Technicians is lowest over the 15-year time frame. This is due in part to the fact that Computer workers and Engineers and Engineering Technicians start off with relatively high wages.

FIGURE 14: Engineering wages grew more slowly over the last 3 decades than any other occupational category



Source: CPS, various years

STEM workers between the ages of 40 and 44 earn $23,600 more (on average) than non-STEM workers of the same age. This represents a 55 percent premium for STEM talent at the beginning of one's peak earning potential.

Engineers and Engineering Technicians wage growth is low—but they start from a position of very high wages.

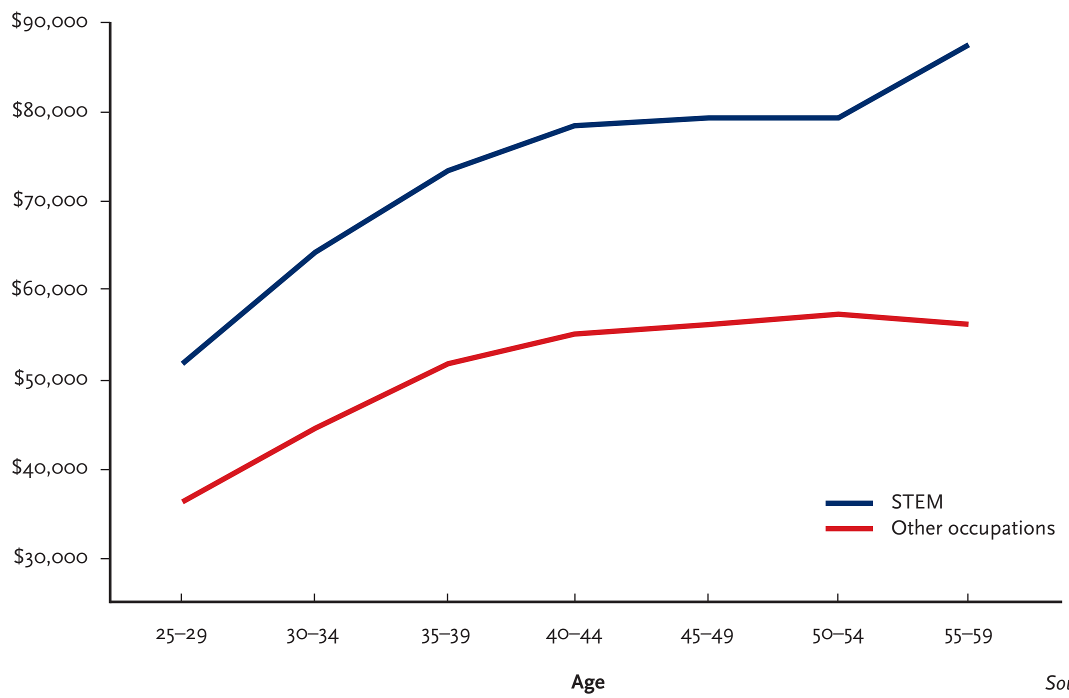
WAGE GROWTH WITHIN STEM VARIES BY OCCUPATION

Not all STEM occupations have grown at the same pace over this 30-year time period.[38] Figure 8 shows the largest absolute jump for Managerial and Professional ($29,000) between the decades. This is confirmed in Figure 14 by the 54 percent growth rate in wages for Managerial and Professional occupations, followed closely by a 53 percent bump in the wages of Healthcare Professional occupations over the same period.

However, Engineering and Engineering Technician wages grew much slower than all other STEM occupations—and even slower than non-STEM occupations. The reason for this slow growth is not a lack of demand for Engineers and Engineering Technicians. Rather, wages for Engineers and Engineering Technicians grew slowly because in the beginning of the 1980s they had higher salaries than any other category of STEM worker. Thus, while they've experienced slow wage growth, it is because Engineering and Engineering Technician wages were relatively high to begin with. Even with this slow growth rate, Engineering and Engineering Technician wages today are still higher than all other occupations. (Mathematical Science occupations, a small group in terms of share of the STEM workforce, make slightly less but are statistically equivalent.)

[38] The time period we refer to is from the 1980's (1983–1986 CPS data) to the 2000's (2005–2009 CPS data).

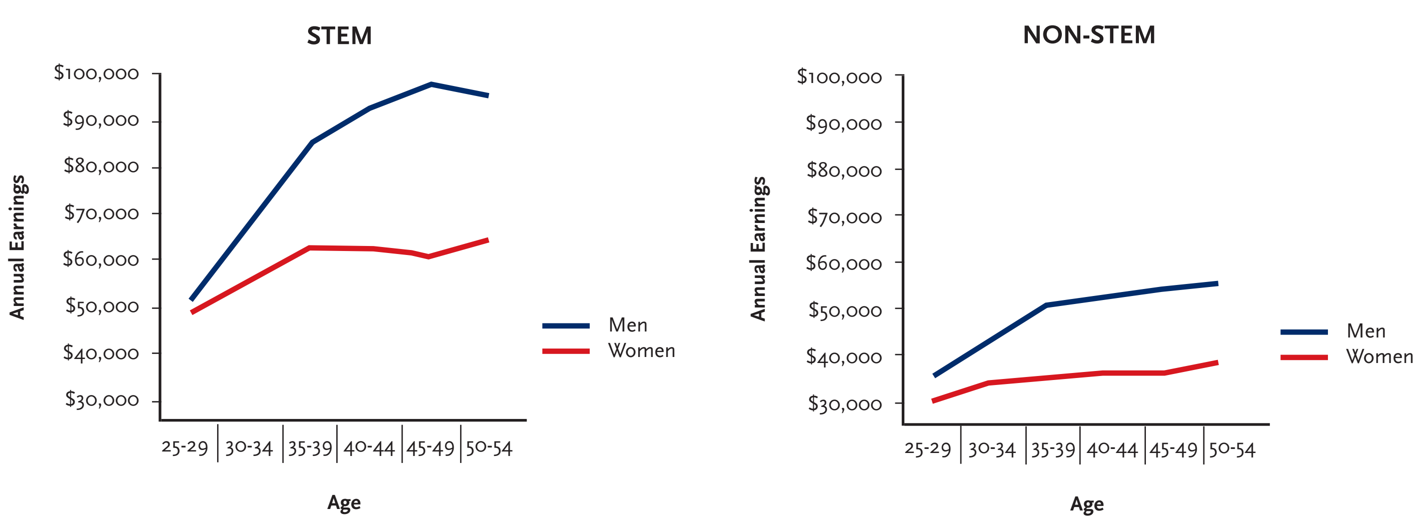
Figure 15: The STEM wage premium increases with age (2009$)



Source: ACS, 2005–2009

THE WAGE PREMIUM FOR MEN OVER WOMEN STARTS OUT SMALL BUT EVENTUALLY IS LARGER IN STEM THAN IT IS IN OTHER OCCUPATIONS

Figure 16 (2009$)

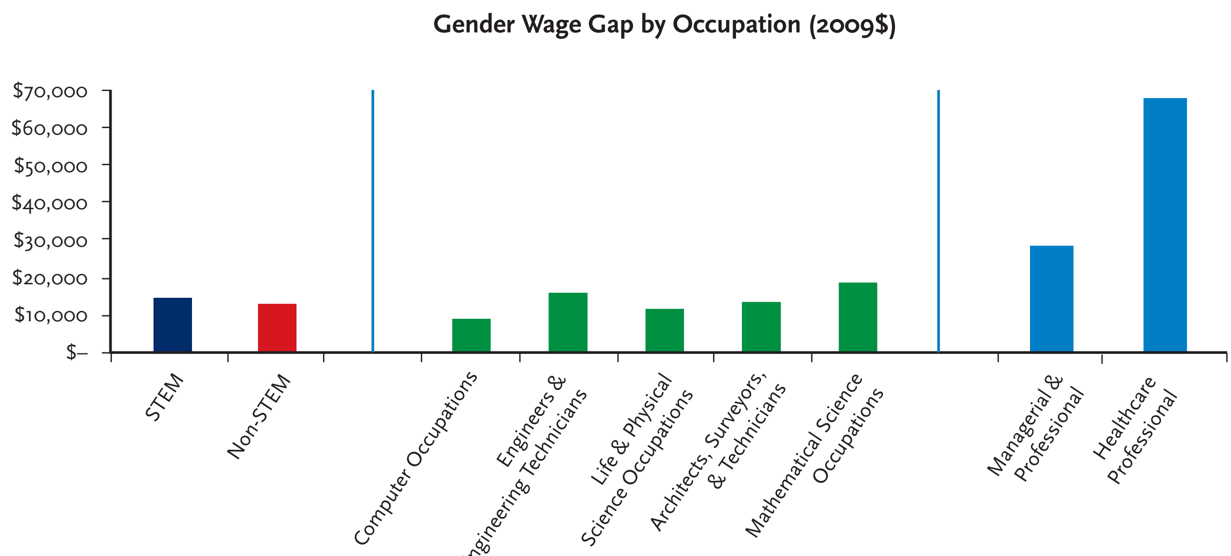


Source: ACS, 2005–2009

Although it starts out small, the wage premium for men over women in STEM balloons as careers progress. At $2,500 upon entry, the gender gap in wages for STEM workers is relatively small and, at 5 percent, substantially below the average for all occupations. As people age, however, gender pay gaps increase, due mostly to the flattening out of women's wages while men's wages continue to rise. By age 45–49, men earn almost 60 percent more than their female counterparts in STEM (men earn 50% more than women in non-STEM for the same age-cohort 45–49). This amounts to a $36,000 premium (compared with $18,000 for non-STEM), the largest of any age group. In short, although the wage gap in STEM is smaller than in other occupations, it is still quite significant, and it varies greatly over the course of a career.[39]

Francine Blau and Lawrence Kahn (2007) attribute 27 percent of the differences in earnings between men and women to occupational choices. This is also true of STEM occupations.[40] Engineering and Engineering Technician and Mathematical Science occupations pay the highest wages among STEM. Women are very sparsely concentrated in these occupations, which partly explains their lower earnings potential.[41]

Figure 17: The gender pay gap is higher for STEM workers than non-STEM workers. The gap for Managerial and Professional and Healthcare Professionals is even more substantial.



Source: ACS, 2005–2009

[39] A recent study by the Economics and Statistics Administration of the U.S. Department of Commerce also found that the STEM gender wage gap is smaller than in other occupations (Beede et al. 2011).

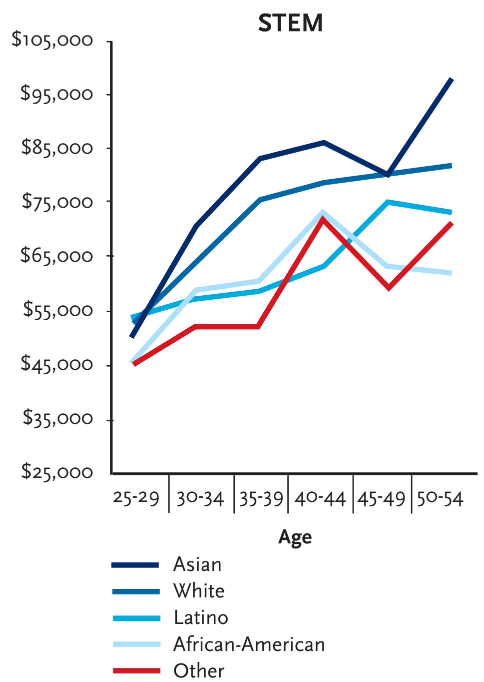
[40] When we control for occupational choice and restrict to full-time worker status, the percentage premium afforded to males over females for STEM and non-STEM workers is statistically equivalent.

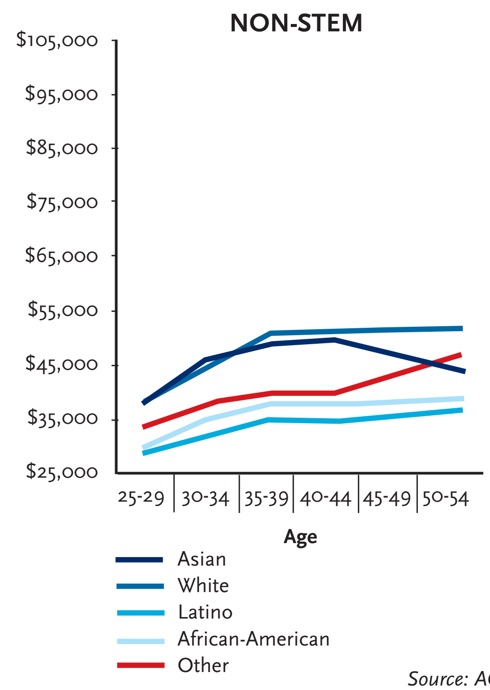
[41] This is true of STEM in general as well. This diversion of female STEM talent is highly correlated with personal and work interests in STEM majors, which itself is correlated with cultural and traditional workforce roles that women have adopted in the past. We find that although women receive 52 percent of high school diplomas, 62 percent of Associate's degrees, 57 percent of Bachelor's degrees, and 50 percent of Doctoral degrees and Professional degrees, these degrees are concentrated in liberal arts and care-providing professions. In turn, the earning power of women as a group tends to be lower than men with the same education level largely due to occupational and industry choices away from STEM fields.

AS IN OTHER OCCUPATIONS, AFRICAN-AMERICANS AND LATINOS EARN LESS IN STEM THAN THEIR WHITE AND ASIAN COUNTERPARTS

Overall, racial and ethnic wage gaps are relatively smaller in STEM occupations than in non-STEM occupations.

Figure 18 (2009$)





Source: ACS, 2005–2009

There are racial and ethnic wage gaps among STEM workers. Even early in the labor market, the pay gap by race/ethnicity is apparent. When compared with White workers, African-Americans between the ages of 25 and 29 earn $7,600 less. This gap fluctuates at other age-cohorts but increases again to just over $15,000 for 45- to 49-year-olds and to $20,000 for 50- to 54-year-olds. Asian workers in STEM fare better than any other ethnic or racial group. Indeed, Asians earn an average of $7,000 more than Whites in STEM occupations and twice that amount over African-Americans and Latino workers.

While there is a racial and ethnic wage gap among STEM workers, the gap is not nearly as wide as it is among non-STEM workers. Wage gaps for non-STEM workers are larger than those for STEM workers. The White/Latino wage gap is the largest gap among non-STEM workers. It averages about $16,000 across age-cohorts. When compared with White workers, African-Americans between the ages of 25 and 29 make $8,000 less; a sum very similar to the size of the gap for STEM workers of the same age. That gap tops out at $13,000 by age 30 and persists through the late years of an individual's career. Asians have the smallest pay gaps when compared with White workers in non-STEM occupations. This gap fluctuates slightly between $1,000 and $2,000 for all age-cohorts, except ages 50 to 54, where it increases to $8,000.

Overall, racial and ethnic wage gaps are relatively smaller in STEM occupations than in non-STEM occupations. The largest gaps in both STEM and non-STEM occupations occur between White workers and Latinos, followed by African-Americans, Other Races/ethnicities, and Asians. On average, Whites earn more than other racial/ethnic groups. However, for STEM workers, Asians have very favorable wages that, for some age-cohorts, exceed those of White workers.

Part 4: *Students and workers divert from STEM*

People with STEM competencies have lots of opportunities in school and in the labor market. STEM students and workers divert from STEM because their competencies are valued in a growing share of highly paid non-STEM occupations—and because students and workers have both personal and work values and interests that are better satisfied in non-STEM occupations.

SHORTAGES IN STEM TALENT ARE REAL—BUT MORE COMPLEX THAN TRADITIONALLY CLAIMED

Many prominent studies have sounded the alarm that we are underproducing STEM talent. Those arguing that we have persistent shortages have set the tone of the debate. However, determining whether or not we are producing enough STEM workers to meet demand is fraught with complications. Many observers have blamed STEM workforce shortages on poor preparation and weak academic performance at the elementary and secondary school levels. Compared with international students, Americans perform favorably in math and science early in elementary school. The gap between the scores of American students and the scores of students in other industrialized countries, however, has widened with time.[42]

As other researchers have pointed out, the overall performance of all American students is a different matter than the performance of the most high-achieving students. The American education system is capable of producing sufficient high-end talent to fill the 5 percent of jobs represented by traditional STEM occupations (Lowell and Salzman 2007). However, there is no guarantee that the most capable students will start or stay in traditional STEM occupations.

As the demand for STEM competencies grows, the overall disappointing performance of the K-12 system does harm our global competitiveness and our commitment to equal opportunity. The expansion in the demand for STEM competencies beyond the traditional STEM occupations does point toward the underperformance of the American K-12 education system in extending STEM competencies to a much broader share of students. Moreover, the aggressive sorting of American students to produce a relatively small cadre of high-performing STEM workers does not account for the need for STEM talent at the sub-baccalaureate level in a wide range of occupations.

Putting aside the issue of K-12 education and looking at college graduation rates alone, it appears possible to plug gaps in the STEM pipeline with our current production despite the fact that degrees conferred in other subjects are rising at faster rates and that STEM degrees have generally declined as a percentage of all degrees awarded. The overall number of STEM credentials (from sub-baccalaureate credentials to PhDs) has been increasing over the last three decades; the growth rate is also fairly stable at 1 or 2 percent annually.

[42] The United States ranked 24th out of 30 OCED countries in science scores in the 2006 Program for International Student Assessment (PISA), performing substantially below average for Organization for Economic Co-operation and Development (OECD) countries. Math scores for our students were even worse, ranking 25th out of the 30 OECD countries.

More rigorous standards, better preparation, and improved graduation rates are necessary but not sufficient to plug the gaps in our STEM pipeline.

A cursory look at the data shows that the number of STEM college graduates at the Bachelor's degree level exceeds the number of job openings in these occupations. Based on our summation of National Center for Education Statistics (NCES) data on degrees conferred, we graduate about 271,000 Bachelor's degrees in STEM on an annual basis. Our projections show that we will create, on average, 277,000 job vacancies annually in STEM fields at *all* education levels, including those for high school graduates, those with some college, and those with Associate's degrees.[43]

These discrepancies have led some researchers to protest that shortages are a mirage. Some studies have compared the number of STEM degrees conferred with job openings and vacancies for STEM workers. These studies find that there is no excess demand for STEM workers. Indeed, B. Lindsay Lowell and Hal Salzman (2007, 30) estimate that for every job in science and engineering, there are as many as three workers in the economy who hold at least one degree in the relevant subjects.[44] It is true that the supply of STEM degrees and demand for STEM workers in a purely mechanical sense are fairly equal. Yet rising relative wages indicate that we are still not producing enough STEM workers to fill demand in the economy, especially below the graduate level.

Rising wages, coupled with stagnant production, have often been presented as indicators of a shortfall in the supply of STEM graduates. Yet why are employers offering more and more money for STEM talent if we graduate enough or more than enough STEM students to fill the demand for traditional STEM workers?

The discrepancy between apparent equilibrium in the supply and demand for STEM degrees on the one hand, and the rising wages for STEM workers on the other hand, can be resolved by presenting a clearer picture of the national market for STEM competencies. STEM workers embody a wide range of STEM competencies, skills, and talent that are desired throughout the economy. The market for STEM competencies far exceeds the 5 percent of science, technology, and engineering occupations. As a result, the demand for STEM competencies throughout the economy diverts STEM workers into nontraditional STEM occupations—making what seems like plenty, not enough to go around.

In this section, we attempt to reconcile the two sides of the debate. We present a market-based theory of the demand for STEM workers that includes the sub-baccalaureate market in

[43] We graduated approximately 270,000 STEM baccalaureate degrees in 2007–2008, according to NCES counts of degrees conferred by postsecondary institutions participating in Title IV programs, with an annual growth rate of about 3 percent. (We aggregated the following majors as STEM: Agriculture and Natural Resources, Architecture and Related Services, Biological and Biomedical Sciences, Computer and Information Sciences, Engineering, Engineering Technologies, Mathematics and Statistics, Physical Sciences and Science Technologies, and Precision Production.) We are excluding advanced degrees in this immediate aggregate analysis to avoid double counting, since everyone with an advanced degree had a Bachelor's degree as a prerequisite. This number must be decreased for labor force participation rates (assumed 75% labor force participation rate), including those who immediately return to graduate school and multiple-job holders (assumed 5%). We then roughly compare this estimate of supply to our estimate of the demand for STEM Bachelor's degrees and better at approximately 160,000 per year from our model forecasts. After making these adjustments for double counting and labor force participation, we estimate more new STEM Bachelor's degree graduates each year on average than market demand. This rough-and-ready mechanical comparison of demand and supply can leave one with the impression that there is an oversupply. Yet the wages for STEM workers are high relative to many other workers. Why this is an indicator of an undersupply is discussed later.

[44] However, as stated previously, we agree with Michael Teitelbaum's (2008) empirical analysis that in certain subsets of the market for STEM workers, demand is low. The evidence is clear that this is especially true of the academic market for PhDs in STEM. The STEM labor market, however, is not all graduate degrees. Policy makers are often rightly concerned with graduate STEM workers based on the assumption that the top level of the field keeps us globally competitive fostering economic growth and maintaining supremacy in national security. While STEM occupations are highly concentrated in the number of graduate degrees required, this is truer of Mathematical Science and Life and Physical Science occupations but less so of Engineering and Engineering Technician and Computer occupations, which also rely heavily on Bachelor's degrees as well as sub-baccalaureate degrees, certificates, and industry-based certifications.

addition to the Bachelor's and better market, something often lacking in studies that find no shortage.[45] To establish the demand for STEM workers means that we address those at the highest end of the education spectrum, such as PhD physicists, but also that we account for the demand for technical workers, computer programmers, systems managers, database administrators, and all types of engineers.

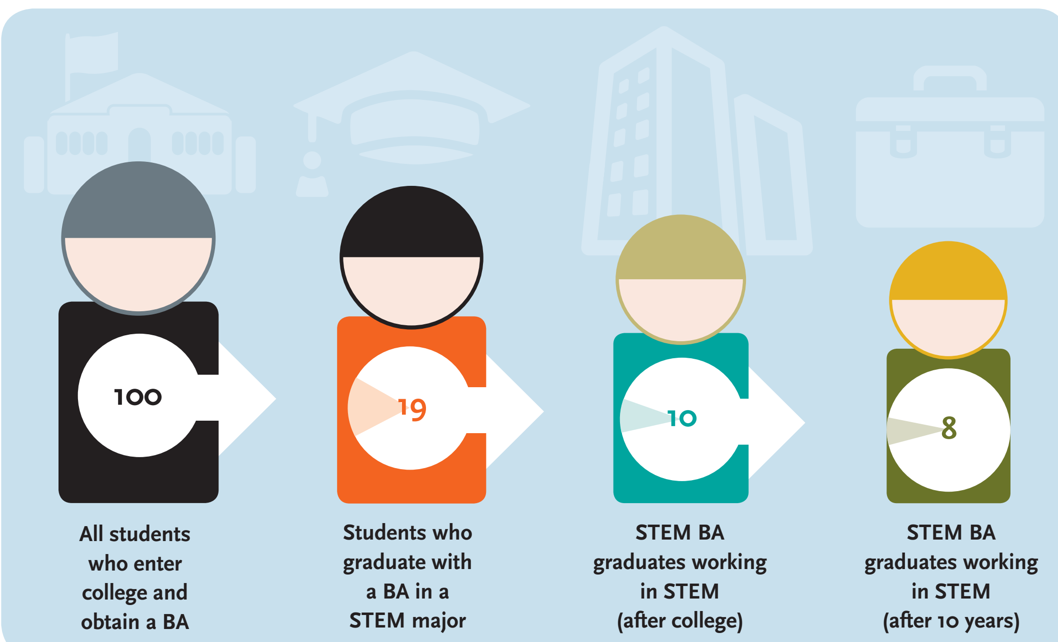
STEM STUDENTS AND EMPLOYEES ARE DIVERTED FROM STEM OCCUPATIONS AT MULTIPLE JUNCTURES

The missing piece of the STEM puzzle is *diversion*—students, college graduates, and workers steering away from STEM careers at various points. We define diversion as a process in which students and workers who have a demonstrated capability in STEM (either at the high school or postsecondary levels) do not end up in STEM fields of study or STEM occupations for a variety of economic and noneconomic reasons. We include people who may never intend to major or work in STEM, even if they are capable (as determined by a math SAT equivalent or their chosen major) of becoming future STEM workers.[46] Diversion, coupled with the observation that the market for STEM competencies is broader than the market for STEM workers, illuminates why we look like we're producing enough STEM workers—but we're actually not.

Students and workers divert at many junctures. We have identified four for which we have empirical data:

1. In college, when more than three out of four high school students who test in the top math quartile don't start with a STEM major in college.

Figure 19: Diversion from STEM



Source: NELS: 1988 and B&B: 1993/2003

[45] See Teitelbaum (2003) and Lowell and Salzman (2007). The Information Technology and Innovation Foundation (ITIF) supports this view. This ITIF report (Atkinson and Mayo 2010) finds that instead of using salary growth and unemployment rates, we should measure the length of time it takes for companies to hire STEM workers and analyze the global job market for STEM workers to determine whether there is a shortage of STEM workers.

[46] We define diversion this way because we are interested in the potential STEM workforce and with the extent of STEM competencies in the labor market.

2. In college, where only half of all students who start in a STEM major graduate with one. In fact, out of 100 students who obtain a Bachelor's degree, only 19 will graduate with a STEM major.
3. In the workplace, where just 10 of the 19 graduates with a Bachelor's degree in a STEM major will work in a corresponding occupation early in their careers.
4. After 10 years in the labor market, only eight of these original 10 will still be working in a STEM occupation.

Although we don't discuss it in detail, it should also be noted that there is significant diversion before college as well. About 30 percent of students who test in the top quartile in math do not have a Bachelor's degree eight years later, representing an enormous loss of potential STEM workers.[47]

Students divert for many reasons. Some students are not interested in STEM in spite of their abilities, some succumb to social pressure that tells them they don't fit in the discipline, some don't see people who look like them working in the top research universities, and some realize that they could earn more money doing work outside of a lab or manufacturing plant. For many, it is a combination of all these factors. However, the general demand for their competencies outside of traditional STEM occupations is what enables these students and workers to divert in the first place.

While we describe attrition at the first two junctures, we do not analyze the various reasons that students divert because we lack in-depth and accurate data about students' intentions and interests; instead, we rely on existing literature. We do, however, analyze reasons for attrition in STEM once individuals hit the labor market. We find that higher wages in fields that compete for STEM talent, and differing work interests and work values, account for much of the workforce diversion.

DIVERSION IS NOT UNIQUE TO STEM

In spite of seemingly high rates of diversion out of STEM, it is important to note that diversion into other occupational fields is not a phenomenon unique to STEM occupations. Even among subjects that have tight linkages with specific careers (such as education, business, and healthcare), diversion occurs at rates lower than, but similar to, the rate for STEM. Although attrition from STEM may appear unusually high at first glance, it is not.

We define a high persistence rate for all tightly linked occupations as 84 percent immediately following graduation and 72 percent 10 years out of college; we define a low persistence rate at somewhere around 25 percent (see Table 3).[48] The rate for STEM, as calculated by longitudinal surveys,[49] is 56 percent immediately after graduation and 46 percent 10 years later,

[47] For other quartiles, the percentage who do not get a degree is higher. In the second quartile, nearly half (48%) do not get a degree; in the third quartile, 63 percent do not get a degree; and in the bottom quartile, 79 percent do not get a degree.

[48] The issue of low persistence highlights the issue of linkages between majors and occupations in the first place. Few majors actually line up with only one occupation, or even a set of occupations, as neatly as a nursing Bachelor's degree lines up with being a nurse. Thus, for many occupations, ascertaining persistence can be a judgment call. For example, persistence in arts for Fine Arts majors initially appears low, at 28 percent. However, 20 percent are working in education occupations; presumably most (or at least many) of these are working as art teachers. The question becomes, is being an art teacher working in field? Are there other art majors doing similar work that are not grouped in either of these occupations? There is a similar issue for those classified as in management positions. Should we assume that they are in management in field?

[49] The Baccalaureate and Beyond Longitudinal Study (B&B) is a survey conducted by the NCES, an agency of the Department of Education. According to NCES, the B&B "examines students' education and work experiences after they complete a bachelor's degree, with a special emphasis on the experiences of new elementary and secondary teachers. Following several cohorts of students over time, B&B looks at bachelor's degree recipients' workforce participation, income and debt repayment, and entry into and persistence through graduate school programs, among other indicators. It addresses several issues specifically related to teaching, including teacher preparation, entry into and persistence in the profession, and teacher career paths. B&B also gathers extensive information on Bachelor's degree recipients' undergraduate experience, demographic backgrounds, expectations regarding graduate study and work, and participation in community service" (http://nces.ed.gov/surveys/b%26b/about.asp). Accessed via Power Stats. The 1988 National Education Longitudinal Survey (NELS) is another survey conducted by the NCES, which describes it thus: "[A] nationally representative sample of eighth-graders were first surveyed in the spring of 1988. A sample of these respondents were then resurveyed through four follow-ups in 1990, 1992, 1994, and 2000. On the questionnaire, students reported on a range of topics including: school, work, and home experiences; educational resources and support; the role in education of their parents and peers; neighborhood characteristics; educational and occupational aspirations; and other student perceptions" (http://nces.ed.gov/surveys/nels88/index.asp).

which situates it somewhere in the middle in terms of persistence rates, but not much lower than other occupations (see Table 3).

Table 3: Diversion exists in many fields

MAJOR	WORKING IN FIELD IMMEDIATELY AFTER BACHELOR'S ATTAINMENT	WORKING IN FIELD AFTER TEN YEARS
STEM	56%	46%
Education	84%	66%
Healthcare	61%	72%
Business	62%	53%

Source: NELS: 1988, B&B: 1993/2003

In addition, younger cohorts with STEM training start off working in STEM occupations but are much more likely to transition into managerial positions when they are older. Using a cross-sectional survey (ACS), we calculate that at ages 25–29, 48 percent of STEM majors are working in STEM occupations, and only 16 percent are working in Managerial and Professional occupations. However, at ages 45–49, the composition changes—37 percent of STEM majors are in STEM occupations, while 30 percent are in Managerial and Professional occupations.

However, diversion in STEM is not the same across all the occupational groups that make up STEM. While persistence for Life and Physical Science and Mathematical Science workers is extremely low, Engineers and Engineering Technicians and Architects, Surveyors, and Technicians have high persistence—as high as any of the other tightly linked occupations 10 years after graduation.[50] Computer workers persist at very high rates—in fact, there are more people working in field 10 years after obtaining a Bachelor's degree than immediately after graduation. Their rate of persistence is as high as the highest other field—healthcare. Therefore, while on average, eight out of every 100 Bachelor's degree-holders with a STEM degree work in a STEM occupation, there is variation among STEM occupations. This discrepancy demonstrates that although we talk generally of STEM diversion, not all occupations within STEM divert at the same rate. In fact, some STEM occupations have higher than average rates of persistence, while others, in particular Mathematical Science and Life and Physical Science, have much lower rates of persistence (see Table 4).

Finally, there are some who protest that even if diversion is a primary factor in keeping workers out of STEM occupations,

Table 4: STEM Diversion

	WORKING IN FIELD AFTER GRADUATION (All levels of educational attainment)	WORKING IN FIELD AFTER GRADUATION (Bachelor's and above)	WORKING IN STEM: FIELD AFTER TEN YEARS (Bachelor's and above)
STEM–ALL	50%	56%	46%
Engineer/Architects	69%	77%	65%
Computers	51%	64%	72%
Math/Life/ Physical Scientists	31%	35%	24%

Source: NELS: 1988, B&B: 1993/2003

[50] For information on where particular majors end up by occupation and industry, see Carnevale, Strohl, and Melton (2011). The difference between these data and the B&B data is that the latter are longitudinal, while the majors report analyzes cross-sectional data.

it is possible that it is *involuntary* and an indicator of the oversupply of qualified STEM workers. Even if STEM-capable students and workers are working outside of their field of study, and even if they are making more money as a result, they may still want to be working in STEM. We find that STEM talent chooses to divert because the best available evidence demonstrates that involuntary changes of career or involuntary unemployment in STEM is relatively low. We discuss those data at the end of this section.

PERSONAL PREFERENCES MATTER: CAPABLE STUDENTS ARE DECIDING AGAINST STEM AT THE JUNCTURE BEFORE COLLEGE

Many students with high competency in mathematics, as indicated by their SAT scores, choose not to pursue STEM majors.[51] Consider the following: on average, college-bound seniors who intended to pursue STEM majors scored between 511 and 613 out of a possible 800 on the mathematics portion of the SAT exam. College-bound students who intended to major in other fields—general, multidisciplinary, foreign languages, and classics—had comparably high mathematics scores, averaging between 532 and 594 points during the 2008–2009 school year. Many students who have adequate math scores to pursue STEM majors are choosing other disciplines.

Students may choose to pursue non-STEM majors for many reasons. At this stage, a wage-based explanation for diversion is weaker because students are relatively unattached to the labor market. At this point, information, perceptions, personal and work interests, and work values are likely to be the most important diversionary forces.

The formulation of career aspirations is complex but is influenced heavily by perceptions that are formed relatively early in adolescence and develop based on experience in early

Table 5: Many college-bound students capable of majoring in STEM choose to major in other fields

FIELDS	INTENDED COLLEGE MAJOR	MATHEMATICS SAT SCORE (2008–2009)
STEM fields	Engineering technologies/techniques	511
	Biological sciences	557
	Computer or information sciences	533
	Engineering	582
	Mathematics	613
Non-STEM fields	Foreign/classical languages	545
	Legal professions and studies	530
	Language and literature	532
	Multi/interdisciplinary studies	594

Source: Digest of Education Statistics 2009. Table 145

[51] We use SAT scores here instead of the cognitive math scores found in NELS because SAT scores, though not a completely adequate indicator of student achievement, are correlated with student performance in college (NCES 2009). In addition, only SAT data have information on intended majors, while the NELS does not. Therefore, although the two measures of test scores are not a perfect match, there is enough overlap to be confident in the comparison.

Table 6: Diversion differs based on demographic and other factors

BASED ON 100 STUDENTS ENTERING ALL POST-SECONDARY INSTITUTIONS	START WITH A STEM MAJOR	START AND GRADUATE WITH A STEM MAJOR	START, GRADUATE, AND WORK IN STEM (EARLY YEARS IN THE LABOR MARKET)
All	13%	6%	3%
White	12%	6%	3%
African-American	14%	5%	2%
Men	17%	9%	5%
Women	8%	3%	1%
Top math quartile	23%	15%	8%

Source: NELS: 1988

adulthood. Influences range from peers to parents to the media. In general, perceptions about careers are influenced by factors other than those associated with what actually happens in labor markets (Foskett and Helmsley-Brown 1999). Some occupations are less visible to youth than others, and perceptions of occupations are more attached to the perceived lifestyle of incumbents than to realistic understandings of what an occupation entails (Higgins et al. 2008).

There has been groundbreaking work done by the Business Higher Education Forum (BHEF) in tying STEM work interest to the choice of STEM careers. BHEF uses census data and standardized test scores to track students as they proceed through the K-16 system and into STEM careers. BHEF recognizes that "Both interest in a STEM career and proficiency in STEM subjects . . . are necessary prerequisites for students to select and succeed in a STEM major" (2010, 2). They further recommend that "interventions should be targeted to help maintain student interest" in STEM, recognizing that sheer competency is not enough. In this way, they are unique in moving beyond mere capability as a determining factor that influences students' choices to pursue STEM learning and STEM careers.

STEM IN THE POSTSECONDARY SYSTEM: DIVERSION

Once in college, many students who originally majored in STEM change their minds. That is, students may start with a STEM major but do not graduate with a STEM major.

The Cooperative Institutional Research Program (CIRP) freshman survey, an annual survey administered by the Higher Education Research Institute (HERI) at the University of California–Los Angeles shows that between 1971 and 2009, the percentage of students entering college who say they plan to major in STEM fields has remained constant at around 31 percent, in spite of STEM's strong wage growth and growing (though still small) share of all jobs.

The number of students who actually enter college with the desire to pursue STEM majors falls off from the 31 percent figure recorded by the CIRP/HERI study, suggesting that students are diverted even between high school and declaring a major in college. This pattern varies by race/ethnicity and sex, as well as by whether a student is a top-performing math student.

Top-performing math students, defined as those scoring in the top quartile on a cognitive math test, start and finish STEM majors at higher rates than their counterparts (see Table 7). They also enter the STEM workforce in higher numbers.[52] This is in contrast with women and African-Americans, who enter STEM majors at a lower rate than their counterparts and graduate with STEM majors at lower rates as well. This indicates that there are additional barriers within college that push women and minorities away from STEM. We turn our attention to these specific groups later.[53]

Students are diverted within college for several reasons, including their individual personal and academic interests. Many students may decide as they work through the course of study that STEM is not for them. They may decide it is too difficult. Some studies have suggested that persistence in STEM majors in college is related to grades and precollegiate preferences (Rask 2010), while others have suggested a combination of factors related to academic performance and preparation (Kokkelenberg and Sinha 2010).

Table 7: Diversion is a two-way street; many students divert into STEM in college

	DON'T START IN A STEM MAJOR	GRADUATE WITH A STEM MAJOR
All	87%	4%
White	88%	5%
African-American	91%	3%
Men	83%	5%
Women	92%	3%
Top math quartile	77%	6%

Source: NELS: 1988

Work interests are also likely a driving factor in STEM diversion in college. Students may be exposed to other subjects and classes that they enjoy more than their original major. However, work interests function both ways. There are some students who don't enter college intending to major in a STEM subject who then graduate with a degree in one, although this number is relatively small. Overall, out of 100 students entering postsecondary institutions at all levels, 87 do not start with a STEM major—but four of those 87 end up graduating with one.

LABOR MARKET DIVERSION: WAGES AND DIFFERING WORK INTERESTS AND WORK VALUES APPEAR TO PLAY A STRONG ROLE IN DIVERSION ONCE STEM WORKERS ARE ON THE JOB

Diversion from STEM careers continues in the labor market even though jobs in STEM pay well relative to most other occupational clusters (see wages section above). STEM workers at all levels of educational attainment have consistently earned family-sustaining wages, which makes STEM a relatively safe occupational choice in financial terms.

Even so, there is evidence that many workers have made rational economic decisions in selecting careers in non-STEM occupations, because some of the alternatives pay better. Across all education levels, while STEM occupations pay $68,750 a year, Managerial and Professional occupations average $83,000, while Healthcare Professional occupations pay $75,000. Moreover, at the highest levels of educational attainment, those with STEM competencies can get paid more to use their talents

[52] As noted above, however, 30 percent of top-quartile math students have not earned a degree eight years after graduating high school.

[53] See Amanda Griffith (2010) for an in-depth analysis of why women and minorities switch out of STEM majors at higher rates than their counterparts. Griffith concludes that sorting of women and minorities into different undergraduate programs, along with differences in background and preparation, have a significant impact on persistence rates.

in Managerial and Professional and Healthcare Professional occupations. For those with at least a Bachelor's in STEM, average earnings in STEM occupations are $78,550, while those for Healthcare Professionals are $110,090 and those for Managerial and Professional are $102,070 (see Table 8).

MANY DIVERT BECAUSE EARNINGS ARE HIGHER IN HEALTHCARE PROFESSIONAL AND MANAGERIAL AND PROFESSIONAL POSITIONS, ESPECIALLY FOR THOSE WITH HIGHER EDUCATIONAL ATTAINMENT

Leaving STEM jobs for Managerial and Professional occupations appears to pay off the most for workers with Bachelor's degrees, while STEM pays more or about the same as these other occupations at the high school or less, some college/no degree, and Associate's degree levels. At the graduate degree level of educational attainment, it is clear that both Managerial and Professional occupations and Healthcare Professional occupations pay substantially more than STEM.

In jobs requiring some college/no degree or an Associate's degree, pay is comparable between STEM occupations and Managerial and Professional occupations.

This is not the case, however, for those jobs requiring a Bachelor's degree and better. Figure 18 shows that those with graduate degrees in Managerial and Professional fields earned, on average, about $20,000 per year above those with equivalent qualifications in the STEM occupations. The discrepancy is even greater for those in Healthcare Professional occupations.

STEM CAREERS PAY BEST EARLY AFTER COLLEGE BUT MANAGERIAL AND PROFESSIONAL AND HEALTHCARE PROFESSIONALS CATCH UP AND SURPASS STEM AT MIDCAREER

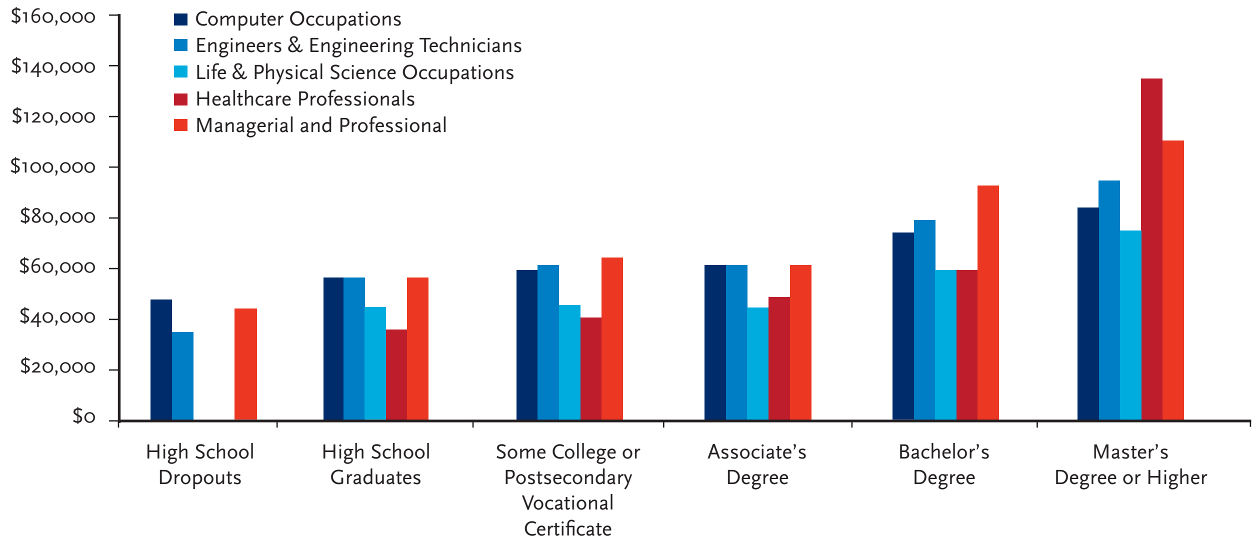
The point in the career cycle also matters for STEM workers. Initially, STEM jobs pay better than those in the Managerial and Professional and Healthcare Professional occupations

Table 8: Average annual earnings by occupation

OCCUPATION	AVERAGE ANNUAL EARNINGS, ALL MAJORS (2009$)	AVERAGE ANNUAL EARNINGS, STEM MAJORS (2009$)
STEM	$68,750	$78,550
Healthcare Professional	75,000	110,090
Managerial and Professional	83,000	102,070
Social Sciences	66,690	81,570
Sales and Office Support	37,480	58,450
Healthcare Support	22,190	35,410
Education	35,650	44,220
Community and Arts	41,510	44,390
Blue Collar	34,970	32,130
Food and Personal Services	25,320	37,430

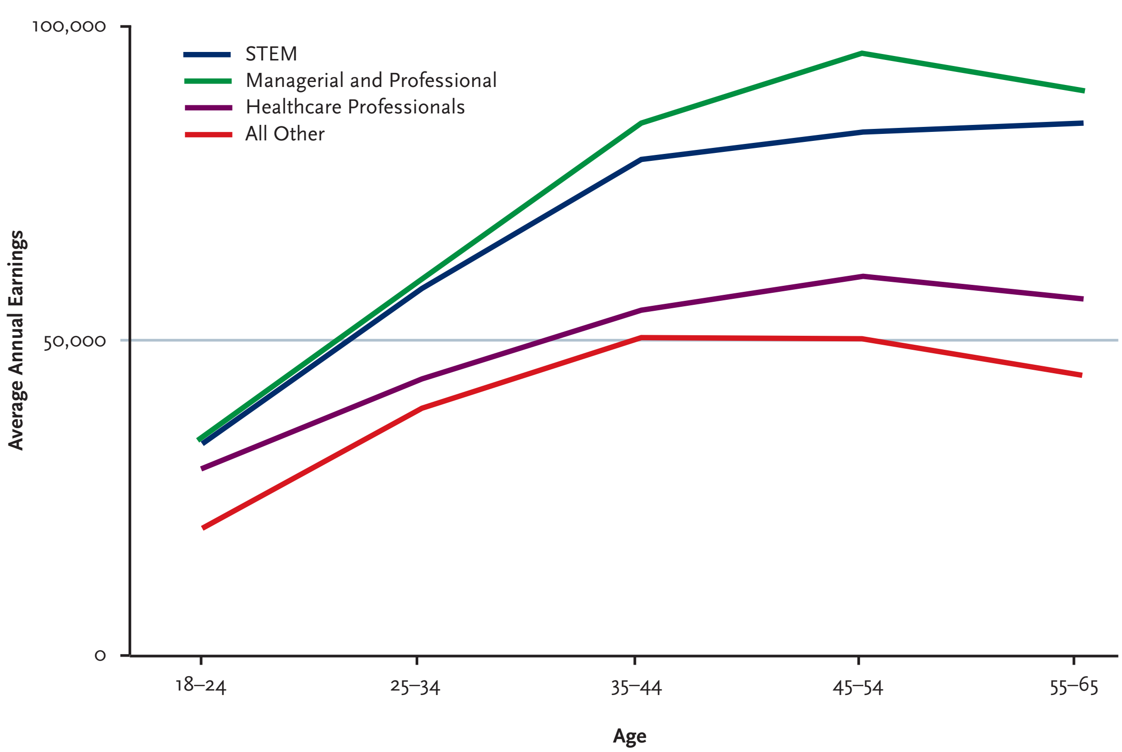
Source: ACS, 2009

**Figure 20: At the highest levels of educational attainment, STEM wages are not competitive.
Degree matters: Graduate degrees confer real advantages to both Managerial and Professional and Healthcare Professional workers (2009$)**



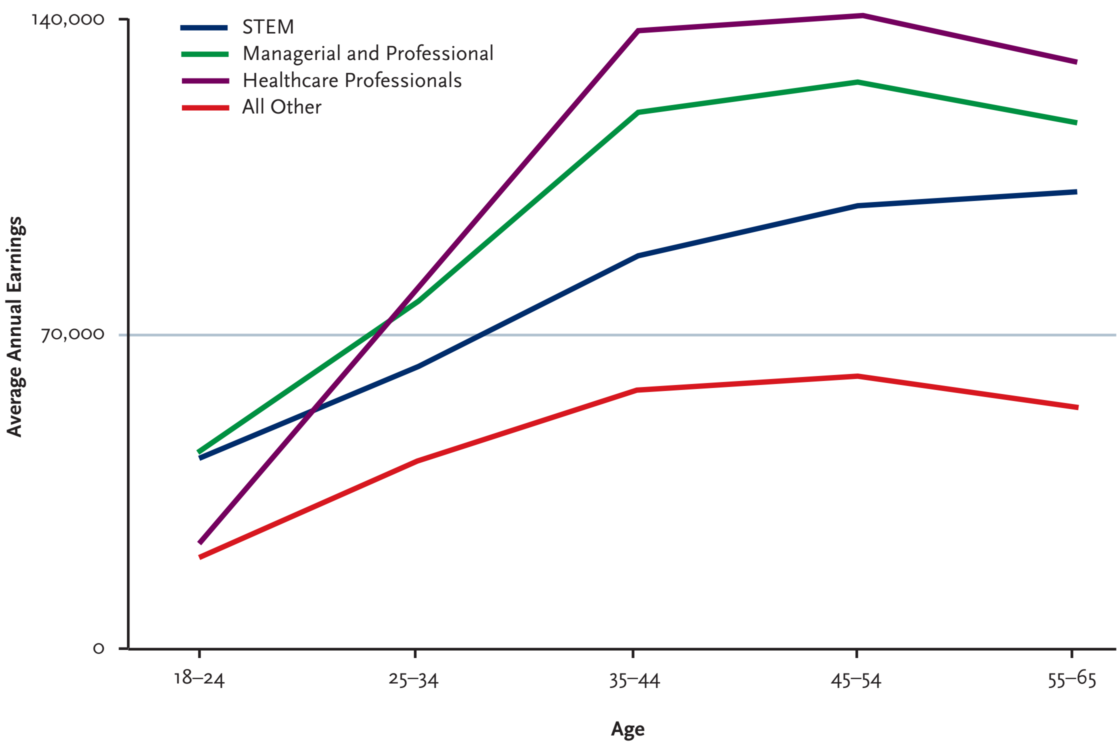
Source: ACS, 2005–2009

Figure 21: At the Bachelor's level, STEM surpasses Healthcare Professional earnings, but not Managerial and Professional earnings (2009$)



Source: CPS, various years

Figure 22: At the graduate level, STEM cannot compete with Healthcare Professional or Managerial and Professional occupations in terms of pay (2009$)



Source: CPS, various years

because workers who have recently entered the labor force do not have enough experience to be managers or enough education to be doctors or lawyers. As STEM workers progress through the labor market, however, discrepancies in pay widen with age and experience. Between ages 25 and 34, wages for Managerial and Professional occupations begin to surpass those for STEM. Healthcare Professional occupations lag because the technical, nondoctor occupations in Healthcare (for example, X-ray technicians) pay much less than Healthcare Professional occupations (see Appendix E). However, if we separate out workers by degree level, both Healthcare Professional and Managerial and Professional occupations surpass STEM in terms of earnings by midcareer for those with a graduate degree (see Figure 22).

PAY ALONE DOES NOT CAUSE DIVERSION

Pay is not the only reason that workers choose an occupation.[54] An economist does not just decide to become a doctor because it pays better, any more than a nurse decides to be a mechanic, or an historian decides to transition seamlessly into a chemistry lab. People with strong STEM competencies are high-performing students and workers who have a broad range of educational and career choices. Those who initially choose

[54] A recent study of the British STEM workforce came to similar conclusions as we did about why STEM majors and workers do not persist in traditional STEM careers. The report notes that STEM majors often pursue careers outside of STEM jobs because of their work interests, and that earnings are an additional important factor in career choice. Moreover, the study also finds that STEM majors are often recruited by employers from a wide range of industries and occupations. The study also confirmed the increasing importance of more general skills—such as teamwork, communication, and organizational skills—to success for STEM majors. (Mellors-Bourne, Connor, and Jackson 2011).

to specialize in STEM careers can transition into other managerial functions throughout their careers. These workers are able to transition into other occupations at critical junctures of choice in school or in the labor market because they share competencies that have value in a number of occupations.

Until very recently, our ability to observe and measure an incumbent's core competencies and their distribution among different occupations in the economy has been largely anecdotal. However, the completion of the Occupational Information Network (O*NET) database in 1998 has changed that. By analyzing O*NET data, we are able to isolate the competencies needed in particular occupations, including STEM occupations. We are also able to determine the degree to which these competencies are unique to STEM and that are shared more broadly with other occupations.

In doing so, we have distinguished STEM competencies that are most prominent in STEM occupations from STEM competencies that are used in both STEM occupations and a variety of other occupations. It is the demand for these transferable competencies outside of STEM occupations that creates the persistent and growing demand for STEM talent and ultimately results in a wide scarcity of workers with those highly transferable STEM competencies.

O*NET also allows us to demonstrate that success in STEM occupations requires a set of competencies beyond an incumbent's knowledge, skills, abilities. Identifying these additional, noncognitive competencies allows us to understand why we have a persistent STEM competency shortage; indeed, our chronic STEM shortage makes more sense once viewed through the prism of these cognitive and personal competencies rather than through mechanical counts of degrees and occupational demand.

WORK INTERESTS AND WORK VALUES ALSO IMPACT DIVERSION

Part of the debate on the adequacy of our education system in producing enough STEM talent focuses on our ability to attract students from the K-16 talent pool into science and technology careers. Recently, many advocacy groups have emphasized the design of education and training programs to increase the interest of students in STEM. Undergirding these efforts is the belief that changes in curricula to increase interest will result in greater numbers of students adopting and persisting in STEM courses and careers. While such a strategy can be expected to result in marginal gains in shifting students toward STEM careers, ultimately this approach has limits. The primary flaw in these strategies is that they overlook the fact that individuals also have powerful personal and work interests and work values *separate and apart* from their STEM knowledge, skills, and abilities that may draw them away from (or into) STEM careers.

Employers have long asserted that jobs require a complex set of competencies that are neither reflected in academic credentials nor directly nurtured through academic pedagogy. Although formal education, which culminates in degrees and certificates, is capable of defining, developing, and teaching knowledge, there are other work interests and work values that draw individuals into particular occupations and make them successful. For example, in order to be a chemist, it is generally accepted that a worker needs a Chemistry degree. But the O*NET data show that a Chemistry degree is not the only factor that makes a chemist successful in a chemistry occupation. Chemists also require strong Achievement and Independence work values and Investigative, Realistic, and Conventional work interests (see below).

Work interests and work values were included in O*NET to facilitate "person-job match for purposes of enhancing job satisfaction and retention" (Tippins and Hilton 2010, 64). This rationale corroborates our assertion that work values and work interests are important in the decision-making process of individuals that study STEM fields as well as pursue careers. In a previous section, we've shown that many STEM-capable students—as evidenced by academic performance—decide against STEM majors and careers. We use O*NET to confirm that this diversion is partially due to mismatches in work interests and work values.

O*NET: A REVOLUTIONARY DATA TOOL

O*NET is a unique database built on surveys of occupational incumbents. The O*NET database specifies the full set of occupational competencies required in particular occupations and related clusters of similar careers. Operated by the National O*NET Consortium and funded by the U.S. Department of Labor, the database includes information regarding occupational knowledge, skills, abilities, work values, and work interests, as well as key performances (tasks and activities) for 965 different occupations. This database allows us to measure the importance of various competencies within an occupation and to begin a dialogue over the appropriate roles of educational institutions and employers in providing core competencies required in today's economy.

O*NET's occupational data are anchored in a set of cognitive competencies: knowledge, skills, and abilities (KSAs):

Knowledge classifications are content domains familiar to educators. Examples include Mathematics, Chemistry, Biology, Engineering and Technology, English Language, Economics and Accounting, Clerical, and Food Production.

Skills are competencies developed in the context of particular knowledge domains that allow continued learning in a knowledge domain. They are divided into content, processing, and problem-solving skills. Content skills are fundamental skills needed to acquire more specific skills in an occupation. These include Reading Comprehension, Active Listening, Speaking, Writing, Mathematics, and Science. *Processing skills* are procedures that contribute to the more rapid acquisition of knowledge and skills. These include Critical Thinking, Active Learning, Learning Strategies, and Self-Aware Monitoring. *Problem-solving skills* involve the identification of complex problems and related information required to develop and evaluate options and implement solutions.

Abilities are defined as enduring and developed personal attributes that influence performance at work. Abilities vary in the extent to which they are innate and developed. The lion's share of abilities are developed, and schools and workplaces are important venues for development. Schooling, for example, adds from 3.5 to 3.8 points per year to IQ (Falch and Sandgren 2006). The evidence shows that developed abilities increase with effective schooling and family income (Turkheimer et al. 2003; Nisbett 2007). In the parlance of education psychology, these closely approximate "aptitudes."

O*NET divides abilities broadly into categories such as Creativity, Innovation, Mathematical Reasoning, and Oral and Written Expression. Each of these broad abilities is subdivided into component elements. For example, innovative abilities include Fluency of Ideas, Problem Sensitivity, Deductive Reasoning, and Inductive Reasoning.

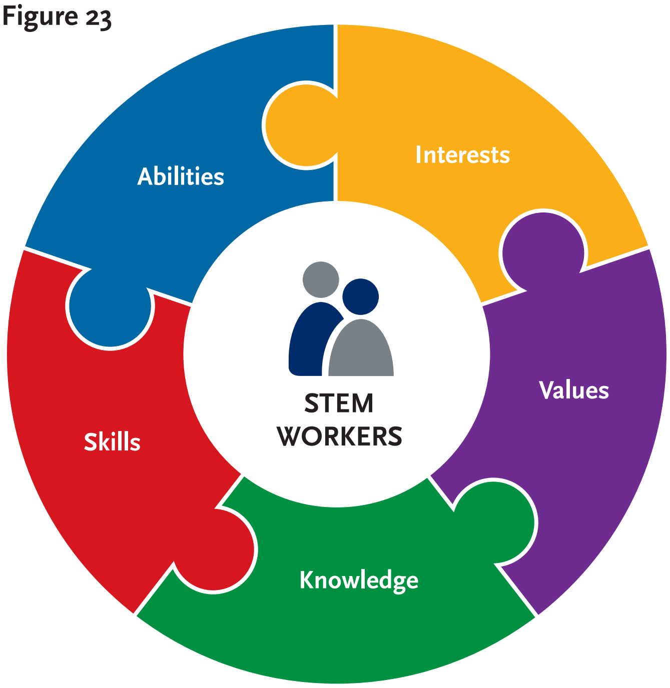
These knowledge domains, skills, and abilities defined by O*NET interact in complex, multidimensional ways. Moreover, the interactions between them are highly correlated—for example, Mathematical Reasoning is an ability that relates to Mathematical Knowledge.

In addition to the cognitive competencies, O*NET classifies competencies that are tied to personal traits that are important in particular occupations, enhancing retention and persistence. Two of these key competencies are work values and work interests:

Work values are individual preferences for work outcomes. Important outcomes for individuals include Recognition, Achievement, Independence, Working Conditions, Security, Advancement, Authority, Social Status, Responsibility, and Compensation.

Work interests are defined as individual preferences for work environment. Interests are classified as Realistic, Artistic, Investigative, Social, Enterprising, and Conventional. Individuals who have particular interests—Artistic interest, for example—are more likely to find satisfaction in occupations that fit with those interests. Of course, an incumbent can have an Artistic work interest and not be in an occupation where he or she is able to exercise that work interest (for example, accounting is an occupation that is not the best outlet for Artistic work interest). However, O*NET allows us to identify which work interests can be fulfilled in which occupations—for example, that an incumbent with Artistic interest might like a job as a designer.

Figure 23



STEM COGNITIVE COMPETENCIES: KNOWLEDGE, SKILLS, ABILITIES

Using O*NET, we have identified the cognitive (knowledge, skills, and abilities) and noncognitive (work values and work interests) competencies that are most highly correlated with STEM occupations, and we show their relative transferability to other occupations.[55]

STEM KNOWLEDGE AND ITS TRANSFERABILITY

Knowledge is one of the most occupation-specific competencies. The 10 knowledge domains below are, for the most part, unique to STEM in their intensity and importance.[56] But even though STEM knowledge tends to be highly specialized, it is both transferable and useful in contexts outside the traditional STEM disciplines and occupations. Ultimately, this dynamic gives rise to careers that mix essentially different academic preparation and occupations. A mix of technical preparation and preparation in other disciplines is increasingly advantageous across a wide array of occupations. In addition, the transferability of knowledge allows STEM professionals to shift into other careers, especially into managerial roles midcareer in which their technical competencies are an advantage.

As technology automates more and more repetitive tasks in every occupation, workers are left with more general nonrepetitive functions like quality control and innovation that require heightened interaction with other workers across intellectual disciplines and occupations. The growth in overlapping assignments and performance goals increases the need for cross training and soft skills like communications and teamwork.

While academic disciplines and occupations tend to overlap more and more, each discipline and occupation still has a core set of knowledge, skills, and abilities as well as work values and work interests at its core.

Computers and Electronics is an example of a core knowledge domain among STEM occupations. Computer and Electronics knowledge, which includes knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software (including applications and programming), is either important or extremely important in 80 percent of STEM occupations. Other occupations also utilize Computers and Electronics knowledge, although to a lesser degree. This is especially true of direct STEM competitors such as Managerial and Professional and Healthcare Professional occupations (see Figure 24).

Mathematics knowledge is the most transferable kind of STEM knowledge. In 55 percent of STEM occupations, Mathematics knowledge is either very important or extremely important to work in that occupation. In 31 percent of direct STEM competitor occupations, Mathematics knowledge is very important, and it is very important in less than 20 percent of other occupations.

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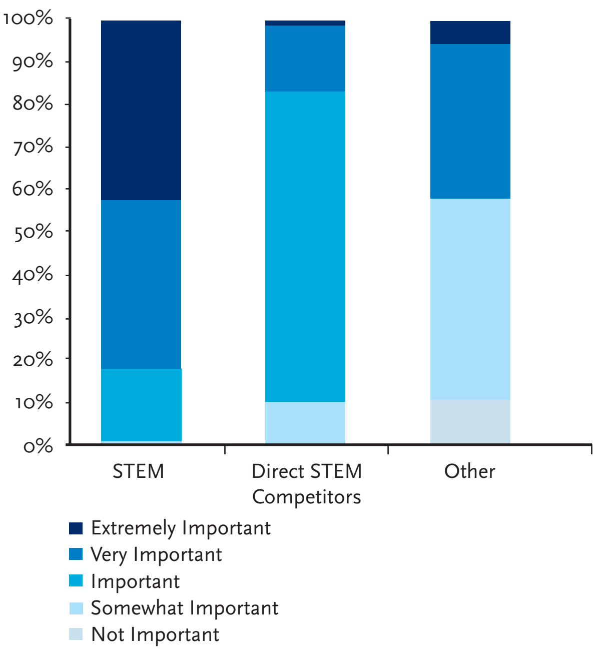
[55] The approach to this connection was twofold. First, we determined the extent of the relatedness of occupational clusters, based on the similarities of the intensity of responses from incumbents in those occupations. Second, we determined the incidence in the national economy, controlling for the size of occupations. Factor analysis was the primary data-reduction tool employed.

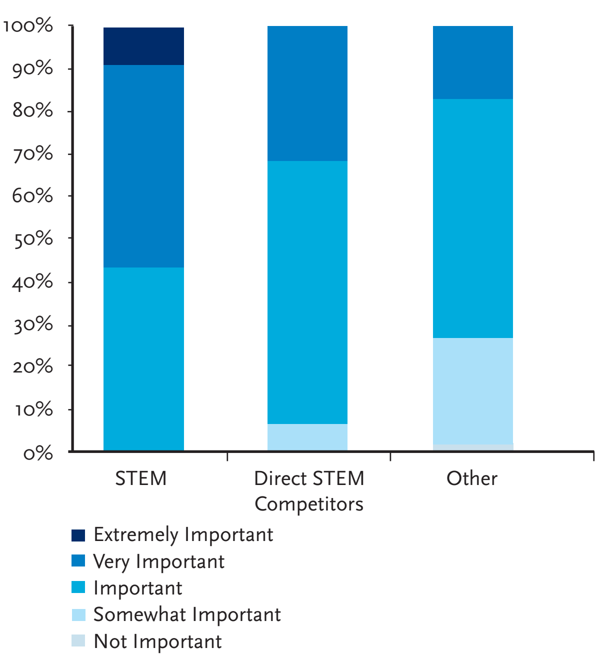
[56] O*NET measures both relative "intensity" of use (level of skill necessary) and "importance" of different competencies in an individual occupation.

Figure 24: Knowledge of Computers and Electronics is highly concentrated in STEM but is Transferable to Other Occupations



*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 25: Mathematical Knowledge



*Source: Authors' analysis of O*NET 14.0 and CPS*

CORE KNOWLEDGE DOMAINS ASSOCIATED WITH STEM OCCUPATIONS

Production and Processing: Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.

Computers and Electronics: Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.

Engineering and Technology: Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.

Design: Knowledge of design techniques, tools, and principles involved in production of precision.

Building and Construction: Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.

Mechanical: Knowledge of machines and tools, including their designs, uses, repair, and maintenance.

Mathematics: Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.

Physics: Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic, and subatomic structures and processes.

Chemistry: Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.

Biology: Knowledge of plant and animal organisms and their tissues, cells, functions, interdependencies, and interactions with each other and the environment.

These results, consistent across STEM knowledge domains, are evidence of the demand for STEM competencies in select occupations outside traditional STEM occupations, especially in Managerial and Professional and Healthcare Professional occupations (what we have termed "direct STEM competitors"). Since the core competencies associated with STEM are found in STEM's direct competitors—occupations that, on average, pay better than STEM—we infer that demand for STEM competencies across the economy is driving STEM diversion.

STEM SKILLS ARE GENERALLY MORE TRANSFERABLE THAN STEM KNOWLEDGE

STEM occupations also have a set of core cognitive skills. Skills that are highly concentrated in STEM can be found in the adjacent box and include, among others, Critical

CORE SKILLS ASSOCIATED WITH STEM OCCUPATIONS

Mathematics:	Using mathematics to solve problems.
Science:	Using scientific rules and methods to solve problems.
Critical Thinking:	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems.
Active Learning:	Understanding the implications of new information for both current and future problem-solving and decision making.
Complex Problem Solving:	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Operations Analysis:	Analyzing needs and product requirements to create a design.
Technology Design:	Generating or adapting equipment and technology to serve user needs.
Equipment Selection:	Determining the kind of tools and equipment needed to do a job.
Programming:	Writing computer programs for various purposes.
Quality Control Analysis:	Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
Operations Monitoring:	Watching gauges, dials, or other indicators to make sure a machine is working properly.
Operation and Control:	Controlling operations of equipment or systems.
Equipment Maintenance:	Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Troubleshooting :	Determining causes of operating errors and deciding what to do about it.
Repairing:	Repairing machines or systems using the needed tools.
Systems Analysis:	Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
Systems Evaluation:	Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.

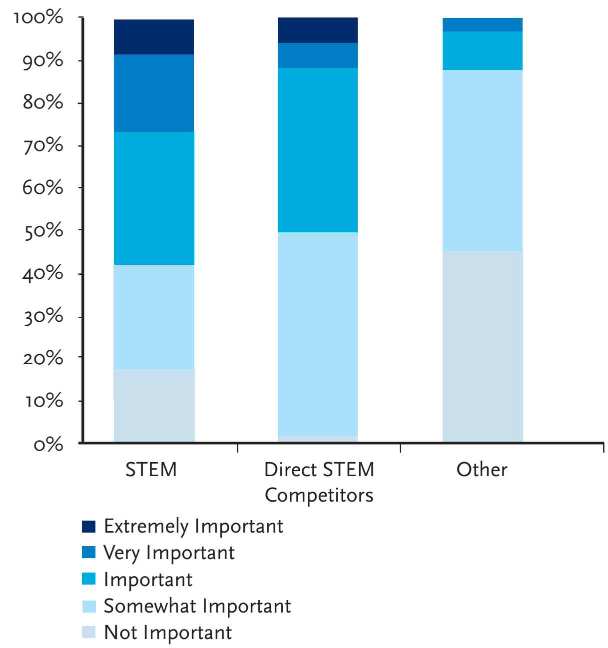
Thinking, Complex Problem Solving, Troubleshooting, and Systems Analysis.

As we turn to STEM skills and abilities, we find that—unlike knowledge—these are less heavily concentrated in STEM and more diffuse across the economy. In other words, while STEM knowledge is concentrated most heavily in STEM occupations, the skills and abilities found in STEM occupations are also found more frequently in other occupations as well.

In 95 percent of STEM occupations, Mathematics skill is considered at least "important" to fulfilling the requirements of that occupation (see Figure 26). The same is true for 82 percent of occupations that are direct competitors for STEM talent.

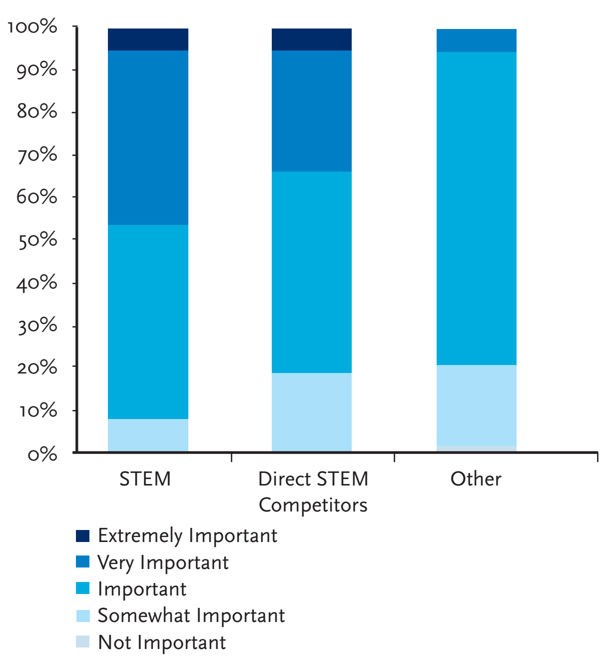
Science skill is considered important, very important, or extremely important in just under 60 percent of STEM occupations (see Figure 27). In more than half of STEM occupations, Science skills are either important or extremely

Figure 27: Science (Skill)



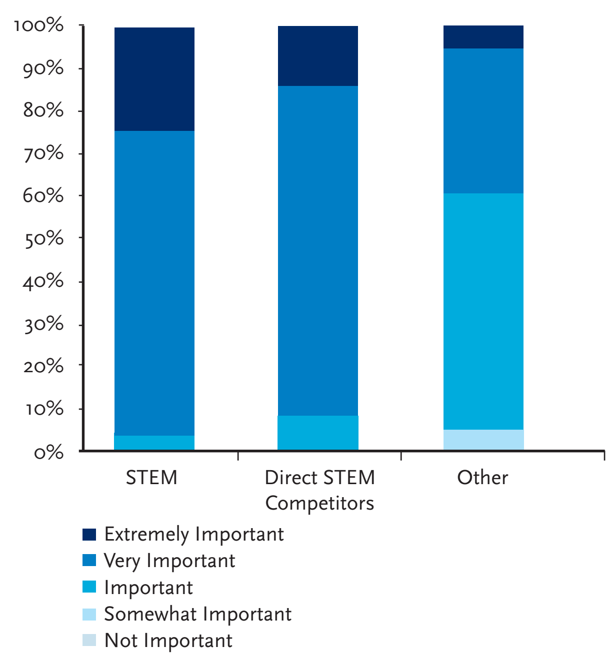
*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 26: Mathematics (Skill)



*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 28: Critical Thinking (Skill)



*Source: Authors' analysis of O*NET 14.0 and CPS* important for performing in that occupation. Direct STEM competitors utilize Science skill to a comparable degree. About half of Managerial and Professional and Healthcare Professional occupations require significant amounts of Science skill. Again, a clear distinction can be seen between STEM and STEM competitors on the one hand and all other occupations on the other.

Critical Thinking is another skill that is often touted by employers as a necessary requirement for success in many occupations. O*NET data confirm this assertion. Ninety-six percent of STEM occupations and 92 percent of STEM competitor jobs consider Critical Thinking to be either very important or extremely important to that job (see Figure 28).

STEM ABILITIES ARE MORE TRANSFERABLE THAN STEM KNOWLEDGE

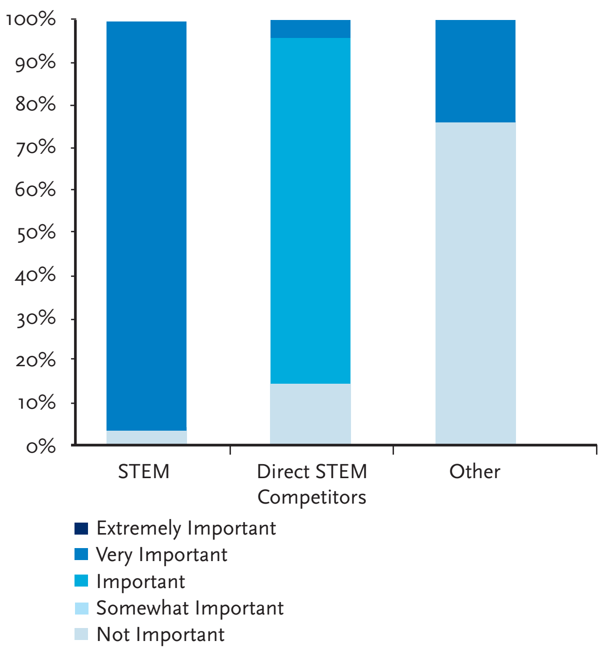
Similar to skill, ability is associated with the capacity to utilize knowledge learned to solve problems. Abilities are generally believed to be much more stable and enduring than skills. Abilities refer to capacities that are to some extent present in a person at early ages and developed over time. They include generic characteristics that allow individuals to acquire a skill. In other words, abilities are "relatively enduring attributes of an individual's capability for performing a particular range of different tasks. Abilities are regarded as traits in that they exhibit some degree of stability over relatively long periods of time. It is recognized, however, that abilities may develop over time and with exposure to multiple situations" (Fleishman, Costanza, and Marshall-Mies 1999, 175).

We find that Mathematical Reasoning and Deductive Reasoning are two abilities that are used most often in STEM occupations, but they are required at comparable levels in direct STEM competitor occupations as well as across the rest of the economy (see Figures 29 and 30). Mathematical Reasoning is either very important or extremely important to 35 percent of STEM occupations and important to 15 percent of STEM competitors.

ABILITIES ASSOCIATED WITH STEM OCCUPATIONS

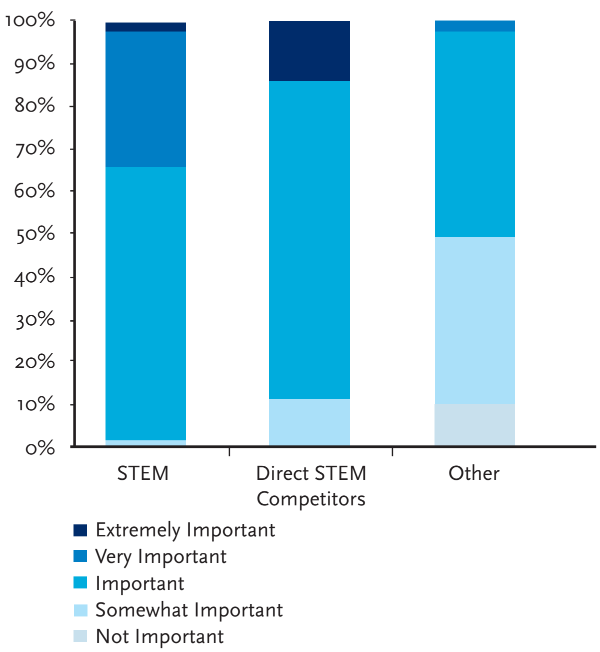
Problem Sensitivity:	The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing that there is a problem.
Deductive Reasoning:	The ability to apply general rules to specific problems.
Inductive Reasoning:	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
Mathematical Reasoning:	The ability to choose the right mathematical methods or formulas to solve a problem.
Number Facility:	The ability to add, subtract, multiply, or divide quickly and correctly.
Perceptual Speed:	The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
Control Precision:	The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.

Figure 29: Deductive Reasoning (Ability)



*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 30: Mathematical Reasoning (Ability)



*Source: Authors' analysis of O*NET 14.0 and CPS*

STEM WORK VALUES AND STEM WORK INTERESTS HAVE A LARGE IMPACT ON DIVERSION

We find that Achievement, Independence, and Recognition work values and Realistic and Investigative work interests are characteristic of STEM occupations.

Achievement, Independence, and Recognition work values are relevant to STEM occupations and direct STEM competitors. People who are looking for Achievement, Independence, and Recognition and don't find it in STEM can most easily divert to other occupations that utilize the skills and abilities they already have. Additionally, for many people, pay is also an indicator of Achievement and Recognition, indicating that work

WORK VALUES ASSOCIATED WITH STEM OCCUPATIONS

Achievement: These jobs let you use your best abilities, see the results of your efforts and get the feeling of accomplishment.

Independence: These jobs allow you to do things on your own initiative, and make decisions on your own.

Recognition: The jobs offer good possibilities for advancement, and offer prestige or with potential for leadership.

WORK INTERESTS ASSOCIATED WITH STEM OCCUPATIONS

Realistic: Realistic occupations frequently involve work activities that include practical, hands-on problems and solutions. They often deal with plants, animals, and real-world materials like wood, tools, and machinery. Many of the occupations require working outside, and do not involve a lot of paperwork or working closely with others.

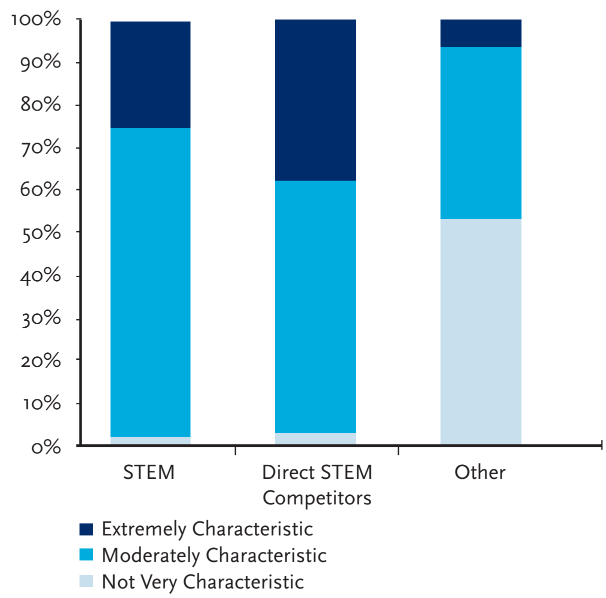
Investigative: Investigative occupations frequently involve working with ideas, and require an extensive amount of thinking. These occupations can involve searching for facts and figuring out problems mentally.

values and pay-based diversion work to reinforce each other (the same is also true of Independence).

Work interests characteristic of STEM include Investigative and Realistic interests. According to O*NET, Investigative interests are exhibited by working with data and ideas. In contrast, other work interests outside the traditional STEM occupations include Social, Artistic, Conventional, or Enterprising interests. Occupations with Social interests at their core frequently involve working with, communicating with, and teaching people. These occupations often involve helping or providing service to others. While Investigative and Social interests are not necessarily mutually exclusive, each is more concentrated in certain occupations. A student who is capable of doing STEM coursework may decide that his or her personal, academic, and/or work interests are more suited to management, direct service, or teaching than to working in a lab or with computers.

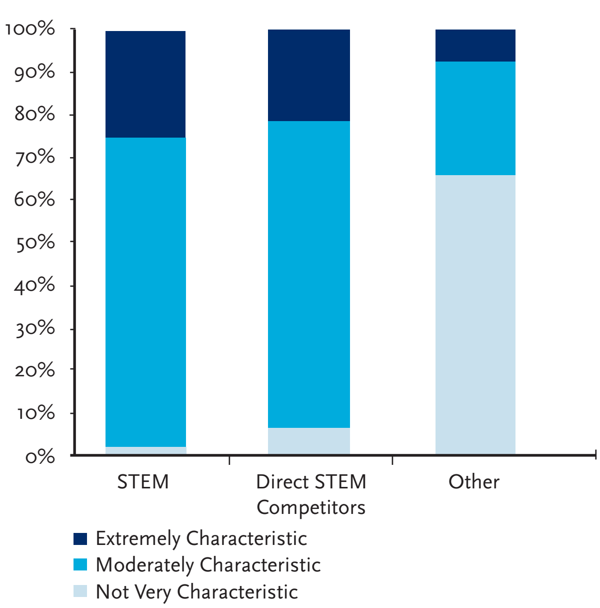
A biologist, for example, may decide that becoming a doctor is more in line with his or her Social interests than working in a lab or in the field as a biologist—but that being a doctor will

Figure 32: Independence (Work Value)



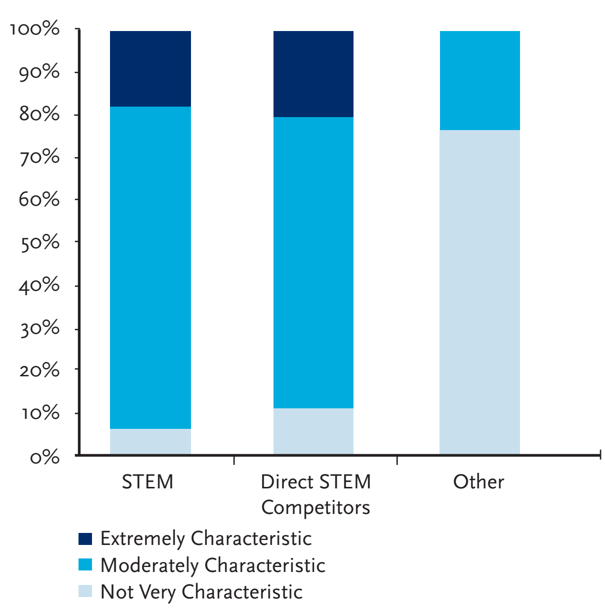
*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 31: Achievement (Work Value)



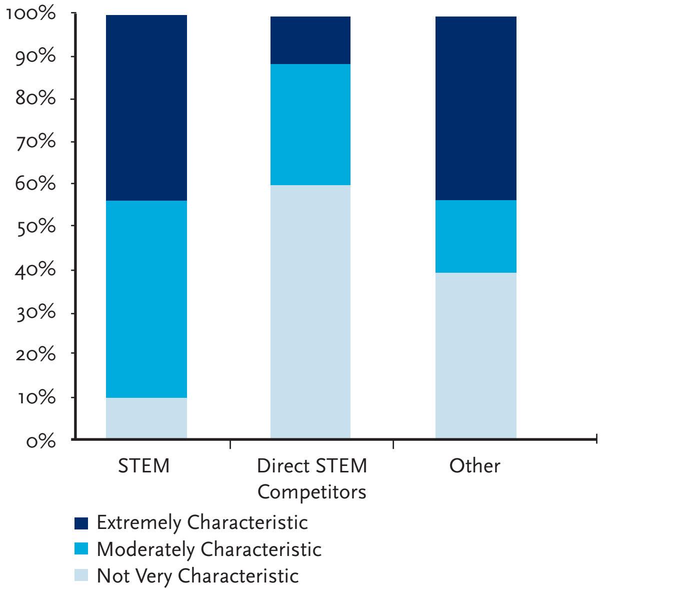
*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 33: Recognition (Work Value)



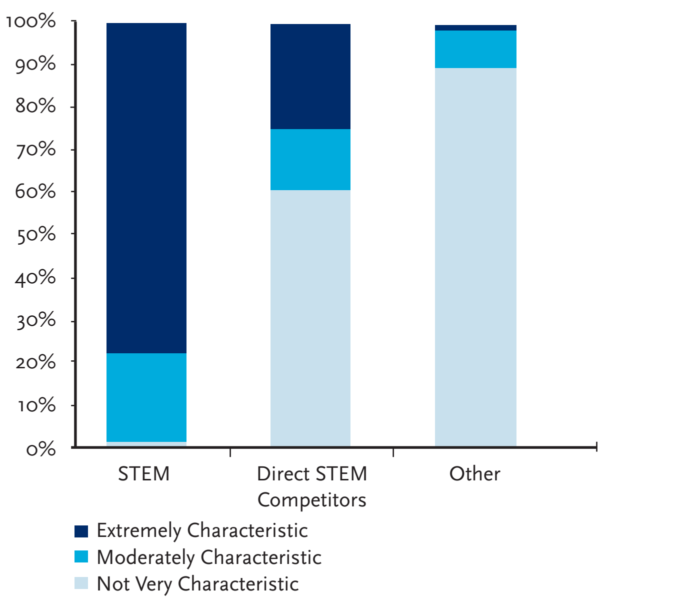
*Source: Authors' analysis of O*NET 14.0 and CPS* also fulfill his or her work values of Recognition and Achievement. Our analysis concludes that differing work interests explain much of the STEM diversion, especially in school and early in the labor market when wage signals are likely to be weak. Therefore, a strategy to increase the STEM workforce that does not take work interests into account will be missing many of the connections between people and labor markets.

Figure 34: Realistic (Interest)



*Source: Authors' analysis of O*NET 14.0 and CPS*

Figure 35: Investigative (Interest)



*Source: Authors' analysis of O*NET 14.0 and CPS*

BUT IS DIVERSION VOLUNTARY? DO STEM STUDENTS AND WORKERS DIVERT TO OTHER DISCIPLINES AND OCCUPATIONS BECAUSE THEY HAVE TO OR BECAUSE THEY WANT TO?

The best available evidence indicates that diversion is mostly voluntary. The data system measuring motivations of STEM workers is the Science and Engineers Statistical Data System (SESTAT), administered by the National Science Foundation. Our analysis of the 2006 SESTAT (the most current) found that, among STEM-trained workers, only 14 percent of those whose highest degree was in STEM and employed reported that they were working outside of their field because a suitable job in their field was not available. Moreover, only 11 percent of unemployed workers whose highest degree was in STEM reported being unable to find a suitable job in their field as their reason for unemployment. These numbers are comparable to those reported by people whose highest degree was not in a STEM field.

The share is about the same for those whose highest degree is a Bachelor's in a STEM field; it is slightly higher for those whose highest degree is a PhD in a STEM field. Even the 17 percent of those who hold PhDs in STEM that cannot find a job in field compares favorably with the numbers for those with a PhD outside of STEM who could not find a suitable job within their field.

These numbers are not considered high for several reasons. First, it is unclear how "suitable" is defined. Those unable to find suitable work may be extremely picky—they have their heart set on a particular job, or with a particular company, that is not obtainable. It is reasonable to infer that at least some of these respondents indicated that they were not able to find a suitable job because it did not meet their preferences and untested expectations. Second, the inability to find a job in their field may reflect more on a job candidate than on a job. Some of the most highly skilled people are ultimately unemployable due to difficult personalities, preferred work styles, or any number of other reasons. Finally, American labor markets are extremely flexible and it is to be expected that a degree of mismatch exists in all occupations.

In addition, among those whose highest degree is a Bachelor's in a STEM field, 24 percent left their field for pay and promotion opportunities, while a slightly smaller number with Master's and PhD degrees left the field for similar reasons. Although these numbers are slightly higher, they are comparable to the numbers who left because they could not find a job in field. Among those whose highest degree is a Master's or PhD in STEM, 22 percent and 27 percent left because they wanted a change in career or because of professional interests (respectively).

Ten percent of people who had top quartile math scores in high school end up working in STEM occupations even though they did not major in STEM fields in college.

STEM DIVERSION IS NOT A ONE-WAY STREET

Finally, diversion does not just push people of out STEM occupations, it also brings them in. High wages in STEM occupations are also a powerful force that draws people who did not graduate with STEM degrees into these occupations. For every 100 workers who do not graduate with a STEM

Table 9: Evidence indicates that diversion is largely voluntary

		STEM is field of study for highest degree (ALL)	STEM is field of study for highest degree (Bachelor's)	STEM is field of study for highest degree (Master's)	STEM is field of study for highest degree (PhD)	Non-STEM is field of study for highest degree (ALL)	Non-STEM is field of study for highest degree (Bachelor's)	Non-STEM is field of study for highest degree (Master's)	Non-STEM is field of study for highest degree (PhD)
Working Full Time or Part Time	Pay, promotion opportunities	23%	24%	17%	18%	26%	28%	21%	15%
	Working conditions [hours, work environment]	9%	9%	7%	4%	10%	11%	9%	2%
	Job location	7%	8%	6%	4%	6%	7%	5%	3%
	Change in career or professional interests	18%	17%	22%	27%	19%	19%	20%	25%
	Family-related reasons	11%	11%	11%	6%	12%	12%	11%	8%
	Job in field of highest degree not available	**14%**	**14%**	**15%**	**17%**	**12%**	**11%**	**13%**	**23%**
	Other reason for not working in field	6%	6%	7%	4%	7%	6%	9%	10%
Not Working	**Reasons for not working: suitable job not available**	**11%**	**10%**	**15%**	**19%**	**8%**	**6%**	**11%**	**13%**

Source: SESTAT, 2006.

Table 10: There are also STEM workers who didn't study STEM

	DON'T GRADUATE WITH A STEM MAJOR* (%)	WORK IN STEM BUT DIDN'T GRADUATE WITH STEM MAJOR† (%)
All	89	6
White	89	7
African American	92	5
Men	86	10
Women	93	3
Top Math Quartile	79	10

*Includes people who did not graduate at all
†Percentage of each group that ends up working in STEM, not percentage of STEM workforce or percentage of STEM workforce without a degree

Source: NELS: 1988

degree, six end up working in these occupations anyway. That number rises to 10 among men and among those who tested in the top math quartile in high school (see Table 10).

THE EFFECTS OF DIVERSION ARE MORE COMPLEX FOR WOMEN AND MINORITIES

Persistence in STEM in school and at work differs by race/ethnicity and sex at different junctures. Still, it is clear that women and African-Americans are subject to greater diversionary pressures than their White, male counterparts at all four points of attrition from STEM that we have identified.

WOMEN

Women begin to divert from STEM well before college. The mean SAT score in Mathematics for women is 500, compared with 533 for men. This difference does not hold for Critical Reading, where men have just a four-point advantage over women, or for Writing, where women have a higher mean than men (501 versus 488). Moreover, while the top scores (750–800) in Critical Reading are divided almost 50–50 between men and women, only 34 percent of the top scores (750–800) in Mathematics were attained by women. These results are particularly disturbing because women report taking math and natural sciences in greater percentages than men (except at the very top level, where they take them at the same rate) (The College Board 2008).

Once in college, women earn Bachelor's degrees at higher rates than men—but they attain degrees in the STEM subjects at shockingly lower rates (with the notable exception of Mathematics. About 44% of Mathematics majors are women). For every 100 men who obtain a Bachelor's degree, 28 of those are in STEM majors; for every 100 women who obtain a Bachelor's degree, only 12 are in STEM majors. Women also are less likely to persist in STEM majors than their male counterparts, make up an even smaller proportion of STEM graduate degrees, and are less likely to make the transition into STEM occupations (Hill, Corbett, and St. Rose 2010). Once in the workforce, women are also underrepresented in STEM occupations. Although women have made great strides in other fields—including law and medicine—gains for women in STEM positions over the past two decades have not been comparable. Women, for instance, account for less than 15 percent of the nation's engineers (Commission on Professionals in Science and Technology 2004).

Other data indicate that women with STEM degrees who are not working in field do so for various reasons. These reasons are primarily (though not exclusively) family-related reasons. This is in contrast to men, whose primary reason for not working in field is reported as pay and promotional opportunities. Women also reported a change in career and pay and promotion opportunities, as well as job in highest degree not available, but they reported all of these at lower or comparable rates as men. However, women were far less likely than men to report not working in STEM due to job location, working

Table 11: Men and women have different reasons for working outside of STEM

	WOMEN (%)	MEN (%)
Pay, promotion opportunities	15	31
Working conditions	12	9
Job location	9	8
Change in career	20	21
Family-related reason	22	7
Job in highest degree not available	15	16
Other reason	7	7
Total	**100**	**100**

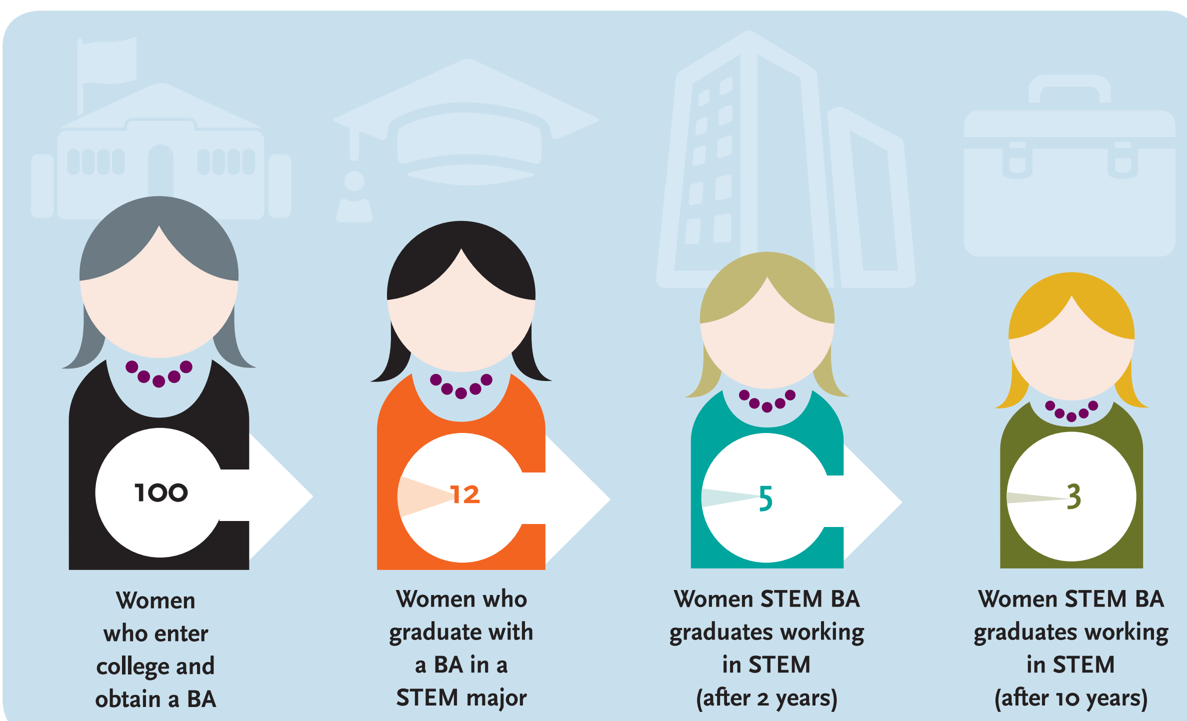
Source SESTAT, 2006.

conditions, change in career, job in highest degree not available, or other reasons, and were far less likely to report pay or promotion opportunities as reason for working outside of STEM.

At all points, then, women are less likely to be found in STEM jobs or fields of study, and these decisions begin well before wages have any significant impact on a student's assessments. Why, then, are women less likely to go into and persist in STEM fields?

At all points, then, women are less likely to be found in STEM jobs or fields of study, and these decisions begin well before wages have any significant impact on a student's assessments.

Figure 36: Diversion from STEM: Women



Source: NELS: 1988 and B&B: 1993/2003

While we do not try to answer the question empirically, there is substantial literature that suggests women are influenced by traditional ideas about women's roles in society and the workplace. These ideas subtly influence women from early childhood, when they are given dolls to play with instead of building blocks. Researchers and advocates have noted that these biases begin having an effect on girls in middle school.

Among the factors reinforcing these biases, researchers have identified classroom climate, stereotypes, gender bias and discrimination,[57] the climate of science and engineering departments in postsecondary institutions, and the lack of female STEM role models in postsecondary institutions and in the wider culture.[58]

Table 12: Men and women have different reasons for working outside of STEM

	WOMEN (%)	MEN (%)	TOTAL
Pay, promotion opportunities	20	80	100
Working conditions	40	60	100
Job location	34	66	100
Change in career	32	68	100
Family-related reason	60	40	100
Job in highest degree not available	32	68	100
Other reason	33	67	100

Source SESTAT, 2006.

AFRICAN-AMERICANS

African-American students are also significantly behind their White peers in STEM commitment before college. Compounding the problem is the persistent test-score gap between African-American and White students within the American education system. That gap is wider in STEM subjects than in others, with African-American students typically scoring one standard deviation below White students. There is a significant test-score gap between African-Americans and Whites on the SAT; mean test scores for African-Americans are about 100 points lower than for Whites, and this gap is even greater on the mathematics portion of the exam. Latinos do slightly better than African-Americans but still score significantly behind their White counterparts (The College Board 2008).

Attrition within college is also a significant problem for African-Americans. Higher proportions of African-Americans than Whites say they intend to major in STEM subjects. According to the National Science Foundation, 34 percent of African-American students intend to major in STEM (compared with 45% of Asians and 30% of Whites) (Higher Education Research Institute 2008). However, our data indicate that far fewer actually receive a STEM degree. Attrition at all these points, and in the workforce, add up to the fact that African-Americans are underrepresented in the STEM workforce—6 percent compared with 11 percent in the general workforce. African-American women account for only about 35 percent of the African-American STEM population (Commission on Professionals in Science and Technology 2005).

Part of the problem is the overall low persistence rate for African-Americans in college. Other researchers and advocates have also pointed to lack of mentors, lack of peer support, discrimination, low expectations, and unwelcoming classroom climates as reasons for African-American underrepresentation in STEM fields (Sasso 2008).

[57] Some researchers have found that discrimination is no longer a barrier to women in science (see Ceci and Williams 2011).

[58] See Hill, Corbett, and St. Rose (2010) and De Welde, Laursen, and Thiry (2007). Both have excellent lists of additional resources on the topic of women in STEM. See also Griffith (2010) and Price (2010).

The distribution of STEM workers by sex and race/ethnicity reflects these biases. Over three-quarters of workers in STEM occupations are men. Over 70 percent of STEM workers are White, compared with 65 percent in the workforce as a whole. Asians are also represented in higher proportions, accounting for 16 percent of the STEM workforce but only 5 percent of the workforce as a whole. Meanwhile, the opposite is true for Latinos and African-Americans; each group is 6 percent of the STEM workforce, while African-Americans make up 12 percent of the workforce as a whole and Latinos account for 16 percent. And although women are 44 percent of Mathematics majors, they are underrepresented in STEM.[59]

Table 13: Women divert from STEM at much higher rates than men

	OF 100 BACHELOR'S DEGREE-HOLDERS, NO. THAT GRADUATE IN STEM MAJOR	BACHELOR'S IN STEM AND EARLY CAREER IN STEM	BACHELOR'S IN STEM, WORKING IN STEM LATER IN CAREER
Men	28	17	6
Women	12	5	2
All	**19**	**10**	**4**

Source: NELS: 1988, B&B: 1993/2003

Table 14: Women are underrepresented in STEM occupations

	MEN	WOMEN
Proportions of workers in STEM occupations (%)	77	23
Proportions of workers in all occupations (%)	52	48

Source: CPS, 2008

Table 15: Representation in STEM, by Race/Ethnicity: Minorities are Underrepresented

	WHITE	AFRICAN-AMERICAN	LATINO	ASIAN	OTHER
Proportions of workers in STEM occupations by race (%)	71	6	6	16	2
Proportions of workers in all occupations by race (%)	65	12	16	5	2

Source: March CPS, 2008

59 However, they are underrepresented in other majors, including Engineering and Computer Science.

Table 16: Representation of Men and Women in STEM, by Race/Ethnicity

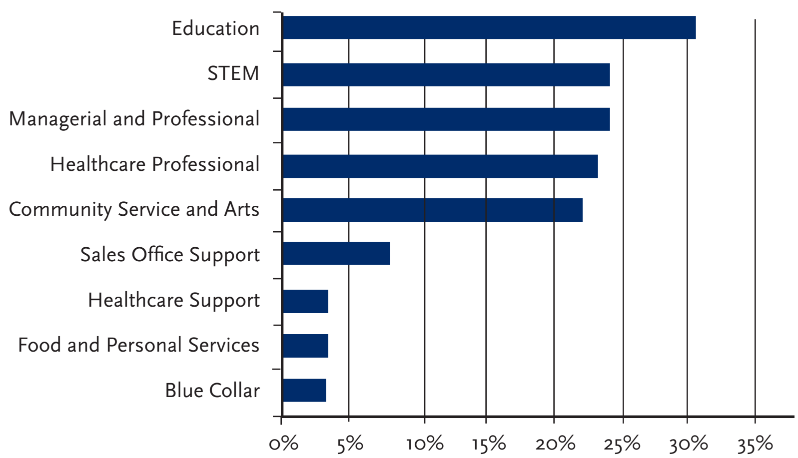
	WHITE	AFRICAN-AMERICAN	LATINO	ASIAN	OTHER
MEN:					
Proportions of workers in STEM occupations by race (%)	72	5	6	15	2
Proportions of workers in all occupations by race (%)	65	11	18	4	2
WOMEN:					
Proportions of workers in STEM occupations by race (%)	66	10	5	19	1
Proportions of workers in all occupations by race (%)	65	13	15	5	2

Source: March CPS, 2008

Part 5: *Our Future STEM Workforce*

THERE IS ADDED PRESSURE TO FIND MORE STEM WORKERS DUE TO BABY BOOMER RETIREMENTS

Figure 37: Percentage of occupation composed of baby boomers with a Bachelor's and above



Source: ACS, various years.

Demographics have made the shortage of STEM competencies much more imminent. The impending retirement of large numbers of baby boomers[60] will affect the nation's entire workforce, but the impact it will have on STEM and its competitor occupations is disproportionate. STEM ranks fourth out of the 10 main occupational clusters for its share of baby boomers with a Bachelor's degree or better. Ten percent of all baby boomers with at least a Bachelor's degree—nearly 5 million workers—are in STEM occupations. The occupational cluster with the most baby boomers—Managerial and Professional—will lose more than 13 million workers as baby boomers shift out of the workforce, and Healthcare Professional occupations will lose well over 4 million workers. Other occupations that will see significant numbers of retirements are Education and Sales and Office Support, which combined will lose the accumulated experience of more than 16 million workers with at least a Bachelor's degree in these occupations.

The need to produce more workers with STEM competencies is heightened when looking at the occupations competing for STEM talent—Managerial and Professional occupations, especially.

[60] Baby boomers are defined as those born between the years of 1946 and 1964, inclusive.

Further complicating this picture is the fact that decades of experience and human capital built up over the course of their careers is lost when these workers retire. Replacing these workers with new college graduates cannot make up for all of the accumulated knowledge these experienced workers possess. As a result, it is important to increase the production of STEM talent not only down the road, when the baby boomers phase out of the workforce, but also now, to ensure that there is adequate time to transfer workplace knowledge to the new generations of employees.[61]

THE NATION NEEDS MORE WOMEN AND MINORITIES IN STEM JOBS FOR MANY REASONS

Diversity takes on broader meanings as the STEM workforce becomes more global. If the United States is to achieve both economic goals and equity goals, we need to think of diversity in both domestic and global terms. As innovation and the STEM workforce become more global, international diversity in STEM becomes more important in the global contest for talent.

We must also make STEM careers more accessible to African-Americans, Latinos, women, and people from low-income families who have had little access to the substantial earnings and prestige STEM jobs offer. Adding more women and minorities to the STEM talent pool is crucial to America's future. Equity demands it, but so does the economy. The market is made up of a variety of consumers who have different tastes, experiences, and lifestyles that should be reflected in available products and services—this is true for the development of consumer products as well as management and medicine.

There is also an issue of basic math. Women and minorities are a significant portion of the population—well over half. Failure to access the talent within that population is both inefficient and wasteful.

The implications of diversity in STEM are not just economic, of course, but also social. Diversity is worthy of promotion as an end in and of itself. There are also practical reasons to encourage more women and minorities to pursue careers in STEM. Minorities and women are vital to economic vibrancy and innovation and can also help discourage groupthink. The power that STEM occupations have over the rest of society is great—STEM occupations are not just the impetus for economic expansion; they play an important role in expanding human possibility. STEM workers and those with STEM talent develop and design new medicines, build and design bridges and buildings, develop new technologies, and increasingly control the way we interact with the market by designing the architecture of our computers and the Internet. In a democratic society, groups that hold such enormous power over our lives—whether they are politicians or scientists—must represent all of us.

WE ARE CURRENTLY RELYING ON FOREIGN-BORN WORKERS TO PLUG THE GAPS IN OUR STEM WORKFORCE

As a result of STEM talent shortages throughout the U.S. education and workforce pipeline, many technical industries have come to rely on immigrants to fill the gap between supply and demand for skilled scientific and technical workers. Immigrants are disproportionately concentrated in STEM fields, both in educational institutions and the workforce, partially compensating for native-born American workers who divert into other fields.

Foreign-born students are responding to favorable signals in immigration policy. Currently, there is a preference in the award of F-1 student visas that favors STEM students. About 44 percent of the students on such visas in 2008 were here to study STEM fields (Burrelli 2010). Further, Optional Practical Training (OPT) allows foreign-born students with American degrees to work here for a period of up to 12 months—prior

[61] Although the recession has led to pessimism among many about the job opportunities, all of the evidence points to relatively lower unemployment rates for STEM workers even in the Great Recession of 2007.

to or at the completion of their academic program. Immigration and Customs Enforcement statistics show that roughly 33 percent of all temporary OPT workers are in STEM fields. The 2008 regulation also allows F-1 students who receive degrees included on the STEM Designated Degree Program List to apply for a 17-month extension of their post-completion OPT (Department of Homeland Security 2008). Recently, the Obama administration has pushed harder to allow STEM graduates to stay, expanding the list of science and mathematics fields that are eligible to stay longer (Inside Higher Ed 2011).

Roughly two-thirds of foreign students who study STEM fields (63% in 2009) are found in graduate programs (Burrelli 2010). Foreign-born students, particularly those with temporary visas, represent a disproportionate and increasing share of those obtaining Doctoral degrees in STEM fields from American institutions. In 2009, foreign-born workers with temporary visas represented 31 percent of Doctoral degree recipients in all fields, but 59 percent of those were in engineering fields. In the same year, 46 percent of those studying in the physical sciences and 50 percent of those in mathematics were foreign-born. Furthermore, their share of doctorates in these fields has risen by 6 percent between 1993 and 2005.

Over the same period, Doctoral recipients in STEM fields have increasingly chosen employment in the United States, with the numbers of those finding employment abroad dropping by an average of 9 percent across the different STEM fields (NCES 2008, 1995).

Foreign-born workers are also disproportionately found in science fields compared with all employed workers (see Table 17). While 12 percent of all workers are foreign-born, 25 percent of all Physical Scientists, 23 percent of all Life Scientists, 18 percent of all Mathematics and Computer workers, and 16 percent of all Engineers are foreign-born. Foreign-born STEM workers account for much of the ethnic and racial diversity in STEM occupations.

Moreover, the share of foreign-born workers as a share of the STEM workforce has grown in the last 20 years. The overall share of foreign-born workers in the STEM workforce has more than doubled, from 7 percent in 1950 to 16 percent in 2000. Moreover, the composition of foreign-born workers has also changed. Several decades ago, most of the foreign-born STEM workers were from European countries (54% in 1970); however, in recent years, Asians have come to comprise the majority of the foreign-born STEM workforce (59% in 2000) (Lowell 2010). In total, 8 percent of all STEM workers are foreign-born Asians, compared with 3 percent in the workforce as a whole. In addition, the foreign-born STEM workforce is here to stay: foreign-born STEM workers are more likely than other foreign-born workers to be naturalized citizens (in 2002, 46% versus 39%) (Lowell 2005).

Table 17: Distribution of Foreign-born Workers in STEM occupations

	FOREIGN-BORN (%)
Math & Computer Science Occupations	18
Engineers	16
Physical Science Occupations	25
Life Science Occupations	23
All STEM Professionals	17
All employed workers	12

Source: U.S. Census, 2008

The debate surrounding immigrants and their effects on the workforce is heated. Some question whether immigrants add value to the economy, especially in STEM, or whether they take jobs from native-born workers while depressing wages. Economists are divided, especially since the effect immigrants have on wages and the economy appears to vary based on variety of factors, including time period looked at (long- or short-term) and education level. Some economists argue that foreign-born workers boost productivity and income in the long run.[62] Others claim that immigration drives down wages and take jobs that would have otherwise been filled by native-born workers.

Since foreign-born workers make up such a large portion of the STEM workforce[63] and, in contrast to immigrants in general, are highly educated, the effects of immigration on the STEM workforce may be different than the effect of immigrants on the economy as a whole. Still, the controversy surrounding the effects of foreign-born labor has seeped into the larger debate about STEM shortages: do STEM immigrants make positive contributions to the economy and plug workforce gaps, or do they drive down wages, thus perpetuating workforce shortages by driving native-born workers into higher-paying occupations? Given that the United States allows in roughly 70,000 skilled primary workers per year on permanent visas and about 300,000 on temporary visas, this is not an idle question (Lowell 2010).[64]

Some economists are reluctant to come down definitively on whether immigrants will be able to solve our supply problems. Alan Deardorff shows that the United States could lose out from international trade in the long run if our original source of comparative advantage in the production of STEM workers is obtained by other countries; however, these losses could potentially be offset by the gains from increased exports, gains in consumer welfare, and technological spillovers. Deardorff welcomes the benefits from increasing the world's repository of STEM talent. He writes, "Our country as a whole is most likely to benefit, and our attention should focus more on harvesting those benefits so as to compensate those who are hurt" (Deardorff 2006, 192).

STEM-proficient immigrants work in a variety of companies and institutions but make major contributions in the field and to the economy as a whole; for instance, some research has shown that, between 1995 and 2005, foreign-born STEM workers founded half of the firms in Silicon Valley and 25 percent of tech firms nationwide and, in 2006, were listed as inventor or co-inventor in almost a quarter of all international patent applications filed from the United States (Wadhwa et al. 2007). Clearly, then, immigrants make important contributions to the STEM workforce.

Their effect on wages, however, is hotly debated. Surjit Bhalla (2006) argues that the size of the foreign-born STEM workforce is insufficient to put substantial downward pressure on domestic wages. He cites distance and borders as still being essential characteristics of world trade that prevent the free movement of labor necessary to generate equivalent wages across borders.

This runs counter to George Borjas' work, which attributes a 10 percent decline in the wages of PhDs in computer science and mechanical engineering occupations arising out of a 36 percent increase in the supply of PhD-qualified immigrants in these fields (Borjas 2006). Freeman (2005) also argues that, contrary to the assumptions of traditional international trade models, developing countries are now producing highly skilled STEM workers and that these workers will drive down wage rates in advanced economies. Still, these concerns, he claims, do not warrant policy to limit access to the domestic STEM labor market opportunities. In fact, Freeman sees the growing international supply of STEM workers to be positive for the United States by raising living standards across all countries. He believes that it is still possible to retain comparative advantage in STEM talent if we are able to act as "hubs in the global development of technology" (Freeman 2008, 178).

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[62] A recent report from the Migration Policy Institution suggests that immigration results in higher wages for more highly educated native-born workers but hurts lower-educated native-born workers in the short term (Peri 2010).

[63] This is especially true of workers with a graduate degree in STEM.

[64] There are likely more skilled STEM immigrant workers than these numbers indicate, since there are exemptions for select fields and for nonprofits such as universities.

President Obama recently highlighted in the 2011 State of the Union the importance of science and technology to innovation and job creation—but, as the data demonstrate, we are dependent on foreign-born workers to help us win the future.

Although immigrants have been an important means of compensating for the STEM diversion phenomenon, changes in immigration policy and visa quotas related to the September 11 terrorist attacks have made this source of workers much harder to access. In addition, there are legitimate national security considerations. Work on STEM often includes work on so-called dual-use technologies—those technologies that have both civilian and military applications. Letting noncitizens work in some of our most sensitive research facilities, including our nuclear facilities, is clearly not an option.

Whatever policymakers decide about immigration, the reality is that demand for these workers in their home countries will continue to rise. China, India, and others will be able to compete on wages for top STEM talent in the future. The market for STEM talent is increasingly global, and continuing to rely for future innovation and growth on an increasingly global workforce may be short-sighted. We may not be able to bank on foreign-born talent indefinitely.

Conclusion

The STEM workforce will remain central to our economic vitality, contributing to innovation, technological growth, and economic development well into the future. Capable STEM students, from K-12 all the way through the most highly educated students at the postgraduate level, will continue to be needed in the pipeline for careers that fuel our innovative capability and capacity. Given the importance of STEM occupations to our nation's economic strength and ability to adapt successfully to technological change, some have been justly concerned about whether our students will be able to fill the jobs required to keep our country at the forefront of innovation.

Concern that the United States is losing its competitive edge has been growing, accelerated by recent economic turmoil. Accompanying this turmoil have been longer-term processes that are undeterred by the recent economic malaise. The global economy is rapidly changing and restructuring the way we understand science, technology, and innovation. STEM workers are no longer the only ones responsible for—or capable of—introducing new and innovative technology and products. Increasingly, that function is leaving the confines of the traditional laboratory and moving into the realm of design, customization, marketing, and distribution.

As science and technology shift from the ivory tower to the community, workplace, and the home, demand for STEM competencies has moved from the periphery to the core of the economy. Technology has become deeply entwined in virtually every facet of our modern lives, and the demand for capable workers with science and math competencies continues to grow.

What this means in terms of preparation of the future workforce is that the STEM workers are no longer only bench scientists and engineers with a Bachelor's degree or better. STEM workers now include engineering technicians, systems administrators, and others who require skills that can be obtained at the sub-baccalaureate level.

Unfortunately, rising wage premiums demonstrate that our supply of workers with core STEM competencies is strained already. We have shown conclusively in Part Three that wages for STEM workers are high and rising—although not rising as fast as those occupations that poach STEM talent. Doctors, managers, and other professionals utilize a similar—but not the same—set of baseline competencies in science and math. Capable students with knowledge, skills, and abilities in these areas—and work interests and work values that lead them to these occupations—divert from STEM at various points in the pipeline, both as students and workers. They divert from STEM careers before college, in college, and at several points in the workplace. We are not producing enough students capable of filling all these occupations simultaneously—and as a result, STEM occupations are losing out on the qualified workers they need.

Our schools will be stretched even further as future demand escalates both in STEM occupations and in other occupations competing for STEM talent. And our projections clearly show that demand is rising—there will be 2.4 million job openings for STEM workers by 2018. These trends will continue and likely accelerate as value in products moves from traditional R&D into marketing and customization, driving up demand for business and professional services. Even though it pays well—and pays better than all other occupations at the sub-baccalaureate level—STEM cannot compete with wages in these occupations at the graduate level.

To deal with this impending shortage of competencies, we will need creative and flexible policy solutions that do not try to scare students into liking science or boosting it at the expense of other fields. Moreover, recognizing the different reasons for STEM diversion means that *we will need different interventions to reduce diversion at different points*. Any approach will need to be at least two-pronged.

- First, we must accept that students will not select science and math careers simply because they are capable of doing so. Work interests play a key role in diverting students—and workers—away from STEM careers. More attention must be paid to the role of work interests in forming student and worker desires. We must also nurture students who do have a preexisting personal or intellectual interest in STEM—even if they do not look like traditional STEM workers.
- Second, we need to raise the bar across the board by teaching math and science competencies to a wider audience in a discipline-relevant, more accessible way. Meeting the economy-wide demand for STEM competencies is no longer a matter of sorting our brightest students into STEM. While we wholeheartedly agree that STEM shortages can be addressed by improving student readiness in key subjects and counseling young people on available career choices early in their lives, this report clearly shows the United States must take a broader approach. We elaborate on this in the following section.

THE STEM JOBS DIALOGUE INVARIABLY LEADS TO A BROADER CONVERSATION ABOUT THE AMERICAN EDUCATION SYSTEM

The predominant discussion on STEM in the science and technology policy community focuses on the elite STEM professions that require a Bachelor's degree or better. These workers subdivide further into elite R&D workers and rank-and-file professionals with Bachelor's or graduate degrees. Altogether, these elite workers represent less than 5 percent of the workforce. Hence, the controversy over adequate educational preparation for these workers is less about the overall performance of American K-12 institutions and more about our ability to retain and expand H-1B visas and go offshore for elite professionals.

However, increasing quality across all levels of educational attainment is an especially pressing need because we are not guaranteed to retain our advantages in attracting high-end talent into STEM occupations. Until recently, the sorting process and our ability to attract foreign-born talent have sufficed in creating an elite cadre to staff a world-class economic and scientific power. Moving into the future, however, we cannot be sanguine that the system we have will continue to produce science and math talent at the levels we need.

It is unlikely that relying on foreign-born workers to fill the gaps will work indefinitely, especially as global demand for STEM talent increases. Nor can we continue to depend on our foreign-born STEM workforce as a primary source of diversity. We need to incorporate more women and minorities into our STEM workforce—for equity purposes as well as economic ones.

Some believe that higher STEM wages will be required to compete with other elite occupations if we are to draw more of the top domestic talent into STEM. However, if we draw this scarce talent into STEM with higher wages, we do so at the price of efficiency and quality in other occupations. If we pursue this path, what we gain in STEM we will lose elsewhere.

Concern for the supply of the highest-performing STEM workers tends to point toward strategies targeted at a relatively small portion of American students—our topmost science and math performers. However, in general, issues centered on top levels of STEM technical talent are only indirectly affected by the overall performance of the American K-12 system. In other words, the debate about producing this tiny cadre of elite workers is only marginally about our education system as a whole. The American system has always been relatively good at producing or attracting the highest-performing STEM students (Lowell and Salzman 2007).

The most obvious weaknesses in the American education system relate to the production of workers, especially STEM workers, at the sub-baccalaureate level. One of the most difficult challenges in the American education system will be improving the *middle* of the test score distribution. The demand for high-level skills, including STEM skills, has grown well beyond the elite careers that require a Bachelor's or graduate degree. Presently, 27 percent of STEM postsecondary jobs require competencies at the postsecondary certificate, some college credit, or Associate's degree level. Strengthening the relationship between education and STEM competencies begins with a stronger focus on the middle in education policy.

These weaknesses are long-standing, especially in comparison with other advanced economies. At the community college level, the structure of financing for community colleges exacerbates the problem: the current funding structure favors general education programs, which are less expensive to run, over expensive, technical programs. As a result, community colleges have strong incentives to provide general academic preparation over technical programs and to provide the cheapest career-oriented programs at the postsecondary level.

The trend toward general education and away from career training has accelerated since the report *A Nation At Risk* rocked the education community in 1983. While most students do take some applied courses in high school, only 17 percent take three or more vocational courses in any fields. Even in cases where career and technical preparation is substantial, there are relatively few "programs of instruction" that link secondary and postsecondary curricula.

Our increasing dependence on foreign-born STEM workers is only one facet of the diversity we need in STEM. Our diversity goals need to be both global and domestic.

To remain competitive in the emerging knowledge economy, we need an education system capable of teaching higher-level competencies to all students. Because of the unique funding structure of our education system, it is marked by huge discrepancies in quality. The American education system sorts students in ways that reflect the racial, ethnic, and economic advantages that lie beneath the test scores, grades, and other metrics of educational performance. As the demand for STEM competencies expands beyond traditional STEM occupations, we can no longer afford to rely on a system that sorts instead of a system that develops STEM talent more broadly.

Making sure we have an adequate STEM workforce goes beyond the postsecondary system. More than half of American workers have not obtained any postsecondary certificate or degree. Yet, American high schools offer very little career and technical education or any substantial on-ramps to postsecondary career and technical education. As a result, students who don't get career and technical preparation in high school and don't succeed in the transition to postsecondary programs are left behind.

Part of what's missing starting in the middle years of the K-16 pipeline is a curriculum that caters to the diverse learning styles of young adults. Current math and science curricula are organized as discrete hierarchies—a student moves from geometry, to algebra two, to trigonometry, to calculus. We are too focused on preparing students for the next level. Instead, we should focus on developing curricula that put academic competencies into applied career and technical pedagogies and link them to postsecondary programs in the same career clusters.

The American education system tends to downplay preparation for jobs that require STEM competencies at the sub-baccalaureate level. Apprenticeship systems have declined with the shrinking of industrial unions and have never been a priority in service unions (Lerman 2010). Education for mid-level skill jobs has been superseded by a college-for-all approach in high schools. We do know that career and technical education (CTE) programs reduce dropout rates in high school and increase college attendance (Plank, Deluca, and Estacion 2005; Plank 2001; Stone et al. 2006). Attempts to use more applied curricula, like the Clinton administration's "School to Work" initiatives, have failed for want of support and in response to a cultural aversion to tracking low-income and minority students (Symonds, Schwartz, and Ferguson 2011).

The development of career and technical programs does not mean that we must narrow the focus of curricula, especially below the baccalaureate level. In fact:

- High school and postsecondary career and technical programs should focus on broadly conceived career clusters that maximize further educational choices as well as employability, as many students will need jobs if they are to pay for college and related expenses.
- To the extent possible, "learn and earn" programs in STEM should allow students to work and study in the same field beginning in high school. The vast majority of college students are working while in college, and 39 percent are working full time while they are enrolled. But in only a minority of cases are they working in their areas of study.
- Programs of study that align high school and postsecondary STEM curricula should be strengthened.
- Hybrid programs that mix solid technical knowledge with the development of more general skills and abilities should be encouraged in a broader range of schools.

Hybrid preparation can take many forms. For example, some programs mix technological preparation with the development of more applied cognitive skills and abilities such as problem solving and critical thinking. Other hybrid curricula begin with technical competencies and add soft skill instruction such as teamwork and communications.

Hybrid preparation used to be characteristic of some Bachelor's-level and graduate-level degrees. These degree programs mix different occupational competencies. For example, there are hybrid programs where students take occupationally specific courses (for example, chemistry) as well as broader courses focused on complementary skills (for example, management). Recently, this hybrid preparation has spread to Associate's degrees as well (Townsend, Bragg, and Ruud 2009). Our findings suggest that more hybrid programs are needed that mix solid technical preparation with subjects like business and the social sciences. The Sloane Foundation's Professional Science Master's degree is a good example of one such program. Hybrid programs are filling a gap and making explicit links between educational curricula and careers that were previously implicit.

However, hybrid programs are only the first step toward a system that goes further in connecting the dots between postsecondary education and careers. Even though the vast majority of postsecondary certificates and degrees are awarded in occupational subject matter, there has been no systematic attempt to link postsecondary or secondary education programs (student transcript data) with earnings, job openings, or career pathways—including STEM earnings, openings, and career pathways. As a result, the links between education supply and employer demand are largely driven by personal and professional networks and anecdotal information.[65]

Disconnects between education and careers in the United States have been costly, especially for workers without a postsecondary credential. Our failures in this regard have thus far been partially offset by the extraordinary success of workers with college degrees, especially the successes of those with Bachelor's and graduate degrees. But we should not continue to be complacent about our ability to produce and attract STEM talent.

The dialogue on the adequacy of our STEM workforce ultimately leads to a broader conversation about American education. Because the American education system is only loosely aligned with labor market demands, linking the supply of STEM students with labor market demand is

[65] For a review of recommendations for linking secondary and postsecondary transcript data with labor markets, see the Center's work on the Department of Education's recent gainful employment rule, available at http://cew.georgetown.edu/resources/policy/.

not as simple as matching degree production with occupational demand.

It is clear that our discussion must encompass more than simply looking at the needs of the relatively narrow set of occupations that make up the traditional STEM sector. By widening our view, policy makers, the higher education community, and labor market institutions can gain a keener understanding of the deep need for the core competencies commonly associated with STEM.

We cannot win the future without a competent STEM workforce. The well-being of our workforce, our prosperity, and our nation depend on initiating these discussions, asking the right questions—and then finding the right answers.

APPENDICES

Appendix A: STEM *Competencies*

KNOWLEDGE CLASSIFICATIONS are content domains familiar to educators. Examples include mathematics, chemistry, biology, engineering and technology, English language, economics and accounting, clerical and food production.

SKILLS are competencies that allow continued learning in a knowledge domain. They are divided into content, processing, and problem-solving skills. *Content skills* are fundamental skills needed to acquire more specific skills in an occupation. These include reading comprehension, active listening, speaking, writing, mathematics, and science. *Processing skills* are procedures that contribute to the more-rapid acquisition of knowledge and skills. These include critical thinking, active learning, learning strategies, and monitoring self-awareness. *Problem-solving skills* involve the identification of complex problems and related information required to develop and evaluate options and implement solutions.

ABILITIES are defined as enduring and developed personal attributes that influence performance at work. In the parlance of education psychology, these closely approximate "aptitudes." O*NET divides abilities broadly into categories such as creativity, innovation, mathematical reasoning, and oral and written expression. Each of these broad abilities is subdivided into component elements. For example, innovative abilities include fluency of ideas, problem sensitivity, deductive reasoning, and inductive reasoning. Other abilities include oral expression, spatial orientation, and arm-hand steadiness.

WORK VALUES are individual preferences for work outcomes. Important outcomes for individuals include recognition, achievement, working conditions, security, advancement, authority, social status, responsibility, and compensation.

WORK INTERESTS are defined as individual preferences for their work environment. Interests are classified as realistic, artistic, investigative, social, enterprising, and conventional. Individuals who have particular interests—artistic interest, for example—are more likely to find satisfaction in occupations that fit with those interests. Of course, an incumbent can have an artistic interest and not be in an occupation where s/he is able to exercise that interest (for example, accounting is an occupation that is not the best outlet for artistic interest).

KNOWLEDGE ASSOCIATED WITH STEM OCCUPATIONS

Production and Processing: Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.

Computers and Electronics: Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.

Engineering and Technology: Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.

Design: Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.

Building and Construction: Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.

Mechanical: Knowledge of machines and tools, including their designs, uses, repair, and maintenance.

Mathematics: Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.

Physics: Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub-atomic structures and processes.

Chemistry: Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.

Biology: Knowledge of plant and animal organisms and their tissues, cells, functions, interdependencies, and interactions with each other and the environment.

STEM *Competencies* *(continued)*

SKILLS ASSOCIATED WITH STEM OCCUPATIONS

Mathematics: Using mathematics to solve problems.
Science: Using scientific rules and methods to solve problems.
Critical Thinking: Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems.
Active Learning: Understanding the implications of new information for both current and future problem-solving and decision-making.
Complex Problem Solving: Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Operations Analysis: Analyzing needs and product requirements to create a design.
Technology Design: Generating or adapting equipment and technology to serve user needs.
Equipment Selection: Determining the kind of tools and equipment needed to do a job.
Programming: Writing computer programs for various purposes.
Quality Control Analysis: Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
Operations Monitoring: Watching gauges, dials, or other indicators to make sure a machine is working properly.
Operation and Control: Controlling operations of equipment or systems.
Equipment Maintenance: Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Troubleshooting: Determining causes of operating errors and deciding what to do about it.
Repairing: Repairing machines or systems using the needed tools.
Systems Analysis: Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
Systems Evaluation: Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.

ABILITIES ASSOCIATED WITH STEM OCCUPATIONS

Problem Sensitivity: The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing that there is a problem.
Deductive Reasoning: The ability to apply general rules to specific problems.
Inductive Reasoning: The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
Mathematical Reasoning: The ability to choose the right mathematical methods or formulas to solve a problem.
Number Facility: The ability to add, subtract, multiply, or divide quickly and correctly.
Perceptual Speed: The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
Control Precision: The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.

WORK VALUES AND WORK INTERESTS ASSOCIATED WITH STEM OCCUPATIONS

STEM Work Values

Achievement: These jobs let you use your best abilities, see the results of your efforts and get the feeling of accomplishment.
Independence: These jobs allow you to do things on your own initiative, and make decisions on your own.
Recognition: These jobs offer good possibilities for advancement, and offer prestige or with potential for leadership.

STEM Work Interests

Realistic: Realistic occupations frequently involve work activities that include practical, hands-on problems and solutions. They often deal with plants, animals, and real-world materials like wood, tools, and machinery. Many of the occupations require working outside, and do not involve a lot of paperwork or working closely with others.
Investigative: Investigative occupations frequently involve working with ideas, and require an extensive amount of thinking. These occupations can involve searching for facts and figuring out problems mentally.

Appendix B: STEM Certificates

	POSTSECONDARY CERTIFICATES (%)	POSTSECONDARY CERTIFICATES (#)
COMPUTER AND MATHEMATICAL OCCUPATIONS	13.8%	576,011
Computer and information scientists, research	0.0%	-
Computer programmers	0.0%	-
Computer systems analysts	31.9%	198,600
Computer software engineers, applications	16.5%	124,200
Network systems and data communications analysts	33.1%	122,200
Computer support specialists	15.0%	90,900
Market research analysts	15.9%	43,300
Network and computer systems administrators	8.8%	35,600
Computer specialists, all other	0.0%	-
Actuaries	0.0%	-
Mathematicians	0.0%	-
Operations research analysts	0.0%	-
Statisticians	0.0%	-
Mathematical technicians	0.0%	-
Mathematical scientists, all other	0.0%	-
ARCHITECTURE AND ENGINEERING OCCUPATIONS	6.0%	168,800
Electrical and electronic engineering technicians	14.7%	24,700
Civil engineering technicians	25.4%	24,100
Surveying and mapping technicians	21.4%	18,300
Electronics engineers, except computer	9.7%	14,100
Engineering technicians, except drafters, all other	14.8%	12,200
Electrical engineers	6.5%	10,400
Surveyors	15.2%	10,100
Mechanical drafters	13.0%	9,700
Architectural and civil drafters	8.0%	8,700
Electrical and electronics drafters	21.4%	7,600
Mechanical engineering technicians	14.8%	7,300
Electro-mechanical technicians	32.5%	5,700
Computer software engineers, systems software	0.9%	4,400
Drafters, all other	13.0%	3,600
Biomedical engineers	13.2%	2,900
Life, physical, and social science technicians, all other	4.3%	2,900
Cartographers and photogrammetrists	16.9%	2,800
Architects, except landscape and naval	2.1%	2,700
Nuclear engineers	7.7%	1,800
Forest and conservation technicians	4.3%	1,300
Geological and petroleum technicians	5.8%	1,100
Industrial engineers	0.4%	900

Appendix C: STEM-Related Certifications Listed on Payscale.com

Sun Certified Java Programmer (SCJP) Certification

Sun Certified System Administrator (SCSA) Certification

Red Hat Certified Engineer (RHCE) Certification

Professional Engineer License (p Eng.) Certification

Microsoft Windows NT Certification

Microsoft Office User Specialist (MOUS) Certification

Microsoft Office Specialist (MOS), Excel Certification

Microsoft Certified Technology Specialist (MCTS) Certification

Microsoft Certified Systems Engineer (MCSE) Certification

Microsoft Certified Systems Administrator (MCSA) Certification

Microsoft Certified Solution Developer (MCSD) Certification

Microsoft Certified Professional+Internet (MCP+I) Certification

Microsoft Certified Professional (MCP) Certification

Microsoft Certified IT Professional (MCITP) Certification

Microsoft Certified Desktop Support Technician (MCDST) Certification

Microsoft Certified Database Administrator (MCDBA) Certification

LEED Accredited Professional (LEED AP) Certification

Comptia A+ Service Technician Certification

CompTIA Network+ Certification

CompTIA/Network Technician Certification

CompTIA Security +

Cisco Certified Design Associate (CCDA) Certification

Cisco Certified Internetwork Expert (CCIE) Certification

Cisco Certified Network Associate (CCNA) Certification

Cisco Certified Network Professional (CCNP) Certification

Oracle Certified Professional DBA

Citrix Certified Administrator (CCA) Certification

Certified Professional Engineer Certification

Certified Professional Coder

Engineer in Training

VMware Certified Professional (VCP) Certification

Certified Information Systems Auditor (CISA)

Certified Information Systems Security Professional (CISSP)

Certified Coding Specialist Certification

Appendix D: STEM wages by detailed occupation and education level (2009$)

	HIGH SCHOOL GRADUATES	SOME COLLEGE/ NO DEGREE	ASSOCIATE'S	BACHELOR'S	GRADUATE
Computer Scientists and Systems Analysts	$48,800	$52,700	$57,900	$68,900	$73,200
Computer Programmers	$56,900	$55,800	$56,300	$65,800	$70,000
Computer Software Engineers	$62,800	$68,400	$65,100	$76,700	$84,500
Computer Support Specialists	$ 41,800	$43,400	$47,300	$52,000	$61,500
Database Administrators	$51,600	$57,800	$50,700	$67,400	$74,600
Network and Computer Systems Administrators	$53,400	$49,400	$51,300	$57,500	$70,700
Network Systems and Data Communications Analysts		$53,800	$53,900	$61,900	$64,000
Actuaries		$128,500	$120,000	$109,900	$130,500
Mathematicians					$73,800
Operations Research Analysts	$53,600	$49,400	$56,700	$60,600	$69,700
Statisticians				$64,600	$72,900
Miscellaneous Mathematical Science Occupations, Including Mathematicians and Statisticians					
Architects, Except Naval	$50,600	$49,600	$74,100	$ 71,700	$79,900
Surveyors, Cartographers, and Photogrammetrists		$ 42,600	$50,900	$47,800	$44,800
Aerospace Engineers	$73,400	$89,900		$74,500	$89,200

STEM wages by detailed occupation and education level (2009$) (continued)

	HIGH SCHOOL GRADUATES	SOME COLLEGE/ NO DEGREE	ASSOCIATE'S	BACHELOR'S	GRADUATE
Agricultural Engineers				$74,400	$76,700
Biomedical and Agricultural Engineers					
Chemical Engineers			$76,700	$84,900	$104,100
Civil Engineers		$64,100	$55,200	$71,100	$83,600
Computer Hardware Engineers		$59,300	$59,000	$80,800	$96,900
Electricaland Electronics Engineers	$59,900	$69,700	$61,900	$79,000	$96,900
Environmental Engineers				$76,500	$93,400
Industrial Engineers, Including Health and Safety	$55,600	$51,200	$61,800	$72,000	$84,700
Marine Engineers and Naval Architects				$80,900	$89,400
Materials Engineers				$80,400	$73,400
Mechanical Engineers		$64,700	$61,700	$73,700	$80,400
Mining and Geological Engineers, Including Mining Safety Engineers				$83,300	
Nuclear Engineers				$99,400	$95,500
Petroleum, Mining and Geological Engineers, Including Mining Safety Engineers				$92,200	$78,500
Miscellaneous Engineers, Including Nuclear Engineers	$56,800	$61,500	$64,700	$77,500	$86,600
Drafters		$43,400	$42,300	$39,600	$48,100
Engineering Technicians, Except Drafters	$43,700	$45,500	$49,000	$44,400	$69,500

STEM wages by detailed occupation and education level (2009$) (continued)

	HIGH SCHOOL GRADUATES	SOME COLLEGE/ NO DEGREE	ASSOCIATE'S	BACHELOR'S	GRADUATE
Surveying and Mapping Technicians	$43,700	$35,900	$43,500	$38,200	
Agricultural and Food Scientists	$30,900		$37,700	$46,500	$48,100
Biological Scientists				$44,000	$55,600
Conservation Scientists and Foresters				$47,200	$60,000
Medical Scientists				$57,200	$69,200
Astronomers and Physicists				$61,000	$88,400
Atmospheric and Space Scientists				$62,400	$69,900
Chemists and Materials Scientists		$41,900	$52,700	$59,800	$71,500
Environmental Scientists and Geoscientists	$39,700	$43,700		$60,100	$73,700
Physical Scientists, All Other				$47,600	$73,700
Agricultural and Food Science Technicians		$39,500	$39,500	$43,800	
Biological Technicians	$33,100			$35,400	
Chemical Technicians	$38,400	$46,600	$41,400	$43,100	
Geological and Petroleum Technicians				$55,800	
Nuclear Technicians					
Miscellaneous Life, Physical, and Social Science Technicians, Including Social Science Research Assistants And Nuclear Technicians	$32,200	$31,200	$37,800	$32,400	$42,200

Source: ACS, 2005-2009.
** Empty cells suppressed due to small sample size.*
*** Wages shown above are self-reported and topcoded (where required). Wages may also reflect biases, as sample size by education levels in the tails may be too small to show a representative average wage.*

Appendix E: Education Distribution of STEM jobs (2008 and 2018)

2008	HIGH SCHOOL OR LESS		MIDDLE SKILLS		BACHELOR'S	GRADUATE		
	High School Dropout	High School Graduate	Some College	Associate's Degree	Bachelor's Degree	Master's Degree	Professional Degree	Doctorate Degree
Computers	28,100	252,000	524,400	324,500	1,509,100	552,400	24,100	61,200
Mathematics	-	9,000	16,100	7,600	56,800	28,800	3,500	9,800
Architectural	300	16,400	32,700	31,200	248,200	124,800	8,700	12,700
Engineering	71,000	338,600	359,600	470,700	526,200	224,900	35,000	26,300
Life and Physical Sciences	-	18,000	26,500	16,700	368,200	267,600	24,100	152,300
2018								
Computers	33,600	281,800	612,300	402,800	1,868,400	735,900	28,800	81,600
Mathematics	-	2,400	14,600	5,500	79,100	38,400	6,400	15,400
Architectural	1,000	13,300	15,100	27,500	263,400	132,900	7,700	12,100
Engineering	5,300	433,800	325,500	581,900	605,000	240,700	17,600	31,400
Life and Physical Sciences	-	20,300	11,100	-	430,900	281,900	29,000	229,600

Source: Georgetown University Center on Education and the Workforce forecasts of occupational growth tthrough 2018.

Appendix F: Technical Appendix

This appendix documents the methodology we use at the Georgetown University Center on Education and the Workforce (Center) to project the demand for Science, Technology, Engineering, and Mathematics (STEM) jobs and the education demand for STEM jobs in the U.S. economy. The Center has undertaken this project to enrich estimates of current and future education demand currently provided in the government data series.

The methodology builds on the existing framework used in *Help Wanted*, which can be accessed at http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/Help_Wanted_Technical_Appendix.pdf.

FORECASTING JOBS IN THE MIDDLE OF A STAGNATING ECONOMY

There is no precedent for the Great Recession of 2007. We do believe, however, that past recessions provide evidence on the behavior of firms and the economy in the period preceding the turnaround.

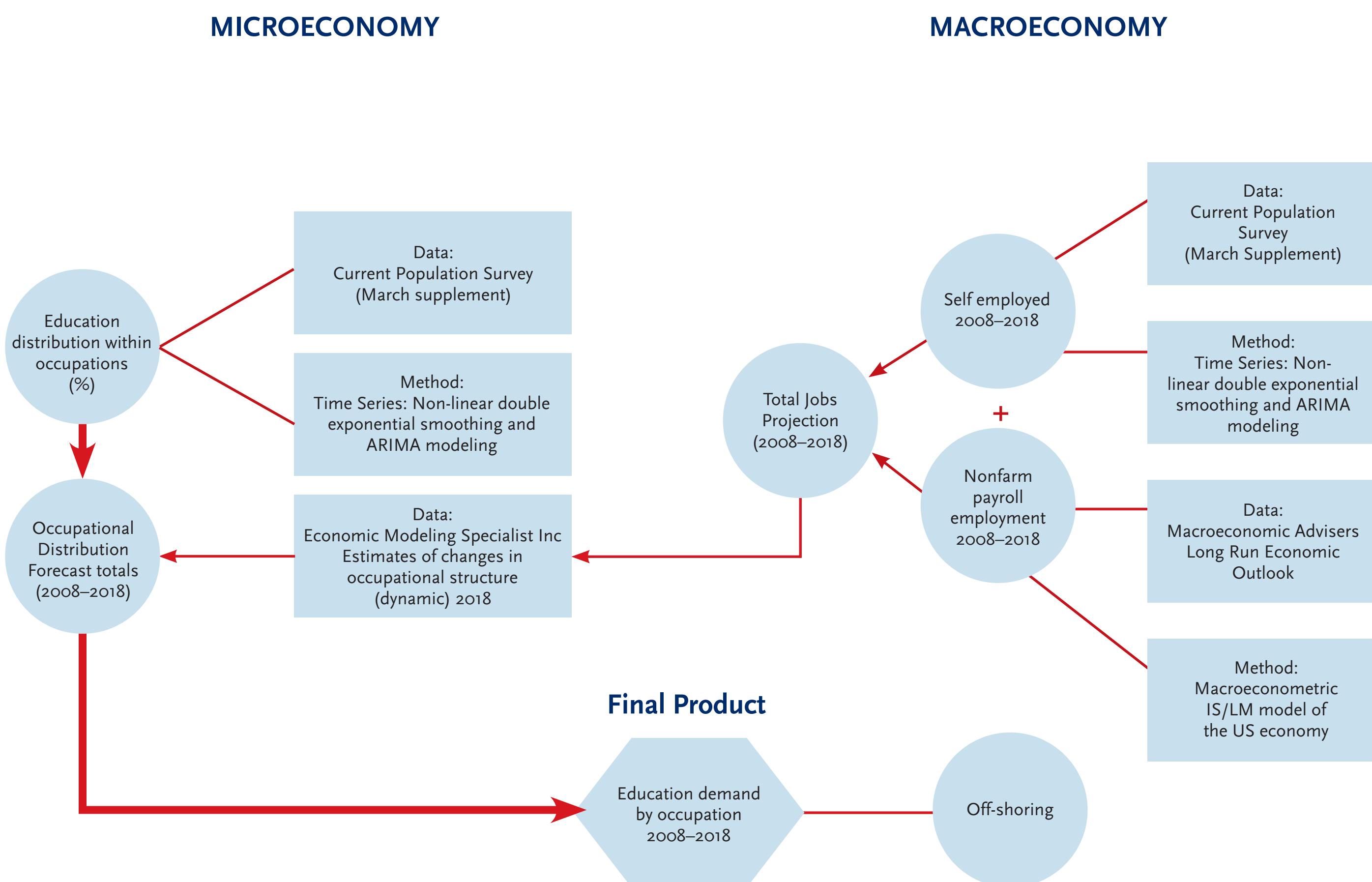
Historic trends demonstrate an active business cycle underlying the dynamics of the U.S. economy where downturns have occurred roughly every 10 years but each downturn has been followed by recovery. Reinhart and Rogoff (2008) use historical data on past financial crises to show that unemployment continues to rise for four years on average over the down phase of the cycle but recovers after that. In fact, the evidence points to a lag between the official end of economic recessions and the eventual increase in overall employment numbers in the recessions of 1990–1991 and 2001. Two separate papers suggest a changing structure to economic recoveries since the 1990–1991 recession. Groshen and Potter (2003) use aggregate payroll information and payroll by industry to show that job growth no longer recovers in tandem with gross domestic product (GDP) growth. Daly et al. (2009) use worker flows into and out of unemployment, involuntary part-time employment, and temporary layoffs to forecast a weak labor market recovery for this current recession.

STEM jobs are estimated as a subset of a larger model of the U.S. economy.

BUILDING CAPACITY FOR PROJECTING EDUCATION DEMAND FOR STEM OCCUPATIONS

In order to provide a robust forecast of STEM occupations using our education demand model, we have designed a method to update the employment forecast using Macroeconomic Advisors (MA) and Economic Modeling Specialist Incorporated (EMSI). We use an updated GDP and employment projection from MA. These data were then used as feedstock for an Input-Output (I/O) model developed by EMSI. The EMSI model produces detailed industry and occupational employment data that have been adjusted for the most current and detailed labor market information from the ongoing recession (see Figure I).

Figure I: Projections Process: Demand



MODEL ROBUSTNESS

Robustness of the modeling procedure is tested using several methods:

- Evaluation of model fit; comparisons of the root mean squared errors (RMSE) and the coefficient of variation between models to monitor the scope of outliers.
- In-sample forecasting; the model is estimated on a portion of the sample and is then used to predict outcomes on the remainder of the sample to test the extent to which the model accurately predicts known events. In addition, we judge the extent of the variation between observed and predicted over varying lag lengths in the forecast horizon.
- Comparison with alternative approaches; education demand is forecast using a Markov transition probabilities process and compared with the Center's time-series approach.

The results of this exercise for the entire economy (including STEM jobs) can be accessed from the Technical Appendix to Help Wanted, found at http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/Help_Wanted_Technical_Appendix.pdf

FOUR-STEP APPROACH FOR FORECASTING EDUCATION DEMAND FOR STEM OCCUPATIONS

We have a four-step approach to forecasting education demand for STEM occupations:

1. Forecasting education distributions within STEM occupations.
2. Estimating long-term employment projections in STEM.
3. Estimating change in the STEM occupational structure.
4. Projecting STEM education demand through 2018.

STEP ONE: FORECASTING EDUCATION DISTRIBUTIONS WITHIN STEM OCCUPATIONS

The Center forecasts changes in the education distribution by eight levels of educational attainment using a time-series method as the first step in the projections process. Data from the March Current Population Survey (CPS) are used to estimate the proportion of persons within occupations by eight educational attainment levels:

1. High school dropouts
2. High school diploma
3. Some college/no degree
4. Associate's degrees
5. Bachelor's degrees
6. Master's degrees
7. Professional degrees
8. Doctoral degrees

We then develop projections based on trend data since 1992 for each of these educational attainment levels within five STEM occupational categories drawn from the Bureau of Labor Statistics' (BLS) Standard Occupational Classification (SOC) occupations. These include the following occupational groupings.

1. Computer occupations
SOC 15-1111–SOC 15-1199
2. Mathematical Science occupations
SOC 15-2011–SOC 15-2099
3. Architects, Surveyors, and Technicians
SOC 17-1011–SOC 17-1022; SOC 17-3011–SOC 17-3019; SOC 17-3031
4. Engineers and Engineering Technicians
SOC 17-2011–SOC 17-2199; SOC 17-3021–SOC 17-3031
5. Life and Physical Science occupations
SOC 19-1011–SOC 19-2099; SOC 19-4011–SOC 19-4099

We draw our data on the relationships between the eight educational attainment levels in the five STEM occupational categories from the CPS conducted in March of every year.[66]

The March CPS is a nationally representative cross-sectional data set that provides information on the socioeconomic

[66] Three-digit occupational detail is provided in the main report for occupations that are large enough to provide a representative sample.

characteristics of the American population. There are about 50,000 households with detailed information on resident demographic and labor market behavior. Our decision to use the CPS over the much larger American Community Survey (ACS) rests solely with the longevity of the former.[67] That is to say, since our methodological framework is time-series in nature, we sought to obtain the longest possible data set available with information pertaining to educational and occupational characteristics of the population.[68] The relatively longer series also makes it easier to demonstrate skills-biased technical change within occupations in the data as the proportion of more highly skilled workers within an occupation increases with time.

The March CPS details inter alia the highest education level attained and occupation of respondents to the survey. We use data on the weighted percentage of workers employed in a particular occupation and with a particular level of education as an estimate of "realized demand" for education within that occupation. Because of changes in the education code in 1992, we have two time frames based on the same methodological approaches.[69]

Changes in the occupational code in 2002 were bridged using a crosswalk developed at Westat, Inc. The occupational recode in 2002 was extensive and was not unique, which required a probabilistic crosswalk that was made possible because the survey double-coded occupations for three years to provide empirical comparison between the two systems.[70]

We assume that each of the time-series variables in the model is one observation of an underlying data-generating process. We assume that this process consists of the summation of both a stochastic and deterministic component.[71] As such, each data point in the stochastic series may be considered as the sample first moment of a probability distribution of an underlying population for each point in time of the time-series variable (with associated moments of each of the distributions). There are initially 27 observations (1983–2009) and the lag of the prediction is 19.[72] Small sample size considerations in this case limit our ability to assume asymptotic properties of the sample realizations as they pertain to approximating population moments of the data-generating process in the limit.

We use two methods to estimate the percentage change in the education distribution within occupation through time. Our objective is to find an economic model that is parsimonious, plausible, and informative and best represents past information to generate conceivable forecasts of education demand within occupations. (Further details of each method can be found in the Technical Appendix to Help Wanted available at http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/Help_Wanted_Technical_Appendix.pdf.)

- Method one is a nonlinear exponential smoothing method with the added restriction that the estimated proportions for each education level sum to one for each of the years in the forecast horizon. Exponential smoothing is a time-series method that uses past observations of a series to forecast the future. It is a variant of a moving average process that places relatively greater emphasis on the most recent past and includes information on the time trend in the data.
- As for method two, assuming that the education distribution for each occupation is a probability density function, we create transition matrices that are advanced from 2009 to 2018.

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[67] The CPS has been conducted for over 50 years (although a smaller segment is available to us due to definitional changes). The ACS was first conducted in 1996 in a subsample of U.S. counties. In addition, the transition to the ACS as the standard from which to derive educational clusters has been a recent change for the BLS.

[68] The CPS fulfils this requirement although the authors recognize that sample size bias might require pooling of some years for state and other smaller scale comparisons.

[69] The two time frames are 1983–2009 and 1992–2009.

[70] These data can be found in U.S. Census Bureau (2003). The program for this crosswalk is available from the U.S. Census Bureau upon request.

[71] The stochastic random process must be modeled.

[72] Indeed, due to a change in the definition of educational attainment by the CPS in 1992, our sample size is reduced to allow for the greater degree of specificity in the definitions of education.

STEP TWO: ESTIMATING LONG-TERM EMPLOYMENT PROJECTIONS IN STEM

Estimates of nonfarm payroll employment numbers are derived in the context of a larger macroeconomic model of the U.S. economy that makes standard neoclassical assumptions within a general equilibrium framework. The macroeconomic model used by MA—the Washington University Macro Model (WUMMSIM)—is a quarterly econometric system consisting of 745 equations, 134 estimated behavioral equations, and 201 exogenous variables of the U.S. economy.[73] It assumes a long-run vertical Phillips curve, a long-run neoclassical model of fixed investment, labor demand, pricing and distribution of income, a life-cycle model of consumption, a transactions model of money demand, and an expectations model of the term structure of interest rates. Exogenous variables are observed or hypothesized and incorporated to obtain a solution to identities and behavioral equations in the model.[74]

The Center has partnered with MA and EMSI to produce forecasts of job creation (including STEM jobs) through 2018.[75] At the macro level, MA forecasts project nonfarm payroll employment totals. Projections of self-employment (unincorporated) are appended to nonfarm payroll employment to obtain forecasts of total job creation in the economy. Unpaid family workers, agricultural employees, and paid private household workers have been excluded from our definition of the total employment.[76]

STEP THREE: ESTIMATING CHANGE IN THE STEM OCCUPATIONAL STRUCTURE

The Quarterly Census of Employment and Wages (QCEW) is conducted from an industry perspective with very little emphasis on the occupational characteristics of workers. As such seasonal reports produced by the BLS on changes in the employment situation are nested solely in an industrial context. We use EMSI to obtain estimates of changes in occupational distribution through time. EMSI combines data updated on a quarterly basis from over 80 government and private-sector sources. In so doing, we capture occupational growth trends and information on skills-biased technological change in the data. Forecasting changes in the occupational staffing mix is the third step in this projections process. Total employment is subdivided into nonfarm payroll employment and self-employed workers. The former are derived from the QCEW surveys and reflect the occupational distribution of the Occupational Employment Statistics (OES) surveys. The latter are derived from the CPS and reflect the occupational distribution of the CPS and ACS surveys.

Structural change in the U.S. economy, including recent substantial reductions in manufacturing and retail employment, can have a substantial impact on the occupational mix. This is especially true of STEM occupations; 46 percent of Engineers and Engineering Technicians are found in the Manufacturing industry. STEM occupations are also unique in the sense that not only is there demand for STEM-trained workers for STEM occupations, but there is also demand for STEM-trained workers in competitor occupations such as Healthcare Professionals and Managerial fields.

QUANTIFYING STEM KNOWLEDGE, SKILLS, AND ABILITIES

We use the O*NET database, operated by the National O*NET Consortium and funded by the U.S. Department of Labor, to isolate the competencies needed in particular occupations, including STEM occupations. O*NET contains information on occupational knowledge, skills, abilities, work values, and work interests, as well as key performances (tasks and activities) for 965 different occupations. This database allows us to

[73] Other notable clients that use the WUMMSIM econometric model are the BLS (to create estimates of the macroeconomy in its employment projections) and the White House (to forecast the macroeconomic impact of the stimulus package).

[74] These assumptions are equivalent to the belief of the absence of a long-run trade-off between inflation and employment with a consistent and stable nonaccelerating inflation rate of unemployment (NAIRU) (currently estimated at 5.2%); wages equate to the value of their marginal product; labor and product markets clear; money demand is determined by interest rates (speculative activity) and income levels (transactions activity); a trade-off exists between current and future consumption; and interest rates reflect inflation-risk premia in their construction.

[75] Current government projections are to 2016.

[76] They accounted for 2.9 million workers in April 2009.

measure the importance of various competencies within an occupation and to begin a dialogue over the appropriate roles of educational institutions and employers in providing core competencies required in today's economy.

Using O*NET, we have identified the cognitive (knowledge, skills, and abilities) and noncognitive (work values and work interests) competencies that are most highly correlated with STEM occupations and their relative transferability to other occupations. By analyzing O*NET data, we are able to determine the degree to which these competencies are unique to STEM and which ones are shared more broadly with other occupations. We have distinguished STEM competencies that are most prominent in STEM occupations from STEM competencies that are used in both STEM occupations and a variety of other occupations. It is the demand for these transferable competencies outside of STEM occupations that creates the persistent and growing demand for STEM talent and ultimately results in a wide scarcity of workers with those highly transferable STEM competencies.

The approach to this connection was twofold. First, we determined the extent of the relatedness of occupational clusters, based on the similarities of the intensity of responses from incumbents in those occupations. Second, we determined the incidence in the national economy, controlling for the size of occupations. Factor analysis was the primary data-reduction tool employed.

STEP FOUR: PROJECTING STEM EDUCATION DEMAND THROUGH 2018

Estimates of education distribution within each of the five STEM occupations (step one) are combined with forecasts of structural change in the occupational distribution through time obtained in step two. Forecasts of changes in the occupational distribution are based on neoclassical assumptions set forth in the WUMMSIM macroeconometric model (step three) of the U.S. economy that incorporate information on the recession, stimulus package, news, and business cycles into final estimates of national levels of occupational demand.

This process provides an estimate of the number of jobs within each STEM occupational subgroup that require an education level equivalent to each of the eight levels of education that are observed in CPS data. We later sum each education level across occupations to get an estimate of national education demand. These estimates:

- *Provide information on the full education distribution by each occupation.* The entire education distribution available in the CPS data is used to generate forecasts, thus removing the bias toward the middle-jobs that results from a methodology enforcing the selection of a single-education level.
- *Allow for possible change in the education distribution across occupation.* The assumption of a fixed distribution of education within occupations is flawed in that it consistently underestimates the demand for higher education. At the Center, we assume that the distribution of education changes over time within occupations. *Information exists on these trends and should be used to improve projected education demand.* Forecasting the full education distribution is in keeping with the up-skilling of the American worker through time. We use the actual education characteristics of the American worker and make no assumptions regarding entry-level requirements.
- *Allow for possible change in the occupational distribution.* We assume structural changes in the macroeconomy impact the occupational distribution of jobs in the U.S. economy. For example, long-term reductions in Manufacturing ought to be reflected in reductions in occupations that are unique or dominant to that industry. By incorporating changes in the occupational distribution, we change the occupational staffing rations in such a way that allows structural changes if the data support them.
- *Incorporate macroeconomic shocks, business cycles, and the stimulus into estimates of national job creation.* As a result, while adhering to general long-run full employment assumed by all government agencies in determining the equilibrium number of occupations, we allow for short-run fluctuations and departure from the steady state that are reflected in booms and recession.
- *Create annual forecasts.* In a related point, this process allows us to see the progression in education demand for every year of the 10-year forecast and not only the beginning and end of the forecast horizon.

Glossary of Terms

Abilities: As defined by O*NET, abilities are enduring attributes of the individual that influence performance. Sub-categories of abilities include cognitive abilities, physical abilities, psychomotor abilities, and sensory abilities.

Achievement (Work Value): As defined by O*NET, occupations that satisfy this work value are results oriented and allow employees to use their strongest abilities, giving them a feeling of accomplishment. Workers on this job make use of their individual abilities and get a feeling of accomplishment.

ACS: American Community Survey, an annual survey of 3 million Americans performed by the Census Bureau.

Active Learning (Skills): As defined by O*NET, understanding the implications of new information for both current and future problem-solving and decision-making.

Artistic (Interest): As defined by O*NET, artistic occupations frequently involve working with forms, designs and patterns. They often require self-expression and the work can be done without following a clear set of rules.

Biology (Knowledge): As defined by O*NET, knowledge of plant and animal organisms and their tissues, cells, functions, interdependencies, and interactions with each other and the environment.

Building and Construction (Knowledge): As defined by O*NET, knowledge of materials, methods, and tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.

Certificate: A postsecondary credential received by a recipient upon completion of a program of study. Certificates can be held by themselves or in addition to other postsecondary credentials, such as an Associate's, Bachelor's, or Master's degrees.

Certification: A credential bestowed upon a recipient recognizing qualification to perform a job or task. A certification is usually issued after successfully passing a test.

Chemistry (Knowledge): As defined by O*NET, knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.

Complex Problem Solving (Skills): As defined by O*NET, identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.

Computers and Electronics (Knowledge): As defined by O*NET, knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.

Control Precision (Abilities): As defined by O*NET, the ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.

Convention (Interest): As defined by O*NET, conventional occupations frequently involve following set procedures and routines. These occupations can include working with data and details more than with ideas. Usually there is a clear line of authority to follow.

CPS: Current Population Survey, a monthly survey performed by the Bureau of Labor Statistics.

Critical Thinking (Skills): As defined by O*NET, using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems.

Deductive Reasoning (Abilities): As defined by O*NET, the ability to apply general rules to specific problems to produce answers that make sense.

Design (Knowledge): As defined by O*Net, knowledge of design technique, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.

Diversion: A process through which potential STEM workers—both students and workers who have either an interest or an aptitude in STEM—steer away from STEM careers. Diversion happens at various points in school and once in the workforce. We include people who never intend to work in STEM careers, but who have proficiency in STEM, because they are a potential source of STEM workers even if they do not intend to end up in a STEM field.

Engineering and Technology (Knowledge): As defined by O*NET, knowledge of practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.

Enterprising (Interest): As defined by O*NET, enterprising occupations frequently involve starting up and carrying out projects. These occupations can involve leading people and making many decisions. Sometimes they require risk taking and often deal with business.

Equipment Maintenance (Skills): As defined by O*NET, performing routine maintenance on equipment and determining when and what kind of maintenance is needed.

Equipment Selection (Skills): As defined by O*NET, determining the kind of tools and equipment needed to do a job.

Full-time, Full-year Workers: People who work a minimum of 50 weeks per year, at least 35 hours per week.

Independence (Work Value): As defined by O*NET, occupational that satisfy this work value allow employees to work on their own and make decisions. Workers on this job try out their own ideas, make decisions on their own, and plan their work with little supervision.

Inductive Reasoning (Abilities): As defined by O*NET, the ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).

Investigative (Interest): As defined by O*NET, investigative occupations frequently involve working with ideas, and require an extensive amount of thinking. These occupations can involve searching for facts and figuring out problems mentally.

Job Openings/Vacancies: Jobs that are open due to new jobs being created or when replacement positions become available due to incumbent workers permanently leaving the workforce due to retirement, disability, or death.

Knowledge: As defined by O*NET, knowledge consists of organized sets of principles and facts applying in general domains, such as chemistry, foreign language, or psychology.

Mathematical Reasoning (Abilities): As defined by O*NET, the ability to choose the right mathematical methods or formulas to solve a problem.

Mathematics (Knowledge): As defined by O*NET, knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.

Mathematics (Skills): As defined by O*NET, using mathematics to solve problems.

Mechanical (Knowledge): As defined by O*NET, knowledge of machines and tools, including their designs, uses, repair, and maintenance.

NCES: National Center for Education Statistics, the primary federal entity for collecting and analyzing data related to education. NCES is part of the Department of Education.

Number Facility (Abilities): As defined by O*NET, the ability to add, subtract, multiply, or divide quickly and correctly.

O*NET: The Occupational Information Network. A constantly-updated database of over 960 occupations, O*NET contains information on the key features of an occupation using a standardized, measureable set of variables. Variables include tasks within an occupation, and the knowledge, skills, and abilities, as well as interests and values, as well as other descriptors. O*NET is sponsored by the Department of Labor's Employment and Training Administration.

Operation and Control (Skills): As defined by O*NET, controlling operations of equipment or systems.

Operations Analysis (Skills): As defined by O*NET, analyzing needs and product requirements to create a design.

Operations Monitoring (Skills): As defined by O*NET, watching gauges, dials, or other indicators to make sure a machine is working properly.

Perceptual Speed (Abilities): As defined by O*NET, the ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.

Persistence: The rate at which people with a degree in a certain field end up working in-field, both immediately after graduation and a decade after graduation. Persistence—like diversion—is driven by a combination of educational specificity, interests, and earnings.

Physics (Knowledge): As defined by O*NET, knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub-atomic structures and processes.

Premium: Percentage by which the annual earnings achieved by STEM workers exceed that achieved by individuals who are not employed in a STEM occupation

Prime Age Workers: People in the labor force between the ages of 25–54.

Prime College Age: People between the ages of 18–24.

Problem Sensitivity (Abilities): As defined by O*NET, the ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing that there is a problem.

Production and Processing (Knowledge): As defined by O*NET, knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.

Programming (Skills): As defined by O*NET, writing computer programs for various purposes.

Quality Control Analysis (Skills): As defined by O*NET, conducting tests and inspections of products, services, or processes to evaluate quality or performance.

Realistic (Interest): As defined by O*NET, realistic occupations frequently involve work activities that include practical, hands-on problems and solutions. They often deal with plants, animals, and real-world materials like wood, tools, and machinery. Many of the occupations require working outside, and do not involve a lot of paperwork or working closely with others.

Recognition (Work Value): As defined by O*Net, occupations that satisfy this work value offer advancement, potential for leadership, and are often considered prestigious. Workers on this job have opportunities for advancement, receive recognition for the work they do, give directions and instructions for others, and are looked up to by others in their company and their community.

Repairing (Skills): As defined by O*NET, repairing machines or systems using the needed tools.

Science (Skills): As defined by O*NET, using scientific rules and methods to solve problems.

SESTAT: The Scientists and Engineers Statistical Data System, a dataset that captures information about employment, education, and demographic characteristics of scientists and engineers in the United States. The data are collected from three national surveys of this population: the National Survey of College Graduates (NSCG), the National Survey of Recent College Graduates (NSRCG), and the Survey of Doctorate Recipients (SDR).

Skills: As defined by O*NET, skills are developed capacities that facilitate learning or the more rapid acquisition of knowledge. O*NET breaks down skills into categories including basic skills, complex problem solving skills, resource management skills, social skills, systems skills, and technical skills.

Social (Interest): As defined by O*NET, social occupations frequently involve working with, communicating with, and teaching people. These occupations often involve helping or providing service to others.

STEM: Science, Technology, Engineering, and Mathematics.

STEM competencies: the set of core cognitive knowledge, skills, and abilities that are associated with STEM occupations, and the noncognitive work interests and work values associated with STEM occupations.

STEM competitor occupations: Those occupations that compete with STEM occupations for STEM capable workers. These include Managerial and Professional and Healthcare Professional occupations.

STEM Major: Anyone of prime working age (25–54) who graduated with a Bachelor's degree in a STEM major, whatever their occupation.

STEM occupations: Computer Occupations (SOC 15-1111–SOC 15-1199); Mathematical Sciences Occupations (SOC 15-2011–SOC 15-2099); Architects and Technicians (SOC 17-1011–SOC 17-1022; SOC 17-3011–SOC 17-3019; SOC 17-3031); Engineers and Technicians (SOC 17-2011–SOC 17-2199; SOC 17-3021–SOC 17-3031); Life and Physical Scientists (SOC 19-1011–SOC 19-2099; SOC 19-4011–SOC 19-4099). Our definition of STEM occupations excludes social scientists.

STEM worker: Workers of prime age (25–54) who work in a STEM occupation, regardless of their level of educational attainment or college major.

Systems Analysis (Skills): As defined by O*NET, determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.

Systems Evaluation (Skills): As defined by O*NET, identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.

Technology Design (Skills): As defined by O*NET, generating or adapting equipment and technology to serve user needs.

Troubleshooting (Skills): As defined by O*NET, determining causes of operating errors and deciding what to do about it.

Work Interests: As defined by O*NET, interests are preferences for work environments and outcomes. O*NET has six categories of interests, including Realistic, Investigative, Artistic, Social, Enterprising, and Conventional.

Work Values: As defined by O*NET, work values are global aspects of work that are important to a person's satisfaction. O*NET recognizes six work values: Achievement, Independence, Recognition, Relationships, Support, and Working Conditions.

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