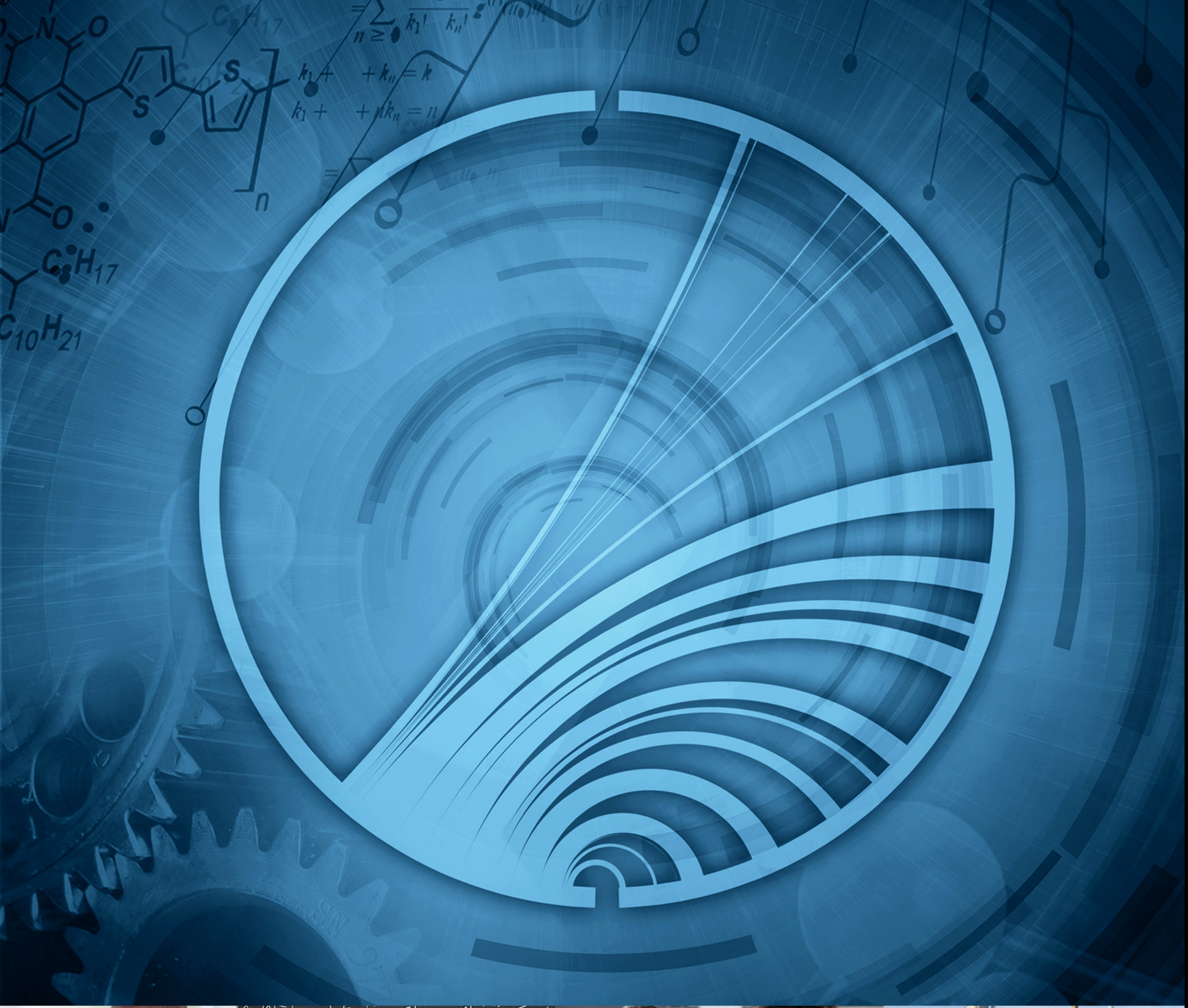

REVISITING THE STEM WORKFORCE

A Companion to Science and Engineering Indicators 2014

NATIONAL SCIENCE BOARD

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NATIONAL SCIENCE FOUNDATION

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* Member, *ad hoc* working group on the STEM Workforce

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National Science Board

February 4, 2015

Dear Colleague:

As part of its statutory responsibility, the National Science Board (NSB, Board) produces the biennial *Science and Engineering Indicators* (*Indicators*) report, a collection of authoritative, quantitative information on the domestic and global science and technology (S&T) landscape. Although *Indicators* is policy-neutral, the information in Indicators often offers insights that pertain to c aritical and timely policy questions or concerns. The Board typically conveys these insights to the President, Congress, and the public in the form of a policy "companion" to the *Indicators* report.

The science, engineering, technology and mathematics (STEM) workforce is an integral facet of the S&T enterprise. The state of this workforce is deeply enmeshed in research and development investment prioritization, national, state and local education policy, and private-sector decisions. The condition of the STEM workforce is also increasingly important for students who must make decisions about majors and careers at a time of increasing tuition costs and uncertain job prospects.

Despite its importance, consensus answers about the state of the U.S. STEM workforce remain elusive. The size and complexity of the STEM workforce has grown by leaps and bounds as science and technology have come to touch many corners of our economy. As the STEM workforce continues to evolve, conflicting claims about the adequacy of the workforce hamper the policy discourse, forcing decision makers to make choices amid confusing and often incomplete information.

As the Board revisited the STEM workforce, we found that data from the 2014 edition of *Indicators*, when put into the context of current policy discussions and long-standing debates, offer valuable insights that can help policymakers and others better understand the workforce. In particular, these insights reveal how STEM knowledge and skills enable both individual opportunity and national competitiveness, and how acquisition of STEM capabilities is increasingly vital to Americans' ability to participate fully in a 21st Century knowledge- and technology-intensive, global economy. Ultimately, we hope that the insights offered in this report will foster a productive dialogue about how to create and maintain a STEM-capable U.S. workforce for the long term.

Sincerely,

Dan E. Arvizu
Chairman

National Science Foundation

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EXECUTIVE SUMMARY

The condition of the U.S. science, technology, engineering, and mathematics (STEM) workforce figures prominently in discussions of national competitiveness, education policy, innovation, and even immigration. But the relevant analyses and conversations are hindered by differing understandings of the composition and character of the STEM workforce and the varied, dynamic career pathways enabled by STEM knowledge and skills.

The National Science Board (NSB, Board) examined recent STEM workforce studies and debates, consulted numerous experts, and explored data in our *2014 Science and Engineering Indicators* (*Indicators*) report to develop insights that could facilitate more constructive discussions about the STEM workforce and inform decision makers.

Three primary insights emerged:

I: The "STEM workforce" is extensive and critical to innovation and competitiveness. It is also defined in various ways and is made up of many sub-workforces.

The STEM workforce consists of a many types of STEM-capable workers who employ significant STEM knowledge and skills in their jobs. This workforce includes the scientists and engineers who further scientific and technological progress through research and development (R&D) activities, workers in non-R&D jobs who use STEM knowledge and skills to devise or adopt innovations, and workers in technologically demanding jobs who need STEM capabilities to accomplish occupational tasks.

Although the concept of a "STEM workforce" is widely used and has been referenced in law, there is no consensus on how it is defined. Various reports employ different definitions of the STEM workforce, which leads to divergent and sometimes conflicting conclusions. Further, the STEM workforce is heterogeneous; it is composed of many different "sub-workforces" based on field of degree, occupational field, the education level required, or some combination of these factors. The demand for, supply of, and career prospects for each sub-workforce can vary significantly by employment sector, industry, or geographic region. Overgeneralizing specific issues or challenges from a particular sub-workforce to the entire STEM workforce often leads to incorrect conclusions about the condition of the workforce. The Board found that to answer important questions about the STEM workforce, it is necessary to focus on data associated with the specific sub-workforce of interest.

II: STEM knowledge and skills enable multiple, dynamic pathways to STEM and non-STEM occupations alike.

In the United States, individuals with STEM knowledge and skills need not follow a linear "pipeline" from receipt of a STEM degree to a job in that same STEM field. Decades of data show that workers with STEM-degrees follow numerous pathways leading to careers in and out of their field of study and even into non-STEM jobs. Although many individuals with a STEM degree do not work in a STEM field, the majority of these workers indicate that their job is related to their STEM education. The relatively loose links between degrees and occupations are a distinctive feature of the U.S. workforce. This feature enables individuals to apply STEM skills in jobs across the economy and employers to utilize workers with STEM skills in whatever ways add the greatest value.

A "pathways approach" to understanding the workforce prompts policy makers to focus on highly productive questions about the workforce. These include: What knowledge and skills are necessary for workers to acquire over a career to maximize individual opportunity and promote national competitiveness? How do we ensure that all Americans have access to STEM knowledge and skills? What are the respective roles for government, educational institutions, and employers in enabling and strengthening these pathways?

III: Assessing, enabling, and strengthening workforce pathways is essential to the mutually reinforcing goals of individual and national prosperity and competitiveness.

To ensure continued U.S. competitiveness and prosperity, our Nation must foster a strong, STEM-capable workforce. First, we must monitor and assess the condition of workforce pathways and identify risks and challenges to them. Second, we must ensure that all individuals have access to high quality education. A well-rounded pre-college education that includes significant engagement with STEM unlocks pathways into the technical STEM workforce and pursuit of additional STEM studies at the bachelor's, master's, and doctoral levels. Third, we need to address roadblocks to the participation of groups traditionally underrepresented in STEM (e.g., minorities, women, individuals with disabilities, military veterans, and individuals from lower socioeconomic backgrounds). Addressing these roadblocks will allow our Nation to benefit from the capabilities of all of its people and ensure that our populace can participate fully in a globally competitive, knowledge- and technology-intensive economy.

As we build our 21st Century workforce, it will be increasingly important to devise policy solutions that address the specific and varied educational and training needs of our citizenry. Governments, educational institutions, and employers have long had important and complementary roles in creating, sustaining, and strengthening the workforce. As the nature of the American workforce changes and as STEM knowledge and skills become vital to a wider range of workers, we have an opportunity to re-envision how government, educational institutions, and employers can best support the range of STEM-capable workers to meet the challenges of today and tomorrow.

INTRODUCTION

Since the National Science Foundation's (NSF) inception in 1950, ensuring the long-term strength of the Nation's scientific workforce has been a key component of its mission. During NSF's early years, this workforce was considered to consist of scientists and engineers engaged in research and development (R&D) in government, academic, or industry laboratories. Over the ensuing 65 years, policymakers, scholars, and employers have come to recognize that science, technology, engineering, and mathematics (STEM) knowledge and skills are critical to an extensive portion of the *entire* U.S. workforce and that a broad range of STEM-capable workers contribute to economic competitiveness and innovation.

The pervasiveness of technology throughout our economy, increasing global competition, and ongoing demographic shifts mean that the U.S. STEM workforce has not only grown in importance, but also in size and complexity. As the STEM workforce continues to evolve, conflicting claims about the adequacy of the workforce—for example, whether the supply and demand for highly-skilled STEM workers is in balance; whether there are "skills mismatches" between workers and employer needs—can be found in journals, government and industry reports, and in many media outlets. Policymakers, students, and others who wish to understand the STEM workforce and make important policy and career choices are often hampered by competing analyses of the state of the STEM workforce and must make decisions with contradictory, confusing, and often incomplete information.

This policy companion to *Science and Engineering Indicators* (*Indicators*) *2014* does not attempt to resolve long-standing debates about the workforce. Rather, the report provides a more nuanced, data-driven portrait of the workforce and offers key insights about its character. It is our hope that these insights will help government, education, and business leaders make better and more informed decisions and foster a more productive dialogue about how to maintain a strong, STEM-capable U.S. workforce for the long term.

On the Use of S&E and STEM in *Indicators* and this Companion Report

STEM is a valuable but loosely defined term. It enables discussions about the many parts of the U.S. workforce that use science, technology, engineering, and mathematics, but it does not provide the precision needed for systematic data gathering and analysis. The Board's *Indicators* reports have traditionally relied on a narrower construct—science and engineering (S&E).

This report draws heavily on *Indicators* data, so it is important to keep in mind that S&E data do not fully correspond with the common idea of STEM. *Indicators'* S&E workforce data focus on workers with at least a bachelor's degree and define the workforce based on a set of occupations and degrees designated by the National Science Foundation as "S&E". By contrast, STEM is less precise and may include workers with an associate's degree or other sub-baccalaureate credential who are employed in occupations that require scientific, technological, engineering, or mathematical capabilities.

***Indicators*' S&E workforce, or "scientists and engineers", includes:**

- Any individual with at least a bachelor's degree in an S&E or S&E-related field of study

  or

- Any college graduate employed in an S&E or S&E-related occupation, regardless of field of degree. Individuals employed in the healthcare industry are included in the S&E-related occupations and thus included in the S&E workforce as defined by Indicators

***Indicators'* S&E occupations are:**

- Computer and mathematical scientists
- Biological, agricultural, and environmental life scientists
- Physical scientists (e.g., physicists, chemists, geoscientists)
- Social scientists (e.g., psychologists, economists, sociologists)
- Engineers
- Postsecondary teachers in S&E fields

***Indicators'* S&E-related occupations are:**

- Health care workers (e.g., physicians, audiologists, nurses)
- S&E managers (e.g., engineering managers, natural and social science managers)
- Science and engineering precollege teachers (e.g., science teachers, math teachers)
- Technologists and technicians in S&E
- Other S&E-related occupations (e.g., actuaries, architects)

***Indicators* defines all remaining occupations as non-S&E occupations.**

This report uses the terms STEM or STEM workforce when discussing general characteristics about this workforce and the importance of science, technology, engineering, and mathematics knowledge and skills to students and incumbent workers. By contrast, it utilizes *Indicators'* S&E, S&E-related, and non-S&E classification scheme when discussing specific *Indicators* data.

I. The "STEM workforce" is extensive and critical to innovation and competitiveness. It is defined in various ways and comprises many sub-workforces.

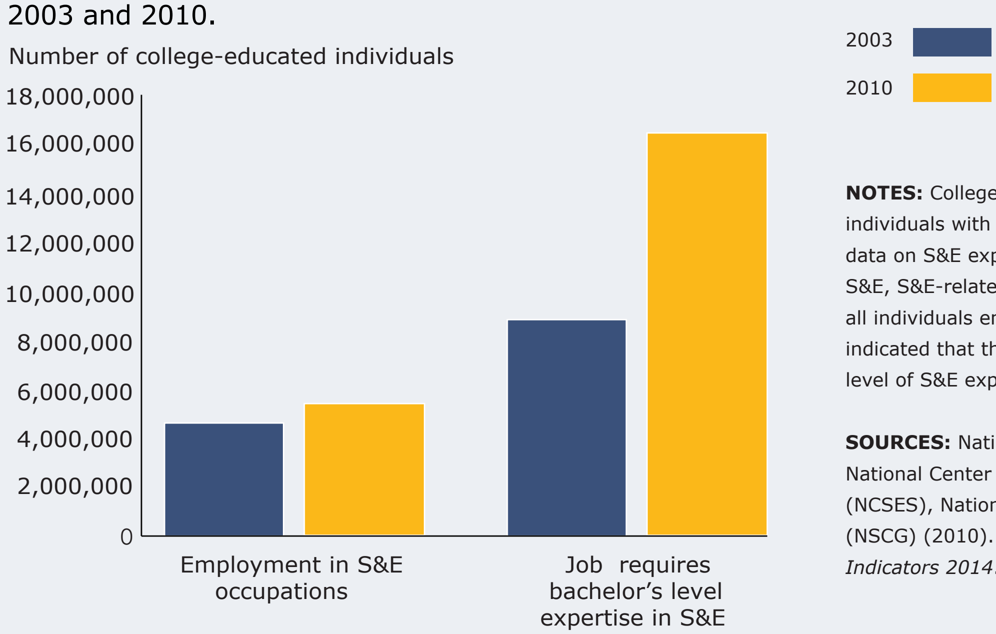
A. Science and Engineering Workers in the U.S. Economy

Sixty years ago, long before the term "STEM" was coined, NSF and NSB began publishing indicators of the condition of the science and engineering (S&E) workforce.[1] This workforce is of particular interest to the Nation because of its central role in fostering innovation, economic competitiveness, and national security. In the early years of the Foundation, innovation was considered to be the province of a "small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research."[2] Thus, NSF's initial compendium of indicators focused largely on scientists and engineers with advanced degrees engaged in R&D in government, academia, or industry laboratories.

In the intervening decades, analysts have come to recognize that scientists and engineers with advanced degrees are necessary but far from sufficient for a globally competitive knowledge- and technology-intensive economy. There are several reasons for this: First, scientific and technological advances have automated many jobs, so that remaining jobs demand higher levels of STEM knowledge and skill.[3] Second, we have learned that innovation is not the sole province of R&D workers. Although companies engaged in R&D activities report a higher *incidence* of innovation, most of the innovation in the U.S. occurs in firms that are *not* significantly engaged in R&D.[4] Adoption and diffusion of innovation commonly requires organizations to rely on workers with STEM competencies to learn, adapt, install, debug, train, and maintain new processes or technologies.[5]

A decade's worth of data demonstrate the growing pervasiveness of science and technology in the American workplace. STEM knowledge and skills are used in many more occupations than those traditionally thought of as science and engineering (Figure 1). In 2010, about 5 million U.S. workers were officially classified as having an "S&E" occupation.[6] Yet an estimated 16.5 million college-educated individuals, including many working in sales, marketing and management, reported that their job required at least a bachelor's degree level of S&E training. Additionally, in recent years, more jobs have come to require these capabilities.[7]

FIGURE 1: Size of the U.S. S&E workforce based on occupation and S&E technical expertise: 2003 and 2010.



NOTES: College-educated individuals refers to individuals with a bachelor's degree or higher. The data on S&E expertise (right) include individuals in S&E, S&E-related, and non-S&E occupations. Not all individuals employed in S&E occupations (left) indicated that their job requires at least a bachelor's level of S&E expertise (78% in 2003; 87% in 2010).

SOURCES: National Science Foundation (NSF), National Center for Science and Engineering Statistics (NCSES), National Survey of College Graduates (NSCG) (2010). http://www.nsf.gov/statistics/sestat/. *Indicators 2014*.

TABLE 1: Size of the STEM/S&E Workforce based on occupation, education or STEM expertise, 2010-2012

Workforce Size	Measure (Year)	Education Coverage	Source (Year)
5,398,000	Employed in S&E occupation[8] (2010)	Bachelor's degree and above	NSF SESTAT (2010)
5,968,000	Employed in S&E occupation (2012)	All education levels	NSF SESTAT (2010)
19,493,000	Holds at least one S&E degree (2010)	Bachelor's degree and above	NSF SESTAT (2010)
16,456,000	Worker reports job requires bachelor's degree level S&E expertise (2010)	Bachelor's degree and above	NSF SESTAT (2010)
26,000,000	Worker reports job requires significant STEM expertise (2011)	All education levels	Rothwell/O*NET (2011)
142,469,000	Total U.S. Workforce (2012)	All education levels	BLS CPS (2012)

SOURCES: Bureau of Labor Statistics (BLS), Occupational Employment Statistics (OES) (2012) and Current Population Survey (CPS) (2012); NSF, NCSES, NSCG (2010), Scientists and Engineers Statistical Data System (SESTAT) (2010) integrated file. http://www.nsf.gov/statistics/sestat/. *Indicators 2014*; Rothwell, "The Hidden STEM Economy," 2014. http://www.brookings.edu/research/reports/2013/06/10-stem-economy-rothwell

As the U.S. economy has changed, so too have occupational tasks and even occupations themselves. New types of jobs emerge as new industries are created, and new problems requiring solutions are encountered. To remain competitive, our Nation needs flexible STEM-capable workers at every education level. Recognizing this, several recent reports have drawn attention to a sub-baccalaureate, or "technical STEM workforce." This workforce consists of workers with high school or two-year technical training or a certification who employ significant levels of STEM knowledge in their jobs (see "The 'Technical' STEM Workforce").[9] According to one report, when these sub-baccalaureate workers are included, there may be as many as 26 million jobs in the United States that require significant STEM knowledge and skill in at least one field. This represents nearly 20% of all U.S. jobs (Table 1).[10]

The 'Technical' STEM Workforce

Technical STEM workers, who are also known as sub-baccalaureate STEM, hidden STEM, or middle-skill STEM workers, combine conventional literacy with technical expertise.[11] Technical STEM jobs, concentrated in the information technology (IT), health care, and skilled trades, require education beyond high school, often in the form of a two-year degree, occupational license, or certification.[12]

Sub-baccalaureate workers are a sizable segment of the STEM workforce. NSF, using its occupation-based definition of S&E worker, estimates that one quarter of all S&E workers have less than a bachelor's degree.[13] Using a broader, skills-based definition and focusing on STEM rather than just S&E, Jonathan Rothwell of the Brookings Institution estimated that half of all STEM jobs are available to workers with less than a bachelor's degree.[14]

Technical STEM jobs are often among the best paying and most stable jobs available to individuals with a sub-baccalaureate education. In 2011, the median earnings among workers 25 and older without a bachelor's degree employed in S&E occupations was twice as high as the median annual earnings among comparable workers employed in other occupations ($60,000 versus $30,000). The unemployment rate of sub-baccalaureate S&E workers was only about half of that in other occupations (6% vs. 11%).

Compared to scientists and engineers with advanced degrees (sometimes dubbed the "professional STEM workforce"), the technical STEM workforce has fewer foreign-born workers with 92% of technical STEM workers being native born. Blacks and Hispanics are represented in higher proportions in the technical STEM workforce than they are in the professional STEM workforce. Also, demand for technical STEM workers is distributed nationwide unlike the professional STEM workforce, which tends to be concentrated in high-tech-heavy regions.[15]

Technical STEM jobs provide a gateway to opportunity for a segment of the U.S. workforce that was hard hit by transformations in the domestic and global economy. However, today's middle-skill workers require STEM knowledge and skills to a greater extent than they did a generation ago. As Anthony Carnevale, director of the Georgetown University Center on Education and the Workforce, noted, "There's a new middle. It's tougher, and takes more skill."[16]

The Challenge of Defining the STEM Workforce

The various workers who comprise the STEM workforce play distinct roles in meeting evolving occupational needs, in enabling innovation, and in enhancing U.S. competitiveness. In recognition of the importance of these workers to our economy, the concept of a STEM workforce is invoked regularly in policy discussions, reports, congressional testimony, and mainstream media. It has even been referenced in law and regulations.[17] However, despite frequent reference to the STEM workforce, there is no consensus definition of it (or, for that matter of the specific disciplines that constitute "STEM").[18]

In the absence of a consensus definition, analysts define the STEM workforce in the way best suited to their specific analyses.[19] In general, STEM workers are thought of as individuals who possess a STEM degree or who work in a STEM occupation. But reports differ in how expansively they view STEM. For example, some definitions of the STEM workforce omit workers with less than a bachelor's degree or omit social scientists. Other commonly used definitions include some or all of those workers. Importantly, definitions that focus on degrees and occupations may also exclude STEM-capable workers who use significant levels of STEM expertise in the workplace, but who do not hold a STEM degree or who do not work in a STEM job. Capturing *all* STEM-capable workers is especially important if we wish to look beyond degree and occupational classifications and understand more broadly how STEM skills are used in the workplace and how STEM-capable workers add value to our economy (see "What are the STEM Capabilities?").

What are the STEM Capabilities?

Efforts are underway to gather data on STEM knowledge and skills. This research promises to supplement degree- and occupation-based analyses by clarifying our understanding of the interconnections among skills, education, and occupation. The U.S. Department of Labor's Occupational Information Network (O*NET) program is developing a database with detailed information on the competencies of workers in nearly 1000 occupations.[20]

Anthony Carnevale and colleagues have analyzed O*NET data to identify which competencies are highly associated with STEM occupations.[21] Among the cognitive competencies associated with STEM are knowledge of math, chemistry, and other scientific and engineering fields; STEM skills, such as complex problem solving, technology design, and programming; and STEM abilities, including deductive and inductive reasoning, mathematical reasoning, and facility with numbers. Among the non-cognitive competencies associated with STEM are preferences for investigative and independent work.

As the use of STEM knowledge and skills becomes more prevalent in the workplace, it is unsurprising that there is no one-size-fits-all definition of the STEM workforce. And while the absence of a consensus definition of the STEM workforce is not necessarily a problem, it presents a challenge for policymakers trying to develop sound, data-driven policies. The analyses in any report depend, in part, on who is included in the definition of the STEM workforce. Therefore, the findings of STEM workforce reports are sometimes not comparable to each other and the conclusions not necessarily generalizable. Confusion over definitions and conflicting beliefs about who is a STEM worker contribute to longstanding and prominent debates about the STEM workforce and exacerbate the challenge of generating consensus answers to specific questions about its adequacy (see "The STEM Worker Surplus – Shortage Debate").

The STEM Worker Surplus–Shortage Debate

Whether the United States has a shortage of STEM workers is a long-standing, highly contested policy issue. Claims of STEM worker shortages have appeared periodically since the 1950s. Once linked to Cold War anxieties about U.S. scientific manpower,[22] today's shortage-surplus debate unfolds against the backdrop of globalization and a worldwide flow of STEM knowledge, expertise, and labor.[23]

Analysts, media, and government reports highlight a variety of concerns regarding the size of the U.S. STEM workforce. These include meeting the demand for workers with scientific and technical knowledge and capabilities[24]; remedying wide disparities in U.S. student achievement in math and science[25]; attending to business sector reports of an inability to locate sufficiently skilled domestic STEM workers[26]; and preparing for demographic shifts that will boost the proportion of the U.S. population hailing from groups that have been historically underrepresented in STEM.[27] In addition, our Nation's reliance on foreign-born STEM workers at a time when these individuals increasingly have options for employment globally raises the question of whether the United States can depend on attracting a steady stream of foreign-born STEM talent.[28]

In light of these concerns, some analysts contend that the United States has or will soon face a shortage of STEM workers.[29] Some point to labor market signals such as high wages and the fact that STEM vacancies are advertised for more than twice the median number of days compared to non-STEM jobs.[30] Other analysts note that the shortage of STEM workers is a byproduct of the ability of STEM-capable workers to "divert" into other high-skill occupations that offer better working conditions or pay.[31] Relatedly, some say even if the supply were to increase, the United States might still have a STEM worker shortage because an abundance of high-skill workers helps drive innovation and competitiveness and this might create its own demand.[32]

Those analysts who contend the United States does not have a shortage of STEM workers see a different picture.[33] They suggest that the total number of STEM degree holders in the United States exceeds the number of STEM jobs, and that market signals that would indicate a shortage, such as wage increases, have not systematically materialized.[34] Analysts also raise concerns about labor market dynamics in academia—where a decreasing share of doctoral degree holders employed in the academic sector are tenured—and in industry—where there are reports that newly-minted degree holders and foreign "guestworkers" on temporary visas (e.g., H-1B, L-1) are displacing incumbent workers.[35] A few of these analysts go as far as to argue that firms claim shortages and mismatches in the hope of lowering compensation and training costs.[36]

Close study of the surplus-shortage question reveals that there is no straightforward "yes" or "no" answer to whether the United States has a surplus or shortage of STEM workers. The answer is always "it depends." It depends on which segment of the workforce is being discussed (e.g., sub-baccalaureates, PhDs, biomedical scientists, computer programmers, petroleum engineers) and where (e.g., rural, metropolitan, "high-technology corridors"). It also depends on whether "enough" or "not enough STEM workers" is being understood in terms of the quantity of workers; the quality of workers in terms of education or job training; racial, ethnic or gender diversity, or some combination of these considerations.

The Board has noted that there are many areas of consensus within the surplus-shortage debate. Analysts on both sides of the debate invariably emphasize the value of STEM skills in jobs across our economy. Likewise, many analysts see a need to improve access to and the quality of STEM education at all levels and to address the lack of racial/ethnic and gender diversity in the STEM workforce. Finally, numerous analysts note the need to pay more attention to the demand for STEM workers and cite the necessity of collecting additional data to improve our understanding of career pathways.

The STEM Workforce – One Concept, Many Stories

While the concept of a STEM workforce has become commonplace, the term obscures the heterogeneity of the workers who comprise it. Many of the most pressing and contentious questions about the STEM workforce—however defined—cannot be answered by examining the STEM workforce in its entirety. What we call the STEM workforce is, in fact, a heterogeneous mix of "sub-workforces" of varying composition and character. These sub-workforces can be understood by:

- Degree/education level (e.g., the PhD or "sub-baccalaureate" STEM workforce)
- Degree field (e.g., life sciences, engineering, information technology)
- Occupation (e.g., postsecondary teacher in STEM, chemical engineer, biomedical technician)
- Geography (e.g., metropolitan vs. rural, Silicon Valley vs. "Research Triangle")
- Employer type/sector (e.g., academia, industry, government)
- Career stage (e.g., new graduates, mid-career, late-stage)
- A combination of these factors

These sub-workforces present strikingly different "stories." Specifically, the markets for the various STEM sub-workforces can vary dramatically.[37] For example, our Nation requires more sub-baccalaureate health-technology workers relative to quantum physicists. The potential volume of health-technology workers is larger because almost every town and city in the country requires the services of numerous health-technologists. By contrast, the societal need for quantum physicists is more limited.

Generalizations about a single field or occupation also can be misleading. For example, in the category of "computer and information scientists"—which accounts for about 40% of the S&E workforce[38]—there are many different workforce "stories." This broad occupational category includes jobs that range from research scientist, to web developer, to network architect, to computer support specialist.[39] These jobs require differing levels of education, training, and experience and, importantly, have different patterns of geographic distribution.[40] As such, it is perfectly conceivable that there might simultaneously be a shortage of one type of computer and information science worker and a surplus of another type, either nationally or regionally.

STEM workforce "stories" for individuals at the same degree level vary by field. For example, about half of the 246,000 individuals with PhDs in the biological sciences are employed in academia. Thus, they are disproportionately affected by fluctuations in Federal funding for basic and applied research, structural changes in academic employment patterns, and declines in state funding for research universities.[41] By contrast, only a little more than a quarter of the Nation's 157,000 engineering PhDs are employed in academia; the majority of engineering PhDs (65%) work in the business sector and are particularly affected by market perturbations.[42]

As these and other examples underscore, the STEM workforce is not a monolith. It does not function as a single entity, and the opportunities and challenges facing workers differ depending on sector, training, experience, and skills, sometimes considerably. When discussing workforce issues or deliberating policy interventions it is vital to be clear and specific about which part of the STEM workforce is being addressed. It is equally important to guard against oversimplifying by eliminating nuance or overgeneralizing by ascribing conditions encountered by a subgroup to the entire workforce. For example, the challenges faced by biomedical PhDs are not necessarily applicable to *all* doctoral degree holders or the *entire* workforce.

II. STEM knowledge and skills enable multiple, dynamic pathways to both STEM and non-STEM occupations.

A. The STEM Workforce and Career Pathways

STEM knowledge and skills are commonly, though not exclusively, acquired through educational programs leading to a STEM degree.[43] These capabilities enable individuals to follow numerous career paths to many occupations, not just those traditionally defined as S&E or STEM.[44] Among college-educated workers in the United States who received their highest degree in an S&E field, less than half are employed in what NSF classifies as either an S&E or S&E-related job (Table 2),[45] a fact that policymakers, the media, and even students are often surprised to learn.

TABLE 2: Occupational distribution of degree holders, by broad field of highest degree: 2010

Field of highest degree	**Total** (percent)	**S&E occupation** (percent)	**S&E-related occupation** (percent)	**Non-S&E occupation** (percent)
S&E field	100.0	35.1	13.9	51.0
S&E-related field	100.0	6.2	72.7	21.1
Non-S&E field	100.0	20.5	29.3	50.2

NOTE: Detail may not add to total because of rounding.
SOURCES: NSF, NCSES, SESTAT (2010). http://www.nsf.gov/statistics/sestat/. *Indicators 2014.*

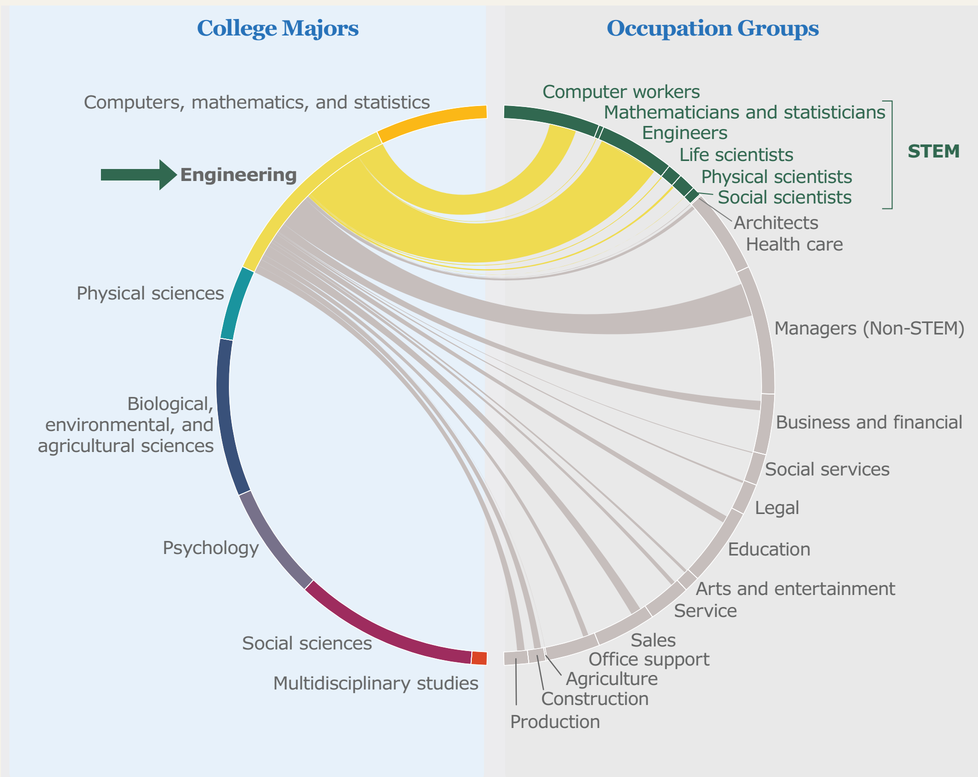
The tendency of U.S. S&E degree holders to pursue careers in a wide range of occupations is a defining and distinctive feature of the U.S. workforce. Data stretching decades show that in the United States "degree is not destiny"—that there is a somewhat loose association between degree and jobs at all education levels and in all degree fields. Compared with other nations, U.S. graduates are generally less constrained by their field of degree in pursuing career options. In some nations in Europe and Asia, it is more common to require certifications for jobs and it is harder for organizations to redesign jobs. By contrast, U.S. employers are able to be quite fluid and can acquire and use employees' skills in differing ways to yield value.[46] As the U.S. economy continues to evolve, this workforce flexibility remains advantageous for individual workers, businesses, and the Nation.

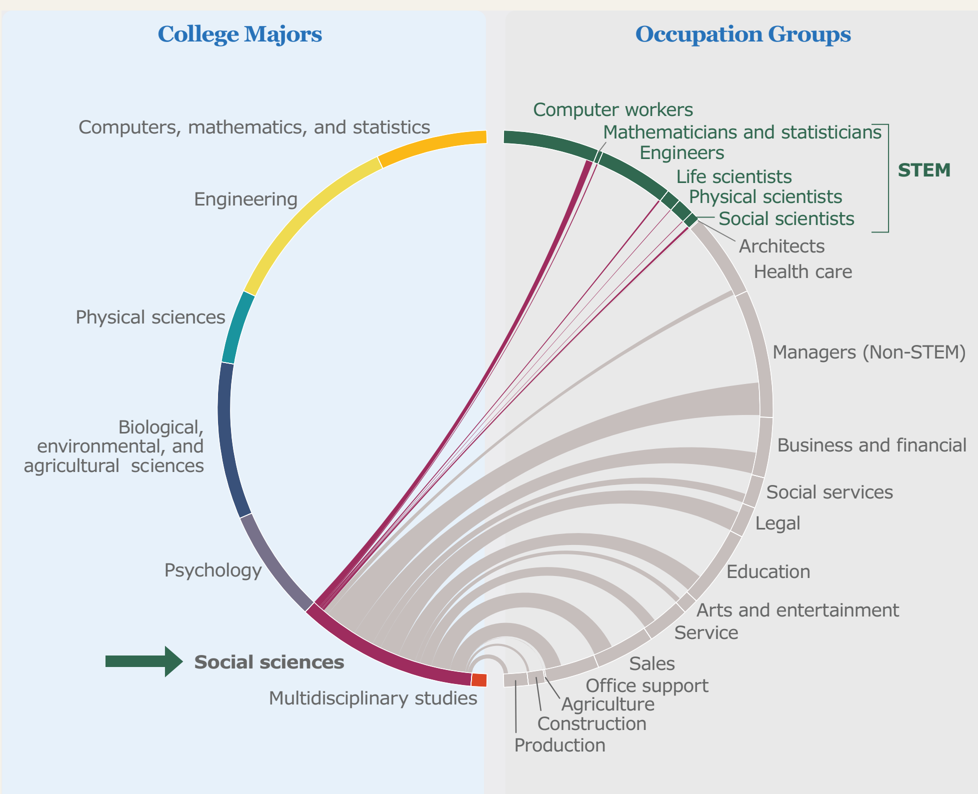
While a majority of U.S. S&E degree holders work in non-S&E occupations, there are distinct patterns of employment by degree level and field. The likelihood of an individual with an S&E degree working in an S&E occupation increases as his or her education level increases. For example, 38% of bachelor's, 58% of master's, and 78% of doctorate holders with degrees in the physical sciences are employed in an S&E occupation.[47] There are also distinct differences in the association between degree and occupation by field (see "Examples of STEM Pathways: Engineering and Social Sciences").[48] Despite these differences, surveys of employees underscore that many individuals with S&E degrees, regardless of where they are employed, feel that their work is related to their degree. Among individuals with an S&E degree not employed in an S&E occupation, two-thirds say that their job is either somewhat (32%) or closely (35%) related to their degree field, further demonstrating the value of STEM capabilities throughout the economy.[49]

Many factors shape career pathways.[50] For workers in STEM occupations or whose jobs require significant levels of STEM expertise obtaining the requisite education and training is critical.[51] As individuals progress through a career, the influence of their initial education and training on pathway choices may yield to other factors. At the individual level these include (but are not limited to) professional interests, availability and relative attractiveness of career opportunities, lifestyle preferences, access to on-the-job training or continuing education opportunities, work experience, and serendipity. Exogenous forces such as scientific and technological change, entrepreneurial activities, business needs, and public policy affect pathway choices. And within a dynamic economy, the pathways themselves are continually being created, supplanted, and reshaped.

These factors coupled with the mobility of today's workers mean that career pathways are not necessarily linear. For example, an individual with STEM knowledge and skills might start out in a STEM job then obtain an additional degree in another field. A STEM-educated lawyer or an individual with both a STEM degree and a Master of Business Administration degree can add unique value in a number of work settings. Similarly, an individual may begin a career in academia and then move into government or industry (and perhaps back to academia).

Examples of STEM Pathways: Engineering and Social Science





The U.S. Census Bureau has created an interactive tool to explore the relationship between college majors and occupations. The circle segments show the proportion of people graduating in each college major (left) and employed in each occupation group (right). The lines between majors and occupations indicate the share of people in a major who work in a particular occupation. Shown above are the education-to-occupation "pathways" for engineering (top) and social science (bottom) degree holders.

The education-to-occupation "pathways" look quite different for engineering and social science degree holders. Engineering degree holders are predominantly employed in STEM jobs (yellow), particularly jobs in engineering and the computer sciences. By contrast, the majority of social science degree holders follow career pathways into non-STEM jobs (gray). Not captured in this illustration is that these patterns will be different for different degree levels and likely evolve over the course of one's career.

SOURCE: U.S. Census Bureau, 2012 American Community Survey. https://www.census.gov/dataviz/visualizations/stem/stem-html/

DEFINITIONS: Field of degree corresponds to the bachelor's degree major, or first-listed major among double-majors, for respondents aged 25 to 64 who have completed a bachelor's or higher degree. Occupations are classified according to the 2010 Standard Occupational Classification system. The Census Bureau defines STEM to include computer and mathematical occupations, engineers, engineering technicians, life scientists, physical scientists, social scientists, science technicians, and STEM managers. STEM-related occupations consist of architects, healthcare practitioners, healthcare managers, and healthcare technicians. Non-STEM occupations are all other occupations not classified in STEM or STEM-related occupations.

B. A Pathways Approach to Understanding the Workforce

Many questions about the status of the STEM workforce are about supply and demand. The commonly used "STEM pipeline" model—with its underlying assumption of a linear progression from formal STEM education to STEM occupation—can encourage the problematic approach of matching the number of people awarded degrees in a given field with projected numbers of jobs in that same field. By contrast, a "pathways approach" provides a more accurate and dynamic picture of STEM workforce (see "Beyond the Pipeline: The Variety of Paths from Education to Career").

Beyond the Pipeline: The Variety of Paths from Education to Career

The "STEM pipeline" metaphor implies a linear education-to-work continuum that starts in elementary school and continues through tertiary education and into a job. The idea of a pipeline is valuable in the context of K-12 education where students must learn fundamental and (sometimes cumulative) STEM and non-STEM knowledge and skills that prepare them for future education, training, and career opportunities. A national commitment to ensuring that all students have this basic foundation represents a collective investment in our future workforce and a well-informed citizenry.

Beyond primary and secondary schooling, the pipeline metaphor is less useful and even misleading. Post-secondary school STEM education and training paths are highly varied. Students planning their post-secondary education and career paths have many options: Technical school or technical training at a two-year college; pursuit of a bachelor's degree through some combination of two-year and four-year college courses[52]; military service that includes significant on-the-job training and/or education benefits; or employment in a job that provides on-the-job training.

Decisions to undertake STEM education are also often made well after high school. Many students step away from school for a time to work, raise children, care for relatives, or for financial reasons. Other individuals return to school due to changing career interests or in response to new opportunities. Many pursue their training or education part time while working. The most recent available data from the National Center for Education Statistics estimates that 73% of all undergraduates could be considered nontraditional for such reasons.[53]

To ensure a strong, flexible STEM-capable workforce in a 21st Century economy, our Nation must ensure that all students acquire a strong educational foundation in primary and secondary school. Building on this foundation, we must ensure the availability of various educational and career "on-ramps" and "off-ramps" that can accommodate the transitions that individuals make during their working years. Ensuring flexible options for workers will necessitate the collective engagement of governments, educators, and employers.

Unlike a linear pipeline model, a pathways approach more accurately represents the relationship between degree and occupation. STEM knowledge and skills enable individuals to pursue myriad occupations. For example, individuals with a bachelor's degree or higher in the computer and mathematical sciences embark on a variety of career paths with more than half working outside of the computer sciences and S&E occupations altogether.[54] A pathways approach also recognizes that a given occupation can draw on the varied expertise of individuals with disparate educational and training backgrounds. For instance, only 44% of individuals working as "computer and mathematical scientists" possess a bachelor's or higher level degree in the field of computer and mathematical sciences, and over a quarter of these workers have no S&E degree at all.[55] Given the loose link between degree and jobs in computer science, attempts to assess the state of the "computer science workforce" that entail matching the number of computer science degree holders with projections for computer-related job openings are bound to be misleading.[56]

C. The Pathways Approach – Asking Better Questions

A "pathways approach" encourages a shift in the focus of questions concerning workforce competitiveness from "*how many* degrees/workers" do we have, to "*what kinds* of knowledge and skills" are needed (see "Complementing STEM: Other Knowledge and Skills for the 21st Century STEM Workforce"). A pathways approach likewise moves away from a near-term focus on educating individuals for *today's* jobs to a strategy that focuses on equipping individuals with applicable skills and generalizable STEM and non-STEM competencies needed to adapt and thrive amid evolving workforce needs.

Complementing STEM: Other Knowledge and Skills for the 21st Century STEM Workforce

Arts and humanities disciplines complement STEM education by teaching students interpretive and philosophical modes of inquiry; by honing communication and writing skills; by fostering multicultural and global understanding; and by cultivating an appreciation for history, aesthetics, and the human experience. As a recent American Academy of Arts and Sciences report highlighted, study of the humanities and arts develops both critical perspectives and imaginative responses.[57] These ways of thinking contribute to inventiveness and, in turn, to competitiveness.[58]

In addition to having a well-rounded education that includes both STEM and non-STEM subjects, employers indicate that today's STEM workers must possess a variety of characteristics important for the workplace.[59] These include the ability to work independently and in teams, a willingness to persist in solving hard problems, and an understanding of workplace expectations.

The pathways approach might also prompt government, education, and industry leaders to assess the condition of these pathways and work collectively to enable and strengthen them. In particular, a focus on pathways highlights our collective challenge to ensure that all our students have access to STEM pathways, and that roadblocks to their success are identified and removed.

As a first step in charting a path forward, the Board has developed a set of key questions that policymakers should address in order to assess, enable and strengthen STEM pathways for the long-term:

- What kinds of policies would be necessary to ensure that all students and incumbent workers, regardless of race/ethnicity, gender, socioeconomic status, locale, and other demographic characteristics, have the opportunity to embark on these workforce paths?
- Once on these paths, what types of roadblocks and obstacles do workers encounter? What policies could help mitigate or remove them?
- How can we assess and strengthen the state of career pathways that we believe are especially important to national competitiveness?
- What are the roles of governments, educational institutions, and businesses in enabling pathways and strengthening the workforce for the long-term?

III. Assessing, enabling, and strengthening workforce pathways is essential to the mutually reinforcing goals of individual and national prosperity and competitiveness.

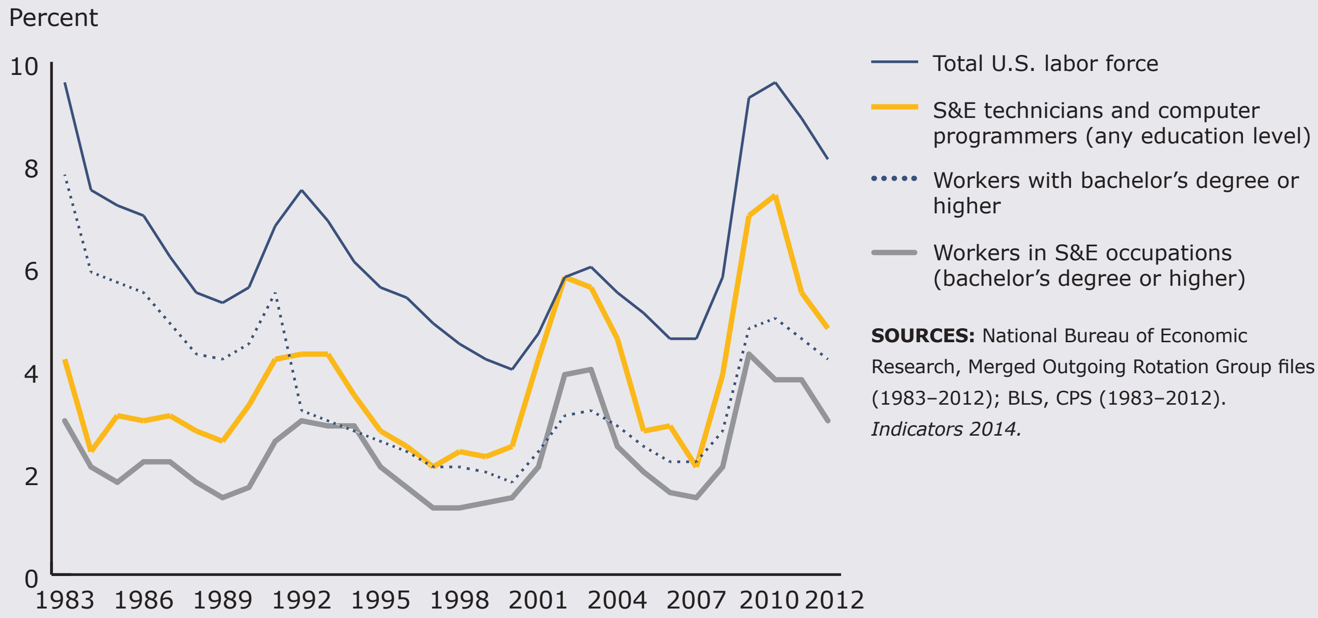
A. Assessing the Condition of Pathways – Indicators

The availability and condition of occupational pathways matter to governments, employers, students, and their families. In the long run, if essential STEM pathways are not attractive relative to other career options, too few students may undertake and persist in STEM courses of study. The state of STEM pathways also affects incumbent workers. If the condition of these pathways is poor, incumbent workers may find them less appealing and consider other careers out of their field of degree or out of STEM altogether. Thus, it is important to monitor and assess the condition of these pathways and identify risks and challenges. Labor market indicators such as earnings and unemployment rates as well as related indicators addressing why individuals with STEM degrees work out of their field of degree help provide information about the availability and condition of STEM pathways.

Indicators about the STEM workforce frequently contrast the data on STEM workers with all workers. Such comparisons show that STEM knowledge and skills (usually acquired via a STEM degree) are associated with distinct labor market advantages. However, aggregate comparisons with the general workforce are not particularly helpful for assessing the conditions within specific STEM pathways. Instead, the availability and relative attractiveness of STEM occupations are better understood by examining the market conditions over time for similarly educated individuals or for individuals in the same occupational category.

To illustrate this point, consider the fact that STEM workers have historically experienced significantly lower rates of unemployment compared to the overall U.S. labor force.[60] One might conclude from this that STEM workforce pathways are unfailingly robust and attractive. This is an oversimplification. Comparisons with the general U.S. workforce do not fully capture the labor market experiences of newly-minted degree holders and incumbent STEM workers in a given field. Like the general workforce, the unemployment patterns of individuals in S&E or STEM occupations are affected by overall economic conditions (Figure 2). For example, during the most recent economic downturn, the unemployment rate for “S&E technicians and computer programmers” more than tripled from a low point of 2.1% in 2007 to a high of 7.4% in 2010 before declining in more recent years.[61] For an even more nuanced analysis, one might explore unemployment data disaggregated by field and sub-field within S&E (e.g., chemical engineers vs. mechanical engineers), geographic region, or sector. Further, unemployment data alone likely represent an underestimate of the labor underutilization of STEM workers.[62] For example, early career doctorate-level workers in the biological sciences and some other STEM fields increasingly accept temporary academic positions—a trend that would not be apparent by examining the unemployment rate alone.

FIGURE 2: Unemployment rate, by occupation:1983-2012



SOURCES: National Bureau of Economic Research, Merged Outgoing Rotation Group files (1983–2012); BLS, CPS (1983–2012). *Indicators 2014.*

Wages are another factor in assessing the relative attractiveness of pathways. Although STEM degree holders at all educational levels experience a wage premium compared to the general workforce, this comparison ignores that the choice facing many students is between an advanced degree in science and a potentially more financially lucrative professional degree (e.g., JD, MD). While comparison of wages across fields and educational levels is complicated, there is some evidence that doctoral degree holders' earnings in basic biological, mathematical and physical sciences have been stagnant or declining relative to either applied science or some professional occupations.[63] Specifically, PhDs in the basic sciences earn about two-thirds of what lawyers earn, while typically investing more years to obtain a PhD. PhDs in the basic sciences earn about half of what individuals with a medical degree earn.

We can also assess the attractiveness of career pathways in STEM—especially for incumbent workers—by asking why STEM-trained individuals work outside their degree field. Of the 22 million college-educated individuals employed in S&E or S&E related occupations in 2010, 1.4 million (6.4%) worked involuntarily out of the field of their highest degree because they were unable to find a job in their field (Table 3). This proportion has been relatively stable over the past decade.[64]

TABLE 3: Scientists and engineers who are working involuntarily out of field, by S&E degree field: 1993–2010 (Percent)

S&E degree field	1993	1995	1997	1999	2003	2006	2008	2010
All scientists and engineers	7.8	7.7	7.3	5.4	5.9	6.2	5.3	6.4
Highest degree in S&E field	9.2	8.9	8.5	6.3	7.8	8.1	7.1	8.4
Biological, agricultural, and environmental life sciences	10.3	10.2	10.0	8.3	10.1	9.7	10.1	10.1
Computer and mathematical sciences	5.3	4.1	4.0	2.9	4.9	5.7	4.5	5.1
Physical sciences	9.7	10.2	10.0	7.6	8.8	8.6	7.1	8.2
Social sciences	13.3	12.7	12.1	8.7	10.1	10.6	9.2	11.3
Engineering	4.4	4.4	3.9	2.7	4.2	4.5	3.6	4.9

NOTES: During 1993–99, scientists and engineers include those with one or more S&E degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E occupation. During 2003–10, scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level orhigher and are employed in an S&E or S&E-related occupation. In 2010, this represented 22 million individuals. The involuntarily-out-of-field rate is the proportion of all employed individuals who report that their job is not related to their field of highest degree because a job in their highest degree field was not available.

SOURCES: NSF, NCSES, SESTAT (1993–2010). http://www.nsf.gov/statistics/sestat/. *Indicators 2014.*

While some workers are employed outside their field of degree because a suitable job is not available, many work outside their field of highest degree for other reasons. The most commonly cited reasons include pay and promotion opportunities, working conditions, job location, and a change in career or professional interests. That STEM-educated workers can and do work in many types of jobs is advantageous for them and for the employers who find them valuable. However, the existence of a range of career options for STEM-educated workers also underscores the importance of ensuring that S&E occupations remain comparatively attractive destinations for students and incumbent workers.

While many factors fuel innovation and competitiveness, cross-national studies suggest that a well-educated workforce is a crucial factor.[65] Recognizing this, China, India, and other nations have significantly increased their investment in post-secondary education with the stated goal of enhancing their economies through the creation of a highly-skilled domestic labor force.[66] As these countries also increase their investment in R&D and Knowledge-and-Technology-Intensive Industries, a global race to attract STEM talent is emerging (see "The U.S. STEM Workforce in a Global Context").

The U.S. STEM Workforce in a Global Context

The U.S. STEM workforce must be considered in the context of an expanding and vibrant global scientific and technological enterprise. For over a decade, *Indicators* data have shown that other nations, led by China, South Korea, and Brazil, have been increasing their innovation capacity by investing heavily in higher education and in R&D.[67] These investments are shifting the balance of the scientific and technological landscape as the Asia-Pacific region now performs a larger share of global R&D than the United States.[68]

The combination of global opportunities for STEM employment and the portability of STEM skills means that almost every policy issue concerning the R&D/high-skill STEM workforce—including supply, wages, and visa policy—needs to be considered in global terms. Models of S&E workforce supply and demand must take into account the global flow of S&E workers.[69] Increased opportunity overseas for acquiring STEM education and working in STEM occupations also has implications for U.S. visa policy as policymakers consider how to keep the United States an attractive destination for foreigners wishing to pursue doctoral study in STEM fields and/or obtain STEM employment in the United States.

Global changes in STEM education and R&D are particularly important to watch because a large proportion of students earning doctoral degrees in S&E subjects at U.S. universities and a sizable proportion of U.S. workers employed in S&E fields are foreign born. A 2012 NCSES InfoBrief reported that in 2010 foreign citizens' share of U.S. earned doctorates in science, engineering and health had reached nearly 40%.[70] At the doctoral level, over 40% of those in each S&E occupation, except the social sciences, were foreign born. While these statistics about doctoral degree recipients and the doctoral level S&E workforce are particularly striking, the proportion of foreign-born workers in S&E occupations has, in fact, increased at every degree level over the past decade. In 2010, according to NSF's SESTAT survey, 27% of college graduates working in S&E occupations were foreign-born, up from 23% in 2003.[71] In comparison, the share of foreign born among the overall population in the United States was 13% in 2010, up slightly from 12% in 2003.[72]

The most recent data (2010) show that the United States remains an attractive destination for foreign-born individuals seeking advanced training or employment in S&E. The advantages that have led two out of three foreign-born graduates of U.S. doctoral programs to stay in the United States include the quality of life, democracy, world-class research universities, entrepreneurial culture, and a wider range of career pathways than might be available in their home countries.[73]

"Stay-rates"—a measure of the number of foreign-born individuals who stay in the United States to work following completion of a U.S. doctoral degree program—remain stable.[74] However, the emerging global competition for highly skilled STEM workers means that we must ensure that U.S. universities remain attractive to the best foreign-born students and that research funding, career opportunities, and visa policies position our Nation to remain globally competitive.

Meeting Business Needs

Numerous recent reports suggest that businesses in many sectors are having difficulty meeting their workforce needs.[75] The precise nature of their hiring challenges is an area of considerable uncertainty. Reports suggest that skills-related mismatches can take a number of forms. For example, a 2011 report from The Manufacturing Institute suggested that manufacturing industries experience difficulty finding workers with specific STEM skills (e.g., problem-solving skills) and "employability" competencies (e.g., work ethic, timeliness).[76] While both categories of response constitute a potential mismatch, the root causes and possible solutions are dramatically different.

In thinking about skills mismatch it is vital to determine where a potential problem lies. Is it a lack of STEM skills or general qualifications (e.g., oral and written communication, ability to work collaboratively)? If it is a STEM issue, is it a deficiency in a specific STEM knowledge or skill (e.g., ability to program in a specific language) or in a generalizable STEM competency (e.g., mathematical reasoning)? Does the challenge manifest in newly-degreed workers, incumbent workers, or both? Are these skill mismatches and shortages observed nationally or are they specific to a geographic region?[77]

Understanding the nature of the problem is essential to devising a solution. In some cases, if a skills mismatch exists, it may be better remedied not through formal education, but instead through "upskilling" or on-the-job training opportunities for new and incumbent workers.[78] Continuing education and training are especially critical for incumbent workers in occupations where knowledge and skills undergo rapid obsolescence.[79] Recent reports have highlighted that training opportunities offered by employers are not as common in the United States as in other nations and may be on the decline.[80] While more research is needed to understand current patterns of on-the-job training, it is important for educators, employers, and policymakers to recognize that today's workers require not just a strong educational foundation, but also opportunities for on-the-job training and skill renewal.

Meeting Basic Research Needs

PhD-trained scientists and engineers are a small but essential segment of the U.S. workforce. To become a PhD research scientist, students must commit to years of specialized education and training. In general, this investment yields distinct labor market advantages with doctoral degree holders in STEM fields experiencing significantly lower rates of unemployment and wage premiums compared to the overall U.S. workforce.[81] Yet, there has been a great deal of concern expressed in reports, congressional testimony, and scientific and popular media that career prospects for PhDs are becoming less rewarding, particularly in the academic sector.[82]

Unpredictable changes in Federal funding for research can significantly disrupt the balance between the number of STEM PhDs and the availability of permanent jobs where they can use their specialized training in the academic sector.[83] For example, large increases in Federal funding for basic research followed by a leveling off or decline in funding can create "boom-bust cycles" for employment as students, who were attracted into the field by opportunities created by a funding "boom," encounter diminishing career prospects after funding flattens or declines.[84] The most recent example of this phenomenon is among PhD-holders in the biomedical sciences. Between 1993 and 2010, the number of U.S.-educated doctorate holders in the biomedical sciences grew about 71% due, at least in part, to the doubling of the National Institutes of Health (NIH) budget between 1999 and 2003 (the "boom").[85] Critically, this doubling was followed by mostly flat budgets (the "bust").[86]

Structural changes in academic employment also can adversely affect career pathways of PhDs. Since the 1970s, there has been a steady decrease in the share of full-time faculty among all U.S.-trained, S&E doctoral holders employed in academia.[87] There also has been a general decline in the proportion of S&E-trained PhDs in academia who have achieved tenure.[88] For individuals with PhDs in life sciences, mathematical sciences, social sciences, psychology, and engineering, the percentage of tenured positions by field decreased by 4–9 percentage points between 1997 and 2010. At the same time, in some fields, there has been a decades-long increase in the number of PhDs employed in temporary postdoctoral positions.[89] The 2012 NIH "Biomedical Research Workforce Working Group Report" documented that both the number and length of postdoctoral appointments have increased for new biomedical PhDs. This has meant that those who eventually secure a tenure-track position do so at an older age and that the average age of receipt of a first major NIH grant is approximately 41 years of age, which is near its all-time high.[90] Additionally, investigators in most fields are experiencing greater competition for Federal funding, a phenomenon that is leading to a sharp drop in the "success rates" of grant proposals.[91]

While the range and condition of career pathways available to doctoral degree holders varies substantially by field—and policymakers should use caution in generalizing the situation of biomedical scientists to all S&E doctoral fields—trends in R&D funding and higher education prompt important questions about PhD training and careers. For example:

- Given doctoral students' numerous post-degree career pathways, the trends affecting academic career paths, and the changing knowledge and skills required for R&D in a global 21st Century economy, how should doctoral education in STEM fields be revised to ensure that PhDs are prepared for a wider range of careers?[92]

- What can be done to strengthen preparation for non-academic career pathways (e.g., Professional Science Master's programs,[93] industry-focused PhD programs[94])?

- What data do we need to better understand the career paths of PhD holders (e.g., better longitudinal data on the career pathways of PhD holders and postdoctoral fellows); who should develop these indicators?

Recognizing that adverse conditions in key career pathways for scientists and engineers could put the U.S. research enterprise at risk, leaders in the community have proposed and undertaken steps to address the situation (see sidebar "Responses to Challenges in Pathways for STEM PhDs").

Responses to Challenges in Pathways for STEM PhDs

The scientific community is responding to the challenges facing the PhD workforce. Several groups have called for curricular reforms and/or the augmentation of career training. For example, a recent American Chemical Society Presidential Commission concluded that graduate chemistry curricula need to be refreshed, and university and governmental leaders should focus on providing opportunities for developing critical professional skills among graduate students.[95] Similarly, a 2012 National Research Council report on research universities called for strengthening the preparation of doctoral students in STEM for a broad range of careers pathways.[96] The challenges facing postdocs has also received greater attention. Noted computer scientist Anita Jones has raised concern about the career progression of PhDs and postdocs in the computer sciences, calling for improvements in the postdoctoral experience, additional mentoring, and career development with exposure to a variety of career pathways.[97]

NIH has launched several program, policy, and organizational changes to address the challenges facing the biomedical PhD workforce. It is expanding the Early Independence Award and the Pathway to Independence Award programs to help facilitate the transition of biomedical PhDs into academic research careers. NIH also created the Broadening Experience in Scientific Training (BEST) program, which provides training for graduate students and postdoctoral researchers to prepare them for careers outside of conventional academic research. NIH has also established a scientific workforce office and is improving data collection on the biomedical workforce.

C. Assessing the Condition of Pathways – Participation and Equity

The long-term strength of our workforce requires that the full range of STEM and non-STEM career pathways be available to all Americans. This imperative is undergirded by two foundational principles: first, that every individual in the United States is afforded the opportunity to reap the benefits of advancements in science and technology; second, that our ability to respond to national needs and remain globally competitive will require the capabilities and ingenuity of individuals of diverse backgrounds.

Our Nation's failure to meet this charge fully takes on increased importance amid national and global developments.[98] Within the United States, the demographic composition of our future labor force is changing. As of fall 2014, the U.S. Department of Education notes that whites are a minority of our public school students.[99] And minorities are expected to compose the majority of the U.S. population before mid-century. At the same time, women and some racial and ethnic minorities (blacks, Hispanics, and American Indians/Alaska Natives) are underrepresented in the U.S. S&E workforce compared to their overall labor force participation.

TABLE 4: Proportion of women in the workforce by occupation and highest degree in S&E: 1993 and 2010 (Percent)

	Year	
	1993	**2010**
College-educated workforce	42.6	49.2
All S&E occupations	22.9	27.5
Computer/ mathematical scientists	30.8	25.1
Biological/agricultural/environmental life scientists	34.0	48.2
Physical scientists	21.3	30.0
Social scientists	50.7	58.1
Engineers	8.6	12.7
S&E highest degree	31.3	37.3
Bachelor's	32.3	37.6
Master's	31.7	38.4
Doctorate	20.4	30.3

SOURCES: NSF, NCSES, SESTAT and NSCG (1993 and 2010), http://www.nsf.gov/statistics/sestat/. *Indicators 2014.*

Although women comprise about half of all employed college graduates, they represented only 28% of the individuals with college degrees working in S&E occupations in 2010 (Table 4). Not surprisingly, this aggregate statistic masks considerable variation within major S&E occupational categories. In 2010, women comprised nearly 60% of social scientists and almost half of biologists, whereas women made up fewer than 13% of engineers. Between 1993 and 2010 women made modest gains in participation in all S&E occupations with the exception of computer and mathematical scientists, where the proportion of women actually declined by nearly 6 percentage points. Women are also underrepresented among individuals with a highest degree in S&E, despite having made modest gains in S&E degree level attainment between 1993 and 2010.

Data on racial and ethnic minorities show that they are generally underrepresented in both S&E degree programs and S&E occupations compared with their overall presence in the U.S. population (Table 5). For example, Hispanics, who are the fastest growing college-age population, represented 13.9% of the U.S. population age 21 and over in 2010, but comprised only 6.8% of S&E highest degree holders and made up only 5.2% of workers in S&E occupations. Asians, however, are the exception. They represented 4.9% of the U.S. population age 21 and over in 2010, but comprised 18.5% of individuals working in an S&E occupation.

TABLE 5: Racial and ethnic distribution of employed individuals in S&E occupations, and of S&E degree holders, college graduates, and U.S. residents: 2010

Race and ethnicity	S&E occupations	S&E highest degree holders	College degree holders	U.S. residential population*
Total (*n*)	**5,398,000**	**11,385,000**	**40,623,000**	**221,319,000**
Total	100.0%	100.0%	100.0%	100.0%
American Indian or Alaska Native	0.2%	0.2%	0.3%	0.6%
Asian	18.5%	13.9%	7.9%	4.9%
Black	4.6%	5.7%	6.8%	11.5%
Hispanic	5.2%	6.8%	7.1%	13.9%
Native Hawaiian or Other Pacific Islander	0.2%	0.3%	0.3%	0.1%
White	69.9%	71.5%	76.2%	67.5%
More than one race	1.4%	1.5%	1.4%	1.5%

* Age 21 and over.

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin. Detail may not add to total because of rounding.

SOURCES: Census Bureau, ACS (2010); NSF, NCSES, SESTAT and NSCG (2010). http://www.nsf.gov/statistics/sestat/. *Indicators* 2014.

Once on STEM pathways, women and underrepresented minorities do not fare as well as their male and white counterparts. For example, among S&E degree holders who work full time in S&E occupations, after controlling for differences in educational backgrounds, employment sector, and experience, women earn 12% less than men at the bachelor's level, 10% less than men at the master's level, and 9% less than men at the doctoral level.[100] Racial and ethnic groups also experience salary disparities, though the differences are smaller than the gender differences.

Data on the career paths of academic women in STEM fields suggest that fewer female PhDs are recruited into the applicant pool for tenure-track faculty positions, that they are more likely than men to shift from tenure-track to adjunct positions, and that differences in promotion and awards become more evident as female faculty proceed up the academic ranks.[101] Data on underrepresented racial and ethnic minorities employed in academia show that they are less likely than white men to be employed in research universities and are more likely to occupy contingent faculty positions.[102] While data on career progression for STEM PhDs outside of academia is harder to trace, black, Hispanic, and white female STEM PhDs working outside of academia were more likely to work in non-STEM jobs as compared with other groups.[103]

D. Enabling and Strengthening Workforce Pathways – Providing Access and Removing Roadblocks

The first step in enabling workforce pathways is to ensure that all Americans have access to a high-quality, well-rounded education that includes foundational concepts in STEM. There is no question that access—particularly for underrepresented minorities and for individuals from low socioeconomic backgrounds—is a significant challenge. Given that achievement in STEM subjects and high school graduation are now pre-requisites for entry into most STEM jobs, it is troubling that underrepresented minority students and individuals from lower socioeconomic background score lower than Asian and white students on measures of math/science achievement and have lower high school graduation rates.

Cumulative evidence suggests that gaps in student performance are the product of disparities that are manifest by the start of formal education. Research efforts aimed at identifying factors underlying these achievement gaps have mostly focused on school-related factors such as teacher quality, available resources, school administration leadership, and school climate, or such non-school factors as sex, race and ethnicity, and socioeconomic status.[104] Increasingly, scholars are exploring additional non-school factors including health, poverty, parenting, and personality to elucidate their impact on student achievement.[105] Identifying and mitigating or even eliminating the causes of these disparities represents a crucial and ongoing challenge for our Nation.

Educational "achievement gaps" are not the only roadblocks to success in the workforce pathways enabled by STEM knowledge and skills. A 2010 report from the American Association of University Women summarized research showing that cultural and environmental factors starting at a young age tend to discourage girls from pursuing or persisting in STEM studies.[106] There is also evidence that women are less satisfied with the academic workplace and more likely to leave these career pathways sooner than men.[107] Research into the experiences of underrepresented minorities has identified a host of additional barriers, including college affordability, self-confidence, feelings of exclusion, and teachers' low expectations of such students.[108]

Women and minorities are not the only groups that face barriers to entering the many career pathways enabled by STEM. Military veterans returning from deployment frequently possess technical training and have significant experience with sophisticated machinery and systems, yet they face obstacles to embarking on STEM pathways. Veterans may not readily know how to translate their experience to civilian careers. Veterans with disabilities encounter especially daunting challenges. Several initiatives focused on academic advising, internships, networking services and peer support are underway to alleviate the roadblocks that veterans, including disabled veterans, encounter.[109] Recently, the Federal Government initiated a program to offer career development opportunities for returning veterans interested in Federal science-related jobs.[110]

DISCUSSION & NEXT STEPS

An Approach to Understanding a Modern, STEM-Capable Workforce

The insights offered in this Companion Report to *Indicators* highlight that STEM knowledge and skills play an indisputable role in fostering individual opportunity and national competiveness. Further, these insights prompt us to begin thinking beyond a distinct and separate STEM workforce and to shift our focus to how to foster a strong, flexible, and diverse *STEM-capable U.S. workforce.* This STEM-capable workforce is considerably larger and more heterogeneous than when NSF was established. It includes workers at every education level who use STEM expertise in different workplace settings to add value to a dynamic U.S. economy.

In this report, the Board offers a more inclusive vision of a STEM-capable U.S. workforce and suggests a more nuanced approach to analyzing and discussing it. This approach necessitates acknowledging both the common and distinctive stories of the various workers comprising this workforce. This approach must recognize that STEM knowledge and skills enable workers to pursue numerous pathways in both STEM and non-STEM careers and allow businesses to meet evolving occupational demands by tapping into a diverse pool of flexible, highly-skilled workers. It must take into account that these workers have distinct career interests and aspirations, require specific educational and training opportunities throughout their careers, and benefit from tailored policies aimed at supporting them. Finally, this approach must acknowledge and address that not all individuals in the United States have access to the numerous career pathways enabled by STEM.

Creating a Strong STEM-Capable Workforce – A Shared Responsibility

Creating and maintaining a STEM-capable workforce for the long term requires governments, educational institutions, and businesses to fulfill their individual and collective responsibilities to assess, enable, and strengthen career pathways for *all* students and incumbent workers. We hope that the insights offered in this report can help inform decision makers as they reflect on their respective roles, and catalyze a dialogue on how to foster a STEM-capable workforce equipped to rise to contemporary challenges and seize future opportunities. Below we offer ideas on how each could contribute to this conversation.

The National Science Foundation

NSF has an important responsibility to provide indicators on the science and engineering enterprise. Specifically, NSF's National Center for Science and Engineering Statistics (NCSES), which prepares *Indicators* on behalf of the Board, is charged with collecting, analyzing, and disseminating high-quality, objective data on the S&E workforce. NCSES has efforts underway aimed at addressing important limitations in our current ability to assess the state of the workforce. These include:

- working in partnership with the Federal statistical community and other organizations to collect more and better longitudinal data on individuals with STEM knowledge and skills
- collecting data that should enhance our understanding of the factors that influence career pathways, especially for women, underrepresented minorities, veterans, and persons with disabilities

- expanding its coverage of the STEM-capable workforce to include information about certifications and other non-degree credentials that are important for technical workers and other professional occupations

- partnering with NSF directorates to develop more and better indicators of K-12 STEM education and the career progression of scientists and engineers supported by NSF's funding mechanisms

NSF also plays a leading role in fostering a STEM-capable workforce by investing in human resource development through its competitive granting mechanisms. NSF also supports STEM education research aimed at identifying core STEM competencies and enhancing STEM learning in a variety of settings and career stages. The insights gained from this research promise to inform how to best provide the education and training that STEM workers need throughout their careers. NSF's Directorate for Education and Human Resources is actively engaging in efforts to build partnerships within NSF, with other Federal Agencies, and with the academic and the business communities to develop evidence-based best practices to foster a globally competitive, innovative workforce for the 21st Century.

Government, Education, and Business Leaders

The Board hopes the insights detailed in this report can offer value for government and education leaders as they allocate resources among competing investment priorities. Much of the current discussion about the Federal Government's role focuses on providing more stable, predictable support for academic R&D. These conversations rightfully acknowledge the adverse effect of unpredictable Federal funding on research productivity. Instability in Federal funding also affects the career trajectories of doctoral students, postdoctoral workers, and researchers whose employment is often supported by federally-funded research grants. Recognizing that strong, steady increases in Federal R&D funding may not always be feasible, it is important for Federal Agencies, Congress, and research institutions to consider how best to mitigate the adverse effects of budget conditions on career paths.

A key question for educational leaders is how, at a time of scarce resources, to protect and strengthen their core educational mission, while meeting the diverse and rapidly changing educational and training needs of students and workers. The traditional role of educational institutions at all levels is to equip students with generalizable knowledge and competencies necessary to learn, think critically, and embark on career pathways. While this responsibility remains as important as ever, it is clear that the relationship between education and careers is changing and that workers will need opportunities for skill renewal and development throughout their careers. Community colleges, career and technical education programs,[111] and newer "business-needs-oriented" educational efforts like the Professional Science Master's programs, can provide a bridge between education and skills-training.

Leaders in the business community can help foster a strong STEM-capable U.S. workforce by considering how employer-provided on-the-job-training, reskilling, and other professional development activities could help strengthen the capabilities of their workers and make their businesses more competitive. Businesses could also explore partnering with local educational institutions to ensure that students and incumbent workers are learning the types of portable STEM and non-STEM skills needed in an environment where tasks are continually changing and job categories are being created and supplanted.

These are just some of the potential conversations that arise when we focus our attention on creating a STEM-capable U.S. workforce that can adapt to the demands of a globally competitive, knowledge- and technology-intensive economy. By embracing this shared responsibility, government, educational institutions, and industry can strengthen our most important resource, our human capital, and position our Nation for continued global leadership in science and technology.

ENDNOTES

[1] The predecessor of *Science and Engineering Indicators* emerged in 1955 when the Foundation published its first "fact book." J. Merton England, *A Patron for Pure Science* (Washington, DC: National Science Foundation, 1982), 254.

[2] Vannevar Bush, *Science – The Endless Frontier* (Washington, DC: National Science Foundation, 1990), 23.

[3] Anthony Carnevale and Donna Desrochers, "The Missing Middle: Aligning Education and the Knowledge Economy," (Washington, DC: U.S. Department of Education, 2002); Elka Torpey, "BLS Career Outlook: Got Skills? Think Manufacturing," June 2014. Retrieved from: http://www.bls.gov/careeroutlook/2014/article/manufacturing.htm; Daren Acemoglu and David Autor, "Skills, Tasks and Technologies: Implications for Employment and Earnings," in *Handbook of Labor Economics*, eds. Orley Ashenfelter and David Card (Elsevier: 2011) vol. 4B, 1043-1171; David Autor, Lawrence Katz and Alan B. Krueger, "Computing Inequality: Have Computers Changed the Labor Market?" *The Quarterly Journal of Economics* 113, no. 4 (November 1998): 1169-1213.

[4] NSF's Business R&D and Innovation Survey (BRDIS) shows that although businesses that perform R&D report a significantly greater incidence of product or process innovation, over three-quarters of reported innovation in the United States derives from businesses that are not significantly engaged in R&D activity. Mark Boroush, "NSF Releases New Statistics on Business Innovation," (Arlington, VA: National Center for Science and Engineering Statistics, 2010). Retrieved from: http://www.nsf.gov/statistics/infbrief/nsf11300/.

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[6] NSF's definition of S&E occupations does not include healthcare workers. NSF includes these workers in its category of S&E-related occupations.

[7] Between 2003 and 2010, the number of individuals with a college degree reporting that their job requires at least a bachelor's-degree level of expertise in S&E increased 28%, from 12.9 million to 16.5 million. National Science Board, *Science and Engineering Indicators 2014* (Arlington, VA: National Science Board, 2014), 3-5.

[8] Categorized using the Bureau of Labor Statistics' Standard Occupational Classification (SOC) system.

[9] Jonathan Rothwell, "The Hidden STEM Economy," (Washington, DC: Brookings Institution, 2013). Retrieved from: http://www.brookings.edu/research/reports/2013/06/10-stem-economy-rothwell;

Executive Office of the President, "President's Council of Advisors on Science and Technology (PCAST) Memo of September 2014," (Washington, DC: Executive Office of the President, 2014). Retrieved from: http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_workforce_edit_report_sept_2014.pdf.

10 Rothwell, "The Hidden STEM Economy."

11 PCAST memo of September 2014.

12 PCAST memo of September 2014.

13 *Indicators 2014,* 3-15.

14 Rothwell, "The Hidden STEM Economy."

15 Rothwell, "The Hidden STEM Economy."

16 Anthony Carnevale cited in "Where the Jobs Are: The New Blue Collar," *USA Today*, 30 September 2014. Retrieved from: http://www.usatoday.com/story/news/nation/2014/09/30/job-economy-middle-skill-growth-wage-blue-collar/14797413/.

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39 NSF identifies 11 different "computer and information scientist" occupations: computer and information scientists—research, computer network architect, computer support specialists, computer system analysts, database administrators, information security analysts, network and computer systems administrators, software developers—applications and systems software, web developers, other CS occupations, and computer engineers—software. See *Indicators 2014*, Appendix Table 3-3.

40 R&D jobs tend to be heavily concentrated geographically, with the vast majority of R&D activity and a substantial fraction of employment clustering in the top 20 metropolitan areas. A 2014 NSF report revealed that in 2011, nearly half of the R&D performed by companies in the United States occurred in just five states: California, Washington, Texas, Massachusetts, and Michigan. Even within these R&D intensive states, R&D work is not evenly distributed statewide with clusters appearing in metropolitan regions like Silicon Valley, Sea-Tac, and the Route 128 corridor. By contrast, employment opportunities for technical STEM workers tend to be much more geographically dispersed. Raymond Wolfe and Brandon Shackelford, "2011 Data Show U.S. Business R&D Highly Concentrated by State and Metropolitan Location," (Arlington, VA: National Center for Science and Engineering Statistics, 2014). Retrieved from: http://www.nsf.gov/statistics/infbrief/nsf14315/; Rothwell, "The Hidden STEM Economy," 12-15.

41 National Science Board, "Diminishing Funding and Rising Expectations: Trends and Challenges for Public Research Universities," (Arlington, VA: National Science Board, 2012).

42 *Indicators 2014*, Appendix Table 3-4.

43 An earned degree is not the sole way of acquiring STEM knowledge and skills and creating STEM-capable workers. Certificate programs, course work, technical and vocational programs, workforce experience, and on-the-job training can all build workers' STEM knowledge and skills.

44 Carnevale et al., "STEM," 40-43.

45 In 2010, about a third of S&E degree holders worked in an occupation classified by NSF as S&E. The rest worked in occupations NSF classifies as S&E-related (14%) and non-S&E (51%). See *Indicators 2014*, Figure 3-5.

46 Giuseppe Bertola, Francine D. Blau, and Lawrence Kahn, "Comparative Analysis of Labour Market Outcomes: Lessons for the US from International Long-Run Evidence," *NBER Working Paper No. 8536*, October 2001. Retrieved from: http://www.nber.org/papers/w8526; Carnevale and Desrochers, "The Missing Middle," 25.

47 *Indicators 2014*, Figure 3-7.

48 For details on the association between degree and occupation by field for individuals with a bachelor's degree or higher in an S&E field, see *Indicators 2014*, Figure 3-6 and Appendix Table 3-3.

49 *Indicators 2014*, Table 3-5.

50 Job mobility, occupational change, and career pathways of S&E degree holders and workers are active areas of research. NCSES and the research community are exploring ways that longitudinal information from NSF's *Survey of Doctoral Recipients* (SDR) and *National Survey of College Graduates* (NSCG) can be used to understand career trajectories.

51 *Indicators 2014*, Figure 3-4. Data from the 2011 ACS show that a larger proportion of workers in S&E occupations (74%) hold a bachelor's or higher degree than workers in all other occupations (30%). Note: these data exclude postsecondary S&E teachers.

52 About half of those who earn S&E degrees in the United States take at least some of their courses through a two-year college. *Indicators 2014*, Table 2-5 and John Tsapogas, "The Role of Community Colleges in the Education of Recent Science and Engineering Graduates." (Arlington, VA: NSF Science Resource Statistics Division, 2004): Retrieved from: http://www.nsf.gov/statistics/infbrief/nsf04315/.

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scientists. *Indicators 2014*, Appendix Table 3-3.

55 *Indicators 2014*, 3-15.

56 Compounding this problem is the well-established difficulty of measuring current and predicting future workforce supply and demand. Peter Freeman and William Aspray, "The Supply of Information Technology Workers in the United States," (Washington, DC: Computing Research Association, 1999), 68; National Research Council, "Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce," (Washington, DC: National Academies Press, 2012), 40.

57 American Academy of Arts and Sciences, "The Heart of the Matter: The Humanities and the Social Sciences for a Vibrant, Competitive, and Secure Nation," (Cambridge, MA: American Academy of Arts and Sciences 2013), 9. Retrieved from http://www.humanitiescommission.org/_pdf/hss_report.pdf.

58 American Academy of Arts and Sciences, "The Heart of the Matter," 9.

59 The New York Academy of Sciences, "The Global STEM Paradox," (New York: New York Academy of Sciences, 2014), 4.

60 In 2010, the unemployment rate was 4.3% among scientists and engineers included in NSF's SESTAT surveys vs. 9.6% for all workers.

61 *Indicators 2014*, 3-28–3-30.

62 BLS reports several measures of labor utilization (see *Indicators 2014*, Table 3-12). The official unemployment rate (U3) is the percentage of people who are not working but who have looked for work in the preceding four weeks. The BLS underutilization measure (U6) includes various kinds of workers who are not employed full time but would like to be. NSF has used a similar measure to examine the underemployment of STEM workers—that is, the ratio to total employment of those who are working part-time but are seeking full-time jobs or who are working in a field outside of their degree because a job in their degree field was not available. See, for example: R. Keith Wilkinson, "For 1993, Doctoral Scientists & Engineers Report 1.6 Percent Unemployment Rate But 4.3 Percent Underemployment," (Washington, DC: NSF Science Resource Studies Division, 1995). Retrieved from: http://www.nsf.gov/statistics/databrf/sdb95307.pdf.

63 Yu Xie and Alexandra Killewald, *Is American Science in Decline?* (Cambridge, MA: Harvard University Press, 2012), 59.

64 There is variability in the rate of working involuntarily-out-of-field (IOF) based on field of highest degree and education level. On a discipline basis, engineering degree holders had the lowest IOF rates at 4.9%, followed by computer and mathematical sciences degree holders at 5.1%. The highest IOF rates were found in the biological, agricultural, and environmental sciences, at 10.1%, and social sciences, at 11.3%. IOF rates decrease with each additional degree level with doctoral degree holders substantially less likely than bachelor's degree holders to be working involuntarily out of field. *Indicators 2014*, 3-31.

65 According to a survey conducted by Deloitte and the Council on Competiveness, an innovative, high skill workforce is the most critical driver of a nation's competitiveness. Council on Competitiveness, "2013 Global Manufacturing Competitiveness Index," (New York: Deloitte Global Services Limited, 2012), ii. Retrieved from: http://www.compete.org/images/uploads/File/PDF%20Files/Council_GMCI_2012.pdf.

66 For more information, see *Indicators 2014,* 2-37–2-45.

[67] "US Lead in Science and Technology Shrinking: Emerging Economies Shifting Global S&T Landscape," NSB Press Release 14-022, February 6, 2014. Retrieved from: http://www.nsf.gov/nsb/news/news_summ.jsp?cntn_id=130380&org=NSB&from=news.

[68] *Indicators 2014*, O-5 and 6-25.

[69] Richard Freeman, "Labor Market Imbalances: Shortages, or Surpluses or Fish Stories?" (paper presented at Boston Federal Reserve Economic Conference, June 14-16, 2006). Retrieved from: http://www.pharmamanufacturing.com/assets/Media/MediaManager/JobShortages.pdf.

[70] Wan-Ying Chan and Lynn Milan, "International Mobility and Employment Characteristics among Recent Recipients of U.S. Doctorates," (Arlington, VA: National Center for Science and Engineering Statistics, 2012). Retrieved from: http://www.nsf.gov/statistics/infbrief/nsf13300/.

[71] *Indicators 2014*, Table 3-27. Among all college-educated workers in 2010, 15% were foreign born.

[72] Elizabeth Grieco, Yesenia Acosta, G. Patricia de la Cruz, Christine Gambino, Thomas Gryn, Luke Larsen, Edward Trevelyan, and Nathan Walters, "The Foreign-Born Population in 2010," (Washington, DC: U.S. Census Bureau, 2012). Retrieved from: http://www.census.gov/prod/2012pubs/acs-19.pdf; Luke Larsen, "The Foreign Born Population in the United States: 2003," (Washington, DC: U.S. Census Bureau, 2004). Retrieved from: http://www.census.gov/prod/2004pubs/p20-551.pdf.

[73] *Indicators 2014*, Table 3-29.

[74] *Indicators 2014*, 3-56–3-58.

[75] See for example: Deloitte and the Manufacturing Institute, "Boiling Point: The skills gap in U.S. manufacturing," 2011. Retrieved from: http://www.themanufacturinginstitute.org/~/media/A07730B2A798437D98501E798C2E13AA.ashx; Rothwell, "Still Searching"; and David Smith, Diego De Léon, Breck Marshall and Susan Cantrell, "Solving the Skills Paradox: Seven Ways to Close Your Critical Skills Gaps," (Accenture, 2012). Retrieved from: http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Solving-the-Skills-Paradox.pdf.

[76] Rothwell, "Still Searching"; Boston Consulting Group Press Release, "Skills Gap in U.S. Manufacturing is Less Pervasive Than Many Believe," 15 October 2012. Retrieved from: http://www.bcg.com/media/PressReleaseDetails.aspx?id=tcm:12-118945.

A study conducted by The Manufacturing Institute in 2011 asked manufacturing industries to identify the most serious skill deficiencies in current employees. Respondents identified "Inadequate problem-solving skills" (52%), lack of basic technical training (43%), and inadequate basic employability skills (e.g., attendance timeliness, work ethic; 40%) as the top skill deficiencies. Deloitte and the Manufacturing Institute, "Boiling Point."

[77] In "Still Searching," Rothwell examined job vacancy data nationwide and concluded that the relative value of, demand for, and scarcity of STEM skills varies depending on the particular skill. He also found that the length of time it takes to fill a job vacancy varies based on the regional supply of workers in a given occupation. Regions with lower unemployment took longer to fill a STEM job vacancy compared to areas with higher unemployment.

[78] Peter Cappelli, "What Employers Really Want? Workers They Don't Have to Train," *Washington Post*, 5 September 2014. Retrieved from: http://www.washingtonpost.com/blogs/on-leadership/wp/2014/09/05/what-employers-really-want-workers-they-dont-have-to-train/.

[79] Skrentny and Lewis, "Building the Innovation Economy?" 6.

[80] Simon Field, Kathrin Hoeckel, Viktória Kis and Malgorzata Kuczera, "Learning for Jobs OECD Reviews of Vocational Education and Training," (OECD, 2009). Retrieved from: http://www.oecd.org/edu/skills-beyond-school/43926141.pdf; Cappelli, "Skills Gaps, Skills Shortages, and Skills Mismatch," 47.

[81] The unemployment rate for biomedical PhDs was around 2% in 1993 and 2010, and the rate of working involuntarily out of field was around 3% in both periods. *Indicators 2014*, 3-39.

[82] "The Disposable Academic," *The Economist,* 16 December 2010. Retrieved from: http://www.economist.com/node/17723223; Bruce Alberts, Marc Kirschner, Shirley Tilghman, and Harold Varmus, "Rescuing US Biomedical Research from its Systemic Flaws," *Proceedings of the National Academy of Sciences of the United States of America* 111, no. 16 (2014): 5773-5777. Retrieved from: http://www.pnas.org/content/111/16/5773.full.pdf+html; Jordan Weissman, "The Ph.D Bust: America's Awful Market for Young Scientists – in 7 Charts," *The Atlantic*, 20 February 2013. Retrieved from: http://www.theatlantic.com/business/archive/2013/02/the-phd-bust-americas-awful-market-for-young-scientists-in-7-charts/273339/; National Institutes of Health, "Biomedical Research Workforce Working Group Report," (Bethesda, MD: NIH, 2012). Retrieved from: http://acd.od.nih.gov/Biomedical_research_wgreport.pdf. An Internet search of "biomedical PhD glut" produces over 10,000 results ranging from government reports to articles in leading scientific and mainstream media publications to blog posts.

[83] "Biomedical Research Workforce Working Group Report," 15.

[84] As explained in the Biomedical Research Workforce Working Group Report, the one-year budget appropriations process means that future NIH funding is very difficult to anticipate and is subject to "booms" and "busts." Demographer Michael Teitelbaum also explored this idea in *Falling Behind*, 206-216.

[85] *Indicators 2014*, 3-39.

[86] Teitelbaum, Falling Behind, 63-68; Mauricio Gomez Diaz, Navid Ghaffarzadegan, and Richard Larson, "Unintended Effects of Changes in NIH Appropriations: Challenges for Biomedical Research Workforce Development," July 2012. Retrieved from: http://iseenetsim.net/community/connector/Zine/2012_Summer/UnintendedEffectsofChanges.pdf.

[87] *Indicators 2014*, Figure 5-12.

[88] *Indicators 2014,* Figure 5-9.

[89] See *Indicators 2014,* Figure 5-18 for employment by individuals with a doctoral degree in science, engineering, or health in academic postdoctoral positions between 1973 and 2010. *See Indicators 2014,* Table 5-19 for reasons for accepting a postdoctoral appointment in 2008 and 2010.

[90] In 1980, about 18% of NIH R01 grant recipients were 36 years of age or younger; in 2010 that number was 3%. "Biomedical Research Workforce Working Group Report," 29.

[91] For NSF, see the "Report to the National Science Board on the National Science Foundation's Merit Review Process, Fiscal Year 2013. Retrieved from: http://www.nsf.gov/pubs/2014/nsb1432/nsb1432.pdf; For NIH, see: NIH Research Portfolio Online Reporting Tools website. Retrieved from: http://report.nih.gov/NIHDatabook/Charts/Default.aspx?showm=Y&chartId=275&catId=2.

[92] For example, see: American Chemical Society, "Advancing Graduate Education in the Chemical Sciences," (Washington, DC: American Chemical Society, 2012). Retrieved from: http://www.acs.org/content/dam/acsorg/about/governance/acs-commission-on-graduate-education-summary-report.pdf; Council of Graduate Schools, "Pathways through Graduate School and Into Careers," (Washington, DC: Council of Graduate Schools, 2012). Retrieved from: http://pathwaysreport.org/; Anita Jones, "The Explosive Growth of Postdocs in Computer Science," *Communications of the ACM 56*, no. 2 (February 2013): 37-39. Retrieved from: http://cacm.acm.org/magazines/2013/2/160156-the-explosive-growth-of-postdocs-in-computer-science/fulltext.

[93] See Professional Science Master's at http://www.sciencemasters.com. Professional Science Master's programs consist of two years of academic training in an emerging or interdisciplinary area, along with a professional component that may include internships and "cross-training" in workplace skills, such as business, communications, and regulatory affairs.

[94] For examples, see the Biotechnology and Biological Sciences Research Council Collaborate Awards in Science and Engineering (http://www.bbsrc.ac.uk/business/training/training-index.aspx) and the European Industrial Doctorate program (http://ec.europa.eu/research/sme-techweb/pdf/european_industrial_doctorates.pdf).

[95] American Chemical Society, "Advancing Graduate Education in the Chemical Sciences," (Washington, DC: American Chemical Society, 2012) Retrieved from: http://www.acs.org/content/dam/acsorg/about/governance/acs-commission-on-graduate-education-summary-report.pdf.

[96] National Research Council, "Research Universities and the Future of America: Ten Breakthrough Actions Vital to Our Nation's Prosperity and Security," (Washington, DC: National Academies, 2012). Retrieved from: http://www.nap.edu/catalog/13299/research-universities-and-the-future-of-america-ten-breakthrough-actions.

[97] Anita Jones, "The Explosive Growth of Postdocs in Computer Science," *Communications of the ACM 56*, no. 2 (February 2013): 37-39. Retrieved from: http://cacm.acm.org/magazines/2013/2/160156-the-explosive-growth-of-postdocs-in-computer-science/fulltext.

[98] These developments include changing demographics (described in the report text), increasing foreign student mobility, and growing global competition in R&D and higher education.

[99] Based on a projection. National Center for Education Statistics, "Projections of Education Statistics to 2022" (Washington, DC: U.S. Department of Education, 2014). Retrieved from: http://nces.ed.gov/pubs2014/2014051.pdf.

[100] *Indicators 2014*, 3-49–3-51.

[101] The National Academies, "Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering," (Washington, DC: National Academy of Science, 2006), 51-52.

[102] Lori Turk-Bicakci, Andrea Berger, and Clarisse Haxton, "The Nonacademic Careers of STEM PhD Holders," (Washington, DC: American Institutes for Research, April 2014). Retrieved from: http://www.air.org/sites/default/files/downloads/report/STEM%20nonacademic%20careers%2 April14.pdf.

[103] Bicakci, Berger, and Haxton, "The Nonacademic Careers of STEM PhD Holders."

[104] *Indicators 2014*, 1-12.

[105] Non-school factors include family characteristics such as primary home language and parenting style, personality traits, health-related factors, and neighborhood characteristics, such as the unemployment rate, concentration of poverty, and incidence of violence. Jeffrey Henig and S. Paul Reville, "Why Attention Will Return to Nonschool Factors," *Education Week*, 23 May 2011; *Indicators 2014*, 1-13.

[106] Catherine Hill, Christianne Corbett, and Andresse St. Rose "Why So Few? Women in Science, Technology, Engineering, and Mathematics," (Washington, DC: AAUW, 2010). Retrieved from: http://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf.

[107] Hill, Corbett, and St. Rose, "Why So Few?" 2010.

[108] National Academies, "Expanding Underrepresented Minority Participation," (Washington, DC: National Academies Press, 2011). Retrieved from: https://grants.nih.gov/training/minority_participation.pdf.

[109] For an example of activities to support the entry of individuals, including veterans, with disabilities into STEM see the work of KC-BANCS at http://www.kcstemalliance.org/about.

[110] Billy Mitchell, "OPM targets vets for Federal STEM jobs," *Feds Hire Vets*, 4 November 2014. Retrieved from: http://www.fedshirevets.gov/BLOG/FHVNews/2014/11/6/OPM-targets-vets-for-Federal-STEM-jobs/.

[111] Anthony Carnevale, Tamara Jayasundera, and Andrew Hanson, "Career and Technical Education: Five Ways That Pay Along the Way to the B.A." (Washington, DC: Georgetown University Center on Education and the Workforce, 2012). Retrieved from: https://georgetown.app.box.com/s/jd4r0nwvjtq12g1olx8v.

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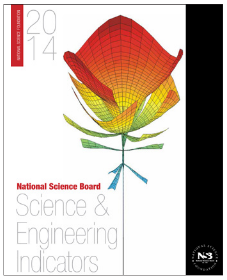

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