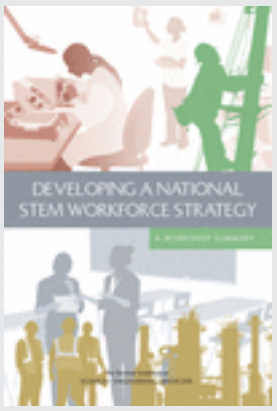

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DETAILS

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DEVELOPING A NATIONAL STEM WORKFORCE STRATEGY

A WORKSHOP SUMMARY

Joe Alper, *Rapporteur*

Board on Higher Education and Workforce

Policy and Global Affairs Division

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

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The committee thanks the National Science Foundation (NSF) for its support of this summit and for the many experts within NSF with whom it met in the course of planning the summit, each of whom provided valuable insights and ideas in shaping the project.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies of Sciences, Engineering, and Medicine's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Daniel Atkins, University of Michigan; Scott Ellsworth, Business Leaders United for Workforce Partnerships; Richard Freeman, Harvard University; Melvin Greer, Lockheed Martin; Peter Henderson, University of Maryland, Baltimore County; and William Rudman, AHIMA Foundation.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. The review of this report was overseen by Marigold Linton, University of Kansas. Appointed by the Academies, she was responsible for making certain that an independent examination of this report was carried out in accordance

with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the rapporteur and the institution.

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Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
AHIMA	American Health Information Management Association
ALL	Adult Literacy and Lifeskills Survey
APS	American Physical Society
ASVAB	Armed Services Vocational Aptitude Battery
CGS	Council of Graduate Schools
CRO	clinical research organization
ED	U.S. Department of Education
ETS	Educational Testing Service
EXITE	Exploring Interests in Technology and Engineering
IT	information technology
K-12	kindergarten through 12th grade
MIT	Massachusetts Institute of Technology
MOOC	massive open online course
MOORP	massive open online research project
NAEP	National Assessment of Education Progress
NCI	National Cancer Institute
NIH	National Institutes of Health

NSA	National Security Agency
NSB	National Science Board
NSF	National Science Foundation
NSF-EHR	NSF's Directorate on Education and Human Resources
OECD	Organization for Economic Cooperation and Development
PIAAC	Program for the International Assessment of Adult Competencies
R&D	research and development
RSS	Rich Site Summary
S&E	science and engineering
STEAM	science, technology, engineering, arts, and mathematics
STEM	science, technology, engineering, and mathematics
UMBC	University of Maryland, Baltimore County

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Introduction

The future competitiveness of the United States in an increasingly interconnected global economy depends on the nation fostering a workforce with strong capabilities and skills in science, technology, engineering, and mathematics (STEM). As was stated in the landmark report *Rising Above the Gathering Storm* (NRC, 2007), the vitality of the U.S. economy is "derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, the U.S. economy will suffer and our people will face a lower standard of living." Indeed, according to a recent National Science Board (NSB) report, some 16.5 million individuals in 2010, including many in non-STEM jobs such as sales, marketing, and management, reported that their job required at least a bachelor's degree level of science and engineering expertise (National Science Board, 2015). According to Kelvin Droegemeier, NSB vice chairman, the key message of the NSB report is that STEM knowledge and skills enable both individual opportunity and national competitiveness, and that the nation needs to develop ways of ensuring access to high-quality education and training experiences for all students at all levels and for all workers at all career stages.

In the United States, the National Science Foundation (NSF) holds a primary responsibility for overseeing the federal government's efforts to foster the creation of a STEM-capable workforce. As part of its efforts to develop a strategy for developing a STEM-capable workforce for the 21st century, NSF's Directorate on Education and Human Resources (NSF-EHR)

asked the National Academies of Sciences, Engineering, and Medicine's (the Academies') Board on Higher Education and Workforce to convene a national summit, or workshop, with the following statement of task:

> An ad hoc committee will plan and convene a workshop to inform the National Science Foundation's Directorate on Education and Human Resources in its mandate to help prepare a broad and diverse U.S. Science, Technology, Engineering, and Mathematics (STEM) workforce for the 21st century. The activity will contribute to NSF-EHR's preparation of a theoretical and evidence-based STEM Workforce Development R&D Core Framework. Workshop participants will suggest refinements in the goals for the framework, discuss research themes, and identify gaps as well as emerging research opportunities related to STEM workforce development. Possible themes for discussion include STEM pathways and transition points, STEM teaching and learning, career preparation and interdisciplinary education and training. An individually authored workshop summary will be prepared by a designated rapporteur in accordance with institutional guidelines. The workshop and summary will also serve as resources to federal and state policymakers, researchers, employers, and foundations that are contributing to the development of a robust and diverse U.S. STEM workforce.

In response to this charge, the Academies brought together about 150 interested stakeholders for a 2-day workshop on September 21–22, 2015, at the Keck Center in Washington, D.C. Participants represented a broad range of STEM disciplines and topics—but the full breadth of all STEM fields was not covered. For example, data science, computation, engineering and some of the biomedical disciplines received significant attention, while environmental sciences and physics received somewhat less.

Continual changes in global networking, data accessibility, and demographics compel the nation to maintain a determined focus on the sustained development of the critically important STEM-capable workforce. In his introductory remarks to the workshop, planning committee chair Rodney Adkins, retired senior vice president for strategic partnership at IBM, set the stage for the subsequent discussions by suggesting that five trends currently drive the U.S. economy: first, networking and interconnectedness are shrinking the world geographically and technologically; second, the unprecedented growth in data drives the need for new skills in analytics and automation that will enhance efficiency and productivity; third, the "age of transparency" that we have entered, characterized by an expectation of honesty and full disclosure, compels the need for greater access to information; fourth, people not only expect access to information, they expect it in real-time—a demand that accelerates the pace of technological change; and fifth, a generational transformation arising from both an aging workforce

and the emergence of the millennial generation is shifting the dynamics of the workforce and the face of both the public and the consumer. All of these trends, he said, oblige the nation to better understand how it should focus its efforts to develop a STEM-capable workforce that meets the challenges of a fast-paced, data-intensive, globally networked world. Adkins added that in his opinion, national security is the only other topic as important to the future of the nation as is preparing a STEM-capable workforce for the 21st century.

WORKSHOP THEMES

In preparing the agenda for this workshop (see Appendix A), the planning committee developed six overarching themes:

1. Exploring new, innovative, and dynamic education and training pathways (and education providers) that lead to college and career success in STEM fields, in addition to the more traditional pathways and education/training providers
2. Understanding the "voice of the employer" and encouraging stronger college-business partnerships for more effective and sustained two-way communication between business and higher education
3. Understanding the role of K-12 education in preparing the workforce of the future, and understanding how stronger university-school partnerships can enhance STEM workforce readiness at all levels
4. Examining current and prospective developments in undergraduate and graduate education and their impact on STEM workforce readiness, including the encouragement of more hands-on, research-based learning; an increased emphasis on both interdisciplinary learning and "team science" at all levels; and the desire for more internships, apprenticeships, and traineeships for undergraduate and graduate students
5. More clearly defining what we mean by a "STEM-capable workforce," including a recognition that many so-called non-STEM careers still require some level of STEM capability or STEM savviness
6. Identifying innovative and effective ways in which federal investments in education and training can enhance STEM workforce readiness

In commenting on these six overarching themes, NSF Director France Córdova said they address some of the most central and challenging questions NSF and the nation face in developing a national strategy focused on the STEM workforce. The first theme, she said, reflects the insight that the route through the education system to STEM jobs should be thought of as pathways rather than pipelines. This observation, she noted, is the central premise in the Council of Graduate School's (CGS's) report *The Path For-*

ward: The Future of Graduate Education in the United States (Wendler et al., 2010). The NSB concurs with the perspective, stating in its report *Revisiting the STEM Workforce* (National Science Board, 2015), "STEM knowledge and skills enable multiple dynamic pathways to STEM and non-STEM occupations alike."

The second theme addresses the need to better understand the employer's voice in developing a STEM workforce. "We have little data indicating what skills employers require of new graduates entering the workforce," said Córdova, who noted that a study conducted by the Association of American Colleges and Universities found that new employees face increasingly complex demands requiring new skills (Wendler et al., 2010). "There is a clear need for communication about workforce training expectations between business and higher education, and perhaps no one cares more about this than the very students we educate—the millennials," said Córdova, citing a recent publication from the Educational Testing Service (Goodman et al., 2015).

The third theme, she explained, focuses on stronger partnerships between kindergarten through 12th grade (K-12) schools and universities. "We know there are many local models, some quite successful, and we're anxious to hear about their evaluation and assessment," said Córdova. "We want to identify those models that are widely translatable so that such programs could potentially make a broader impact.

The fourth theme, Córdova explained, advocates for a better model of learning informed by the science of learning. She noted research showing, for example, that hands-on, research-based learning is more effective in conveying STEM knowledge and capturing students' interest. "Our agency's experience in funding this research shows hands-on learning to be successful in attracting and retaining young people to STEM," she said. Still, she added, a number of questions remain unanswered. "How do we scale such experiences so that more youth can have such hands-on experiences? Are there more effective curricula to engage with them? Are there innovative classroom approaches to STEM learning that can improve retention? How do we evaluate these demonstrations and disseminate them more broadly?"

The fifth theme explores what is meant by a STEM-capable workforce. "How do we provide access to STEM teachings to develop critical thinking skills?" asked Córdova. "How do we broadly provide a level of STEM sophistication, a basic knowledge about science and its methods, to ensure an educated electorate?" She cited a quote from Steve Jobs, who when introducing the iPad 2 in 2011 said, "It is in Apple's DNA that technology alone is not enough—it's technology married with liberal arts, married with the humanities, that yields us the results that make our heart sing." This quote exemplifies the need to develop a broader curriculum that focuses

on STEM but also on its intersection with other disciplines to ensure it benefits everyone and produces an educated electorate. This goal, said Córdova, is in part the focus of the new NSF INCLUDES initiative,[1] which she explained "aims to scale our effort to broaden participation in STEM to include discoverers of all ages and backgrounds."

The sixth theme, she said in concluding her remarks, focuses on the federal investment in STEM education and aims to address the question of what the various federal agencies can do, individually and in concert, to enhance STEM education and STEM workforce readiness. The importance of this question, said Córdova, preoccupies NSF and all of the other agencies represented on the National Science and Technology Council's Committee on STEM Education. It is also, she added, a major focus of President Obama.

ORGANIZATION OF THE SUMMARY

The workshop was organized by an independent planning committee in accordance with the procedures of the National Academies of Sciences, Engineering, and Medicine. The planning committee's members were Rodney Adkins (chair), Daniel E. Atkins, Gregory Camilli, Rebecca Dernberger, Kimberly A. Green, Mary Alice McCarthy, DeRionne P. Pollard, Russell W. Rumberger, Debra W. Stewart, and Holly Zanville (see Appendix B for biographical information for all committee members). This publication summarizes the discussions that occurred throughout the workshop, and highlights the key points raised during the presentations, moderated panel discussions, breakout groups, and open discussions among the workshop participants. Chapter 2 presents an overview of the importance of STEM education and a STEM-capable workforce to the future competitiveness of the U.S. economy. Chapter 3 provides a student perspective on effective preparation for securing STEM jobs. Chapter 4 discusses some of the key challenges facing U.S. employers in high-demand fields, and Chapter 5 describes what is meant by a STEM-capable workforce. Chapter 6 recounts some examples of successful strategies for aligning higher education programs with workforce needs, and Chapter 7 describes alternative pathways and providers for preparing STEM-capable workers. Chapter 8 focuses on the role K-12 STEM education plays in laying the foundation for STEM careers. Chapter 9 summarizes the discussions that occurred in

[1] NSF INCLUDES (Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science) is a scalable, national initiative to increase the preparation, participation, advancement, and potential contributions of those who have been traditionally underserved and/or underrepresented in the STEM enterprise (Kurose, 2015).

six breakout sessions, and Chapter 10 recounts the final open discussion of priority topics, considerations for federal investments in STEM education, and questions that merit further research and analysis.

ISSUES THAT EMERGED DURING THE WORKSHOP

A number of issues and topics surfaced throughout the 2-day workshop—during remarks by speakers and panelists as well as during the breakout group discussions—including those below. While voiced by more than one participant, they do not represent a consensus of workshop participants overall.

- There is often a significant gap between the knowledge, skills, and abilities most often sought by employers (e.g., data analysis skills, problem-solving skills, creativity, and employability skills such as teamwork and interpersonal communication) and the knowledge, skills, and abilities that students bring into the workforce immediately upon graduation. To the extent that employers and colleges/universities can work together to close that gap, and create campus-based and work-based learning experiences for students that enable them to develop those skills, there may be opportunities to better prepare students to thrive in the workplace early in their careers.
- It may be that the traditional boundaries of disciplinary focus—reflected in the undergraduate "major" and the graduate area of concentration—are becoming increasingly blurred, resulting in a need for greater emphasis on interdisciplinary and transdisciplinary approaches to classroom instruction and labs. Institutions of higher education increasingly recognize the need to ensure that students have experiences in multiple disciplines and have the opportunity to work with faculty and other students across many different areas of focus and concentration. Because the workplace of the future may be characterized by an even greater "convergence" of disciplines (and by the need for more STEM-capable workers even among those not in traditional STEM careers), the undergraduate and graduate level experiences for all students increasingly need to reflect this reality as well.
- More work-based learning may be the wave of the future for giving students rich, experiential, project-based learning activities that require them to develop a wide range of knowledge, skills, and proficiencies. This includes off-campus and in a work setting (e.g., through internships or apprenticeships), via simulated learning on campus in the classroom or lab, and through extracurricular activities such as robotics competitions and "Maker" projects. Work-based learning enables students to experience the conditions that help them develop the key skills for career success—

including the aforementioned "employability skills" such as teamwork, problem solving, and communication.

- Equity and diversity were common themes throughout the workshop. While efforts to broaden access and participation in postsecondary education, particularly in STEM fields, have been a national priority for many years, large achievement and participation gaps remain. More targeted and more intensive interventions may be needed, such as programs that connect underrepresented minority and female students with industry mentors, support programs such as the Meyerhoff Scholars Program at the University of Maryland at Baltimore County (now being replicated at the University of North Carolina at Chapel Hill and the Pennsylvania State University), and experiential learning activities that give students the opportunity to build products and solve real-world problems.
- The voices of employers should be more prominent in shaping college and university STEM course and lab curricula. This is a two-way street, with the need for more STEM employers to be involved in curriculum and lab design, and the need for more students and faculty to spend time in a business or industry setting to understand the changing nature of the workforce and its implications for teaching and learning. There may be ways that federal investments can incentivize such college-university-industry collaboration.
- Alternative providers of education and training, such as online institutions and the so-called coding boot camps, play an important role in the training of the STEM workforce. It will be important to study and understand the impact of these providers and the value they bring to both national and regional efforts to improve STEM workforce education.
- While federal investments in STEM workforce development are not the *only* or perhaps even the *most important* vehicle for strengthening the STEM skills of the nation's undergraduate and graduate students, they can still be an important factor—provided they reflect current and (to the extent known) future workforce conditions and skills needs and to the extent they reach students who have the greatest need for development of those skills. NSF's Advanced Technological Education initiative, which brings students into the workplace for guided hands-on learning that can be linked back to their curricula, was cited by many as one model for the types of federal initiatives that can enhance STEM education and workforce training.

In accordance with the policies of the Academies, this report has been prepared by the workshop rapporteur as a factual summary of what occurred at the workshop. The workshop did not attempt to establish any conclusions or recommendations about needs and future directions, focusing instead on issues identified by the speakers and workshop participants. Statements, recommendations, and opinions expressed are those of indi-

vidual presenters and participants, do not necessarily represent the views of all workshop participants or the planning committee, and are not necessarily endorsed or verified by the Academies. They should not be construed as reflecting any group consensus. The planning committee's role was limited to setting the agenda and convening the workshop.

2

The STEM Workforce Landscape

To set the stage for the remainder of the day's discussions and provide background on the state of science, technology, engineering, and mathematics (STEM) education and the U.S. STEM-capable workforce, the workshop featured three formal presentations prior to the first panel discussion. Rush Holt, chief executive officer of the American Association for the Advancement of Science (AAAS), spoke about the importance of revamping the way science is taught in U.S. schools and universities to reflect advances in science education and make science more appealing to all of the U.S. population, not just science majors. Next, Kelvin Droegemeier, vice chair of the National Science Board (NSB), chair of the NSB Science and Engineering Indicators Committee, and vice president for research at the University of Oklahoma, described findings from the NSB's study on the state of the STEM workforce. Irwin Kirsch, director of the Center for Global Assessment at the Educational Testing Service (ETS), then reviewed data from the Organization for Economic Cooperation and Development (OECD) showing how U.S. adults compare to those from other countries on STEM skills.

MODELING WHAT WE TEACH

The central message of Holt's presentation was that science educators should model what they want to teach at all levels of the educational system, and he presented a list of what that modeling should include. "The first thing I would argue we want to teach, at all levels of science education, is that what we as scientists do is grounded in evidence," said Holt. "We must teach a respect for evidence, a delight in evidence, a comfort with

evidence, a facility for evaluating evidence, and a demand that everyone who talks with us about scientific matters should talk about their pursuit of evidence." That this is not currently a key focus of science education in the United States, he argued, is a significant problem with how the nation makes public policy decisions, conducts consumer affairs, and sets business practices. It also negatively affects how average Americans make decisions in their daily lives and is responsible, he said, for the lack of appreciation for the power of science to tackle important problems.

As examples of why this lack of reverence for evidence is a societal problem that should be addressed with every student at every level of education, Holt cited the fact that millions of Americans do not vaccinate their children, and millions more Americans believe this is acceptable; that there are millions of Americans who deny the evidence of climate change; and that the majority of high school biology teachers avoid teaching evolution. "There are teachers we have educated in our colleges who think they can teach biology without teaching the central organizing principle of biology," said Holt.

Another way in which we need to model what we teach, he said, is in the way education policy and curricula are developed. "Our teaching methods should be based on evidence, which means that we should honor research on teaching pedagogy in our academic departments," said Holt. He noted he recently visited a university science department with multiple tenure track positions in science education, and he hoped more departments would follow suit. If the goal is to model what we teach—evidence-based thinking—the science community should not make unsubstantiated claims about the state of affairs regarding whether there are too many or too few science majors or interdisciplinary majors. The fact is, he said, the data currently available do not support either position.

Another important thing to teach is that different perspectives are good because they lead to creativity, and having different perspectives is often essential to effective problem solving. In other words, said Holt, diversity is good, and the sooner that U.S. academia begins to model that by increasing the diversity of its faculty, the better off the nation will be. The reason to address the lack of diversity in U.S. academia, said Holt, is not because it is politically correct or humane policy, but because it is essential for the future of U.S. science. "If science is going to not just strive but succeed, we need to very quickly come to terms with the diverse population of the country and eagerly embrace diversity and build diversity in our scientific enterprise," said Holt. He noted that, in round numbers, more than 70 percent of the U.S. STEM workforce is white and that women are leaving many STEM disciplines at a disproportionate rate. Only in the biological sciences, he said, do women have a "respectable presence" in percentage terms; whereas, in the chemical,

physical, and materials sciences, women hold less than 30 percent of the jobs. "If we want to model what we want to teach, and I would hope we want to teach creativity, problem solving, and the variety of perspectives that are necessary for that, then we should be hard at work on increasing diversity," said Holt.

In addition to modeling diversity, it is also important to model inclusion by teaching science as if it is intended for everyone. Holt noted that in 1990 the AAAS published *Science for All Americans* (Rutherford and Ahlgren, 1990), which laid out principles for teaching science more effectively, and yet in the intervening quarter of a century the nation has made little progress in improving the science literacy of its citizens. As an example of how this deficit in scientific literacy manifests itself, he recounted an incident that occurred when he was a member of Congress. A still-unidentified party sent anthrax spores through the mail, and Holt's fellow members came to him to find out how big a threat this was to their safety on the assumption that since he was a scientist—Holt is a physicist who before he was elected to Congress was assistant director of the Princeton Plasma Physics Laboratory—he must know about *Bacillus anthracis*. "These very smart, very able, very diligent members of Congress were saying, 'I'm not a scientist and you are, and only scientists know science,'" said Holt, who added. "Never mind that they were asking a physicist about anthrax, but I quickly learned about it because I did not mind getting some medical journals and reading about anthrax, something that none of my colleagues, many smarter than I am, chose to do. Why not? Because they had been taught in school that science was for scientists, and that they did not need to take those Advanced Placement courses in high school, and they certainly did not need to take science courses in college." This failure to educate the public at large about science leaves the country with about 80 percent of the population not knowing "even the basic essence of science or even having the ability to ask questions that can be answered empirically and verifiably," said Holt. The lack of appreciation for the essential methods of science—that questions can be answered empirically and verifiably—means that every economic debate in the country, he noted, is based on ideology, not evidence, even though economics is in large part an empirical science, generating evidence an ordinary person should be able to evaluate and that all citizens should demand be the basis of any policy argument their elected officials make.

Today, said Holt, science is taught as a set of known facts to be memorized, "but if we want to model what we teach, science courses should be designed around what we don't know, which is the way science is done." He recounted that the late physician and science essayist Lewis Thomas once noted that too many people do not understand the high adventure that is science. "This way of asking questions so that they can be answered

empirically and verifiably is a powerful concept," said Holt. "It sets science apart from other ways of knowing the world and knowing the universe." Thomas, said Holt, called science the shrewdest maneuver to knowing how the universe works, a phrase that he said brings science down to earth, that makes science something in which any well-educated person can take part. "What we really need to teach is this shrewd maneuver, the process of science, the thrill of the chase, the beauty of the discovery process, the team approach," said Holt. Doing so, he suggested, offers the possibility of reversing the erosion in the appreciation of science and the disturbing retention number of science majors.

In summary, he said taking the attitude that the scientific community should be modeling what it teaches has implications for the composition of college and university faculty, for how materials are presented, for the target audience, and for the cost and accessibility of education. It has implications, he argued, for the disciplinary approach with which science has been taught for the past 150 years, and while there are signs of change in all of these areas, there is still a long way to go. "I'm not an expert in how you teach science, but I think I can say that we would do well if we designed programs that model what it is we want to teach our students."

REVISITING THE STEM WORKFORCE

"Much has been said about the state of the science and engineering[1] (S&E) workforce," said Droegemeier as an introduction to his presentation on the NSB's *Revisiting the STEM Workforce* report, which was released in February 2015. Yet several factors motivated NSB's decision to examine this topic anew, he explained, including a desire to bring context and nuance to the debate of whether there is a shortage or glut of STEM workers, to provide insights that could help move this debate forward, and to identify data and research gaps.

He also noted that three major factors drove NSB's thinking when it prepared this report. First, the nation's human capital is essential to its science and technology ecosystem, and the National Science Foundation (NSF) invests in people through its support of research and graduate education and its support of the development of tools for research. Second, the STEM workforce landscape is changing. At the time of NSF's founding in 1950, and even in NSB's first edition of the *Science and Engineering Indicators* in 1972, the STEM workforce was synonymous with scientists and engineers, often with advanced degrees, performing research and development

[1] The NSF defines science and engineering fields to include the life sciences, psychology, physical sciences, environmental sciences, mathematics and computer sciences, engineering, social sciences, and other sciences not classified elsewhere, including multidisciplinary fields.

in university, industry, or government laboratories. More recently, said Droegemeier, NSB has begun to recognize that STEM knowledge and skills are critical to a far more extensive portion of the U.S. workforce than in the past and that a broad range of STEM-capable workers, including individuals without a formal STEM degree, contribute to economic competitiveness and innovation.

The third major factor influencing NSB's thinking, Droegemeier explained, was that the 2014 *Indicators* report could provide a data-driven portrait of the STEM workforce that might shed light on such longstanding and seemingly intractable policy questions as the following:

- Are we producing a sufficient supply of STEM workers to meet labor demands, or is there actually a glut of STEM workers?
- Are we providing our students with the skills needed to meet occupational demands?
- Is there a "skills gap" or "mismatch"?

Droegemeier noted the report offers three major insights. The first insight is there is no consensus definition of the STEM workforce and it consists of many sub-workforces. "One reason for the vastly different analyses about the state of the STEM workforce is because the definition of a STEM worker is not consistent from article to article and report to report," he said. "For example, some common definitions of the STEM workforce exclude workers with less than a bachelor's degree, while other definitions may omit social scientists or health care workers." Most definitions of the STEM workforce, he added, are based on degree or occupational classifications, yet these can leave out those who use STEM skills in their work but who do not have a formal STEM degree or those with a STEM degree who work in a non-STEM job. He noted that depending on how the workforce is defined—whether by degree, occupation, or fields included—the size of the STEM workforce varies dramatically. For example, in 2010, there were approximately 139 million individuals in the U.S. workforce (Bureau of Labor Statistics, 2015), and among them, 5.4 million were in jobs NSF classifies as science and engineering jobs. However, 19.5 million individuals possessed a bachelor's degree or higher in a science and engineering field and 16.5 million Americans held jobs they claimed required a bachelor's degree level of science and engineering expertise (NSF, 2014). "Considering the STEM workforce through all of these lenses is especially important if we wish to understand more broadly how STEM skills are used in the workplace and how these workers contribute to innovation and national competitiveness," said Droegemeier.

NSB also found that the term "STEM workforce" obscures the heterogeneity of the workers in STEM-related jobs. What analysts call the

STEM workforce is, in fact, a mix of "sub-workforces" that Droegemeier explained can be understood by degree or education level, occupation, geography, and career stage. Each of these sub-workforces has different characteristics in terms of the demand for workers, career experiences, and the education and training that workers need throughout their career. Given those different characteristics, he said, it is clear many of the most pressing questions about the STEM workforce, however it is defined, cannot be answered by treating it as a monolith. "When NSB applied this insight to the question of whether there are too many or too few STEM workers, it became clear there was no straightforward yes or no answer," said Droegemeier. "The answer to this and many related questions about the workforce is 'it depends.' It depends on who you consider a STEM worker and which sub-workforce is being discussed."

The second insight in the NSB report is that individuals with STEM knowledge and skills do not necessarily follow a linear STEM pipeline from receipt of a STEM degree to a job in the same STEM field, nor does a STEM degree indicate that an individual will have a job in a STEM field. In fact, in the United States, STEM knowledge and skills enable career pathways to STEM and non-STEM occupations alike. "Some of us on the board were surprised to learn that only one-third of individuals with an S&E degree are employed in a job classified as S&E, and over half of these individuals are employed in jobs that are considered non-STEM using most definitions," said Droegemeier. The degree with which individuals with a STEM degree pursue career paths both in and out of STEM varies by degree level, he explained. While approximately one-third of the individuals with a science and engineering bachelor's degree work in a science and engineering job, this number increases to 51 percent for those with a master's degree in a science and engineering field and to 74 percent among those with a doctorate.

In addition to variation by degree level, there are also differences based on degree field, which he illustrated using screenshots from an interactive, online tool created by the U.S. Census Bureau that allows users to explore the relationship between college majors and occupations. The first example he showed (Figure 2-1) illustrated that many engineering degree holders, for example, do work in engineering jobs, but others are employed in computer sciences and in non-STEM fields such as education, business and financial, and even arts and entertainment. In contrast, the majority of social science degree holders follow career pathways into non-STEM jobs (Figure 2-2). These visuals, he said, highlight that STEM degrees open up careers in a range of occupations. "While in some fields the link between degree and occupation is tighter than in others, these visuals call into question the idea that an individual necessarily proceeds from a STEM degree to a job in that same STEM field," said Droegemeier. "In practice the association between

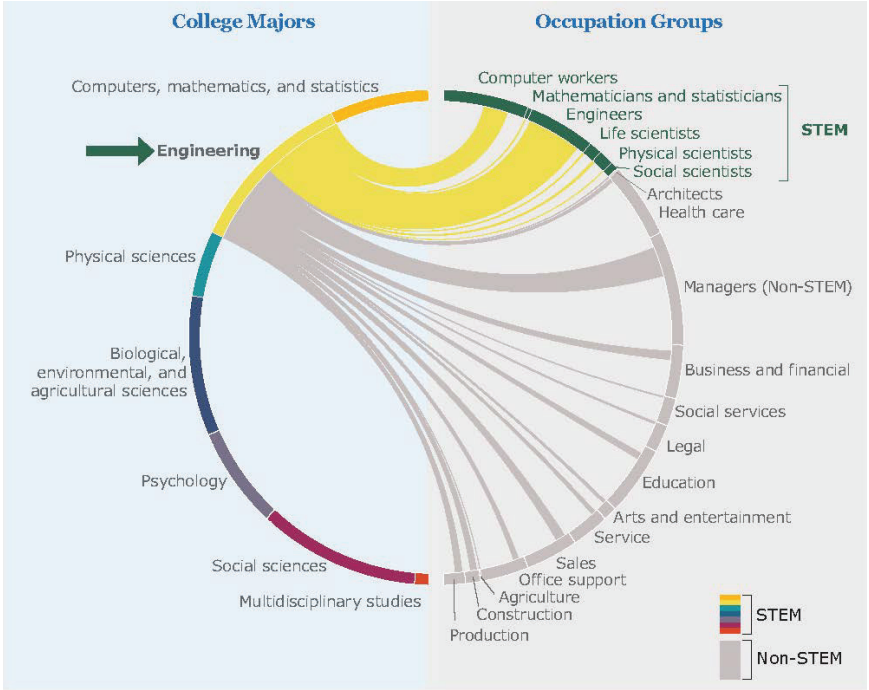

FIGURE 2-1 Career pathways from engineering degrees.
NOTE: Presented in Droegemeier slide 7.
SOURCE: Published in National Science Board, 2015; Data from U.S. Census Bureau, 2014.

degree and occupation is somewhat loose, with individuals with STEM knowledge and skills having the flexibility to embark on numerous career paths both in and out of STEM."

At the same time, these data represent a static picture of employment and do not capture the dynamic experience of workers over the course of a career and the reality that STEM jobs are changing rapidly, he noted. "The idea that one earns a STEM degree and then spends one's career in a STEM job does not reflect reality," said Droegemeier. Workers can gain experience, undergo workplace training, and engage in continuing education activities. They can also develop new competencies and knowledge areas on the job, or they may obtain another degree. Each of these actions may move workers in new directions, such as taking a non-STEM management position or starting a new company. Similarly, today's workforce destinations are not static. The rapid advancement of technology means that today's

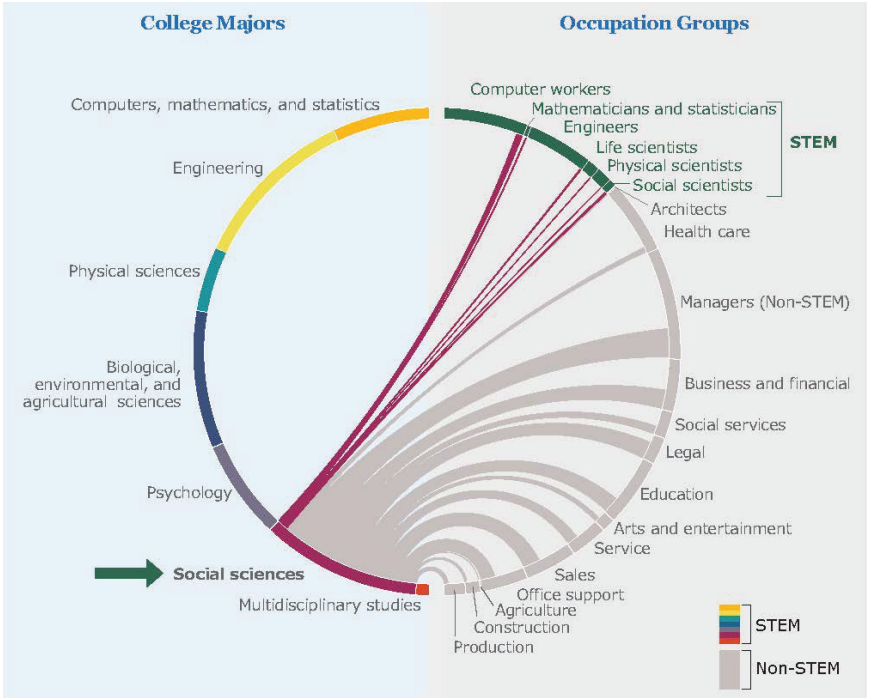

FIGURE 2-2 Career pathways from social science degrees.
NOTE: Presented in Droegemeier slide 8.
SOURCE: Published in National Science Board, 2015; Data from U.S. Census Bureau, 2014.

students may find employment in jobs and job categories that do not exist today, and the jobs they obtain will change over the course of their careers. "We need to start collecting data in ways that more accurately capture and portray this more complicated pathway scenario that we have in this country," said Droegemeier. "That was an important point for the NSB."

In his opinion, the idea of workforce pathways triggers better questions about frequently discussed workforce issues. For example, instead of asking how many degree holders in the computer sciences are needed to fill a given number of jobs, it might be better to ask what skills and capabilities do all students need to maximize their career options, or what continuing education opportunities do incumbent workers need to thrive over the course of a career amid changing workplace conditions. "This idea of pathways, that degree is not career destiny, also forces us to think about how we define success in postsecondary STEM education," said Droegemeier. "Is success

only measured by how many STEM graduates actually work in their field of degree or in STEM more generally? Or should our goal simply be to help individuals to be productive members of society and to be lifelong learners?"

The third important insight from the NSB report is that STEM knowledge and skills enable pathways leading to careers throughout the U.S. economy, which means STEM students have a range of career options. NSB, said Droegemeier, considers this to be a good thing, both for the individual who has career flexibility and for businesses that rely on having access to highly skilled workers who can adapt to rapidly evolving needs. However, this apparent flexibility also raised concerns for the NSB. "Given NSB and NSF's mission and the importance of research and development (R&D) to innovation, NSB is not agnostic to the career choices of STEM graduate students and incumbent workers with advanced degrees," said Droegemeier. "We want to attract a diversity of talented students into these critical R&D pathways, and we want them to have positive and productive experiences once they are on them. Therefore, it is important to monitor and assess the condition of workforce pathways, particularly those central to NSF's mission, and identify risks and challenges to them." Questions raised by this insight that NSB considers important include the following:

- Are undergraduate and graduate students informed about career pathways?
- Do they start out in an R&D STEM job, but then switch to a non-STEM pathway somewhere along the way, and if so, why?
- What impact do fluctuations in federal funding or structural changes within academia have on their careers?
- What other factors impact career pathways?

The NSB report also discusses roadblocks preventing some individuals from obtaining the STEM skills they will need to pursue desired career pathways in today's economy. Droegemeier said the report notes that persistent achievement gaps mean the myriad career opportunities enabled by STEM are unavailable to many of the nation's students. The report also notes that many women and underrepresented minorities who do embark on STEM studies or STEM careers encounter roadblocks that dissuade them from pursuing certain pathways or cause them to leave STEM. "STEM is for everyone and STEM skills provide empowerment for individuals," he said. "Too often, women and students of color who may be struggling with a STEM course are encouraged to drop it and switch to something 'easier,' but this is exactly the wrong advice. They need to be challenged and encouraged and not treated as if they are not smart enough to get the job done."

In summarizing the key findings of the report, Droegemeier said,

"Taken together, the report's insights show that as science and technology continue to permeate our economy, STEM knowledge and skills play an indisputable role in fostering individual opportunity and national competitiveness. They also show that workers with STEM knowledge and skills at all degree levels are employed throughout the U.S. economy and add value in different ways, and that as more jobs require STEM skills, the distinctions between STEM and non-STEM workers are blurring." These findings, he explained, led NSB to reflect on whether policymakers need to be thinking beyond a distinct and separate STEM workforce and instead be discussing what it would take to create a STEM-capable U.S. workforce. He explained that fostering such a workforce—composed of individuals with distinct career interests and aspirations who require different educational and training opportunities throughout their careers—will require government, educational institutions, and businesses to fulfill their individual and collective responsibilities to assess, enable, and strengthen career pathways for all students and incumbent workers.

While the report does not offer specific recommendations, it does emphasize the role of universities is to equip students with the generalizable knowledge and competencies necessary to learn, think critically, and embark on numerous pathways, said Droegemeier. Community colleges, career and technical education programs, and newer "business-needs-oriented" educational efforts, such as 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 their workforce and improve their competitiveness.

Regarding NSF's role in fostering a STEM-capable workforce, Droegemeier highlighted a few of its ongoing activities. The National Center for Science and Engineering Statistics, for example, is addressing limitations in the ability to assess the state of the workforce, by

- working with the federal statistical community to collect more and better longitudinal data on individuals with STEM knowledge and skills;
- collecting data on factors that influence career pathways, especially for women, underrepresented minorities, veterans, and persons with disabilities;
- expanding its coverage of certifications and other nondegree credentials that are important for technical workers and other professional occupations; and
- 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 supports STEM education research aimed at identifying core STEM competencies and enhancing STEM learning in a variety of settings and career stages.

Droegemeier concluded his remarks by noting that NSB sees this report as a starting point for a new approach to the U.S. STEM workforce. As such, NSB intends to follow up on this report with short, timely, rigorous pieces that highlight some of the central issues of the report. For example, NSB will look at what is known about career destinations for holders of STEM doctorate degrees. It also intends to introduce additional nuance to discussions about diversity in STEM by looking at the different roadblocks faced by women from underrepresented groups compared to those faced by men from underrepresented groups.

AMERICA'S MILLENNIALS AND THE FUTURE OF THE U.S. ECONOMY

The ETS report *America's Skills Challenge: Millennials and the Future* focuses on adult skills and is drawn from the Program for the International Assessment of Adult Competencies (PIAAC) survey ETS conducted under contract with OECD, said Kirsch. Unlike school-based surveys, which he explained focus on specific ages or grades of in-school students, PIAAC was designed as a household study of nationally representative samples of adults ages 16 to 65. "School-based samples are limited to what you can learn from students in the classroom, and we felt this gave us a more representative picture of the distribution of what human capital looks like in each of the participating countries," said Kirsch. "This is the first large-scale survey designed as a computer-delivered, one-on-one, in-person assessment, which allowed us to broaden what could be measured, implement computer scoring for all items, and incorporate a multistage adaptive testing algorithm."

Twenty-four countries participated in the first round of the project (Table 2-1), and the data from round one were published at the end of 2013. Data from the second round, which will be combined and compared with the data from round one, will be published in 2016, Kirsch noted. When completed, the project will have surveyed adults in 40 countries, many of which trade and compete with the United States in the global economy.

Before discussing the round one results, Kirsch described PIAAC. Its main instruments include a 30- to 40-minute background questionnaire and components that assessed reading, literacy, numeracy, and problem solving in technology-rich environments. This last assessment, he explained, could only be done on a computer. "It is important to understand that electronic information is similar to, but not identical to, printed tests, and that a paper test is a static test," he said. "If someone is given a problem to solve in an

TABLE 2-1 Countries participating in the Program for the International Assessment of Adult Competencies (PIAAC) survey

Round 1 Countries		Round 2 Countries	Round 3 Countries
Australia	Italy	Chile	Argentina (Buenos Aires)
Austria	Japan	Greece	Colombia
Belgium	Korea, Rep of	Indonesia	Ecuador
Canada	Netherlands	Israel	Hungary
Cyprus	Norway	Lithuania	Kazakhstan
Czech Republic	Poland	New Zealand	Mexico
Denmark	Russian Federation	Singapore	Peru
Estonia	Slovak Republic	Slovenia	
Finland	Spain	Turkey	
France	Sweden		
Germany	United Kingdom		
Ireland	United States		

NOTE: Remade from Kirsch slide 4.
SOURCE: Goodman et al., 2015.

electronic-based environment, they may find different information and use it differently." PIAAC data, said Kirsch, provide a better understanding of the distributions of key skills and proficiencies at both the national and the international levels. They also shed light on the extent skills translate into better opportunities for individuals and economies and help evaluate how effective a nation's education and training systems and its social and workplace practices are in developing required skills and proficiencies.

In his presentation, Kirsch focused on millennials, the respondents who were born after 1980 and who were ages 16 to 34 at the time of the survey. Millennials are important, he said, because they are the most recent products of our educational systems, and according to various reports, they have attained the most years of schooling of any previous cohort. In addition, millennials will be the labor force for the next 40 to 50 years, and as such, will shape the world's economic, political, and social landscape.

In literacy, U.S. millennials scored lower than 15 countries, with only millennials in Spain and Italy scoring lower (Figure 2-3), while on numeracy, U.S. millennials ranked last along with Spain and Italy within statistical significance (Figure 2-4). On measures of problem solving, U.S. millennials again ranked last, along with the Slovak Republic, Ireland, and Poland within statistical significance (Figure 2-5). "In none of these three areas does the United States stand out, and we should not feel good about how we do relative to other countries," said Kirsch.

He also noted that a comparison of PIAAC data with results from the U.S. Adult Literacy and Lifeskills Survey (ALL) conducted in 2003 shows

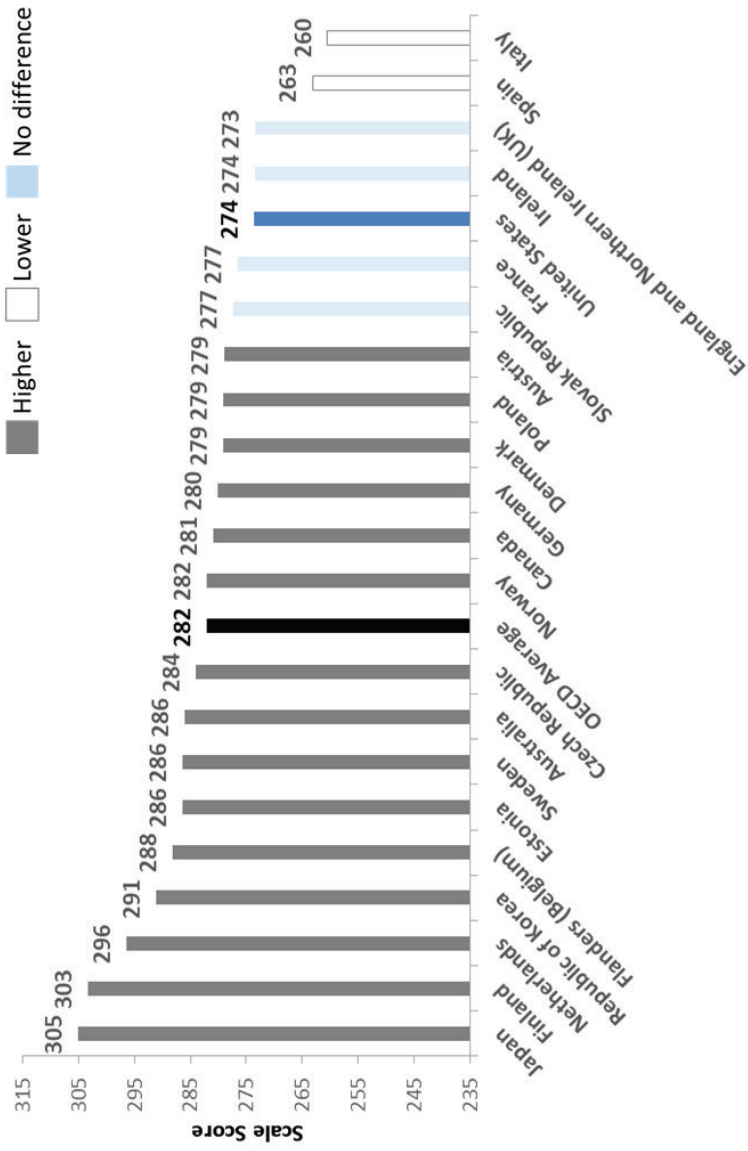

FIGURE 2-3 Program for the International Assessment of Adult Competencies (PIAAC) literacy scores, 2012.
NOTES: "No difference" denotes no statistically significant difference. Presented in Kirsch slide 8.
SOURCE: Goodman et al., 2015.

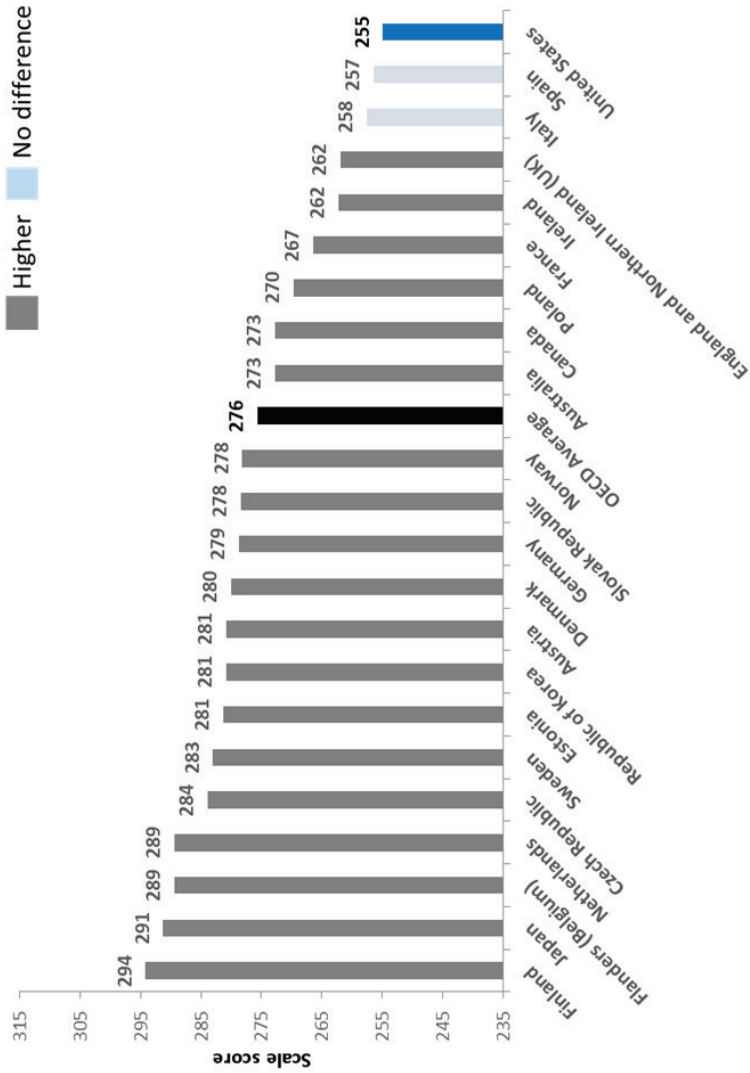

FIGURE 2-4 Program for the International Assessment of Adult Competencies (PIAAC) numeracy scores, 2012.
NOTES: "No difference" denotes no statistically significant difference. Presented in Kirsch slide 10.
SOURCE: Goodman et al., 2015.

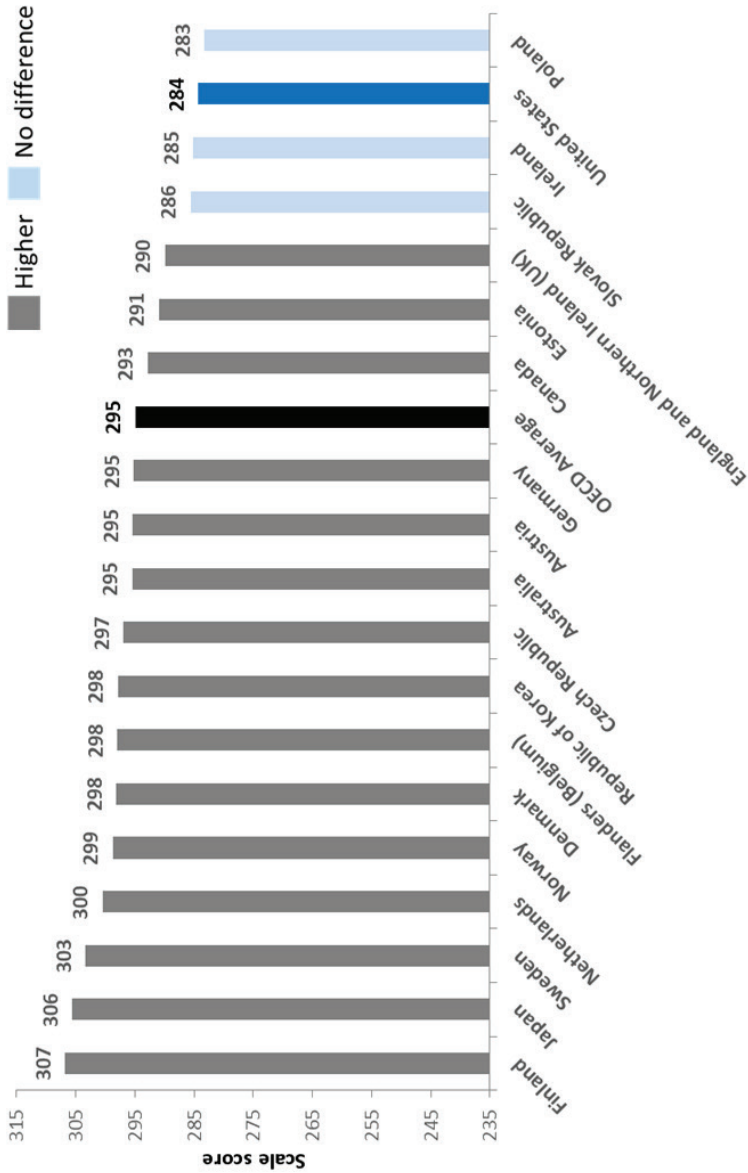

FIGURE 2-5 Program for the International Assessment of Adult Competencies (PIAAC) problem-solving scores, 2012.
NOTES: "No difference" denotes no statistically significant difference. Presented in Kirsch slide 10.
SOURCE: Goodman et al., 2015.

that U.S. millennials have attained more education in the decade since the ALL survey—more people are graduating high school and a larger percentage are going beyond high school to get some postsecondary education—but their average scores have fallen for all levels of educational attainment. Averages can be misleading, though, so he and his colleagues examined the distribution of scores on a scale of one to five, with a score of three being the level that OECD considers necessary to participate in modern society and have access to all of the benefits of society. U.S. results have also gotten worse since 2003 (Figure 2-6). "At a time when we want the distribution of American adults to shift to higher scores, meaning they are more literate, the distribution is shifting toward the less literate and less numerate," said Kirsch.

Kirsch noted that some have argued this is not necessarily a significant problem because the best U.S. millennials will still outcompete the best from other countries, so he and his colleagues looked at the data from those individuals scoring in the 90th percentile. Again, U.S. millennials did not do well, with only Spain ranking lower than the United States (Figure 2-7), with the difference between the United States, Ireland, and Italy being statistically insignificant. "Even our best are falling further behind other countries," said Kirsch. No country's millennials in the 10th percentile scored lower in numeracy than those from the United States, he added.

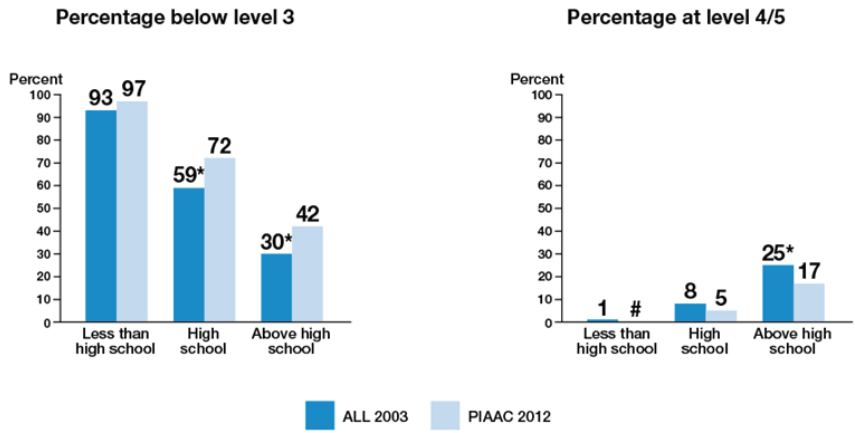

FIGURE 2-6 Comparison of the U.S. Adult Literacy and Lifeskills Survey (ALL), 2003, and the Program for the International Assessment of Adult Competencies (PIAAC), 2012, showing the percent of millennials individuals below level 3 in numeracy and at level 4/5 for different educational attainment levels.
NOTE: Presented in Kirsch slide 12.
SOURCE: Goodman et al., 2015.

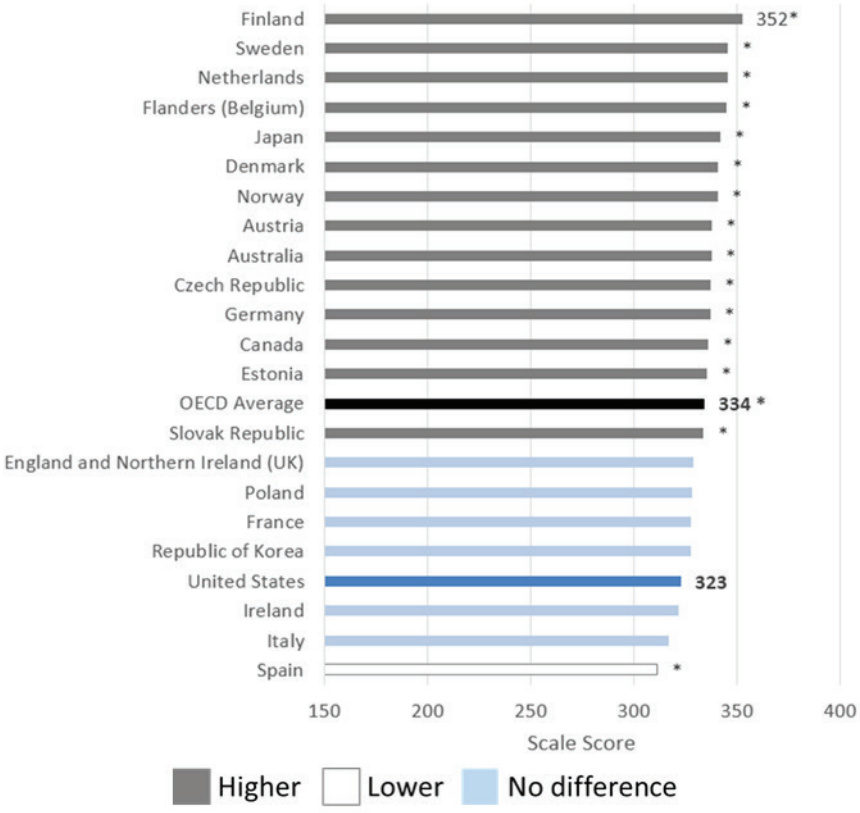

FIGURE 2-7 Program for the International Assessment of Adult Competencies (PIAAC) numeracy scores of millennials at the 90th percentile, 2012.
NOTES: "No difference" denotes no statistically significant difference. Presented in Kirsch slide 13.
SOURCE: Goodman et al., 2015.

Where the United States does rank highly is in the gap between the high and low performers. "Economists talk about inequality in income, but they also talk about inequality in education and skills," said Kirsch. "Our gap is much larger than the OECD average." He said some pundits claim U.S. performance is so low because of the impact of immigration, but excluding immigrants from the analysis still leaves U.S. millennials scoring at the bottom. "These data point to the challenges and issues we face as a nation if our goal is to develop a STEM-capable workforce prepared to compete in the 21st century global economy," said Kirsch.

Kirsch noted that some experts want to ignore international assessments because the United States is more inclusive than other countries, but data from the U.S. Department of Education's 2013 National Assessment of Education Progress (NAEP) show that more than half of U.S. students were below proficient in reading, math, and science by the time they finish fourth grade, and three-quarters of high school students score below proficient when they graduate high school (Figure 2-8). The same relative results are seen on ACT and SAT scores, where a large percentage of students score below established benchmarks for proficiency (Figure 2-9). These data, said Kirsch, argue against the notion that U.S. high school students score poorly on the NAEP because they are not motivated. In fact, he said, less than half of the students who take the ACT, who he considers to be motivated, score at or above proficient on science, math, and reading.

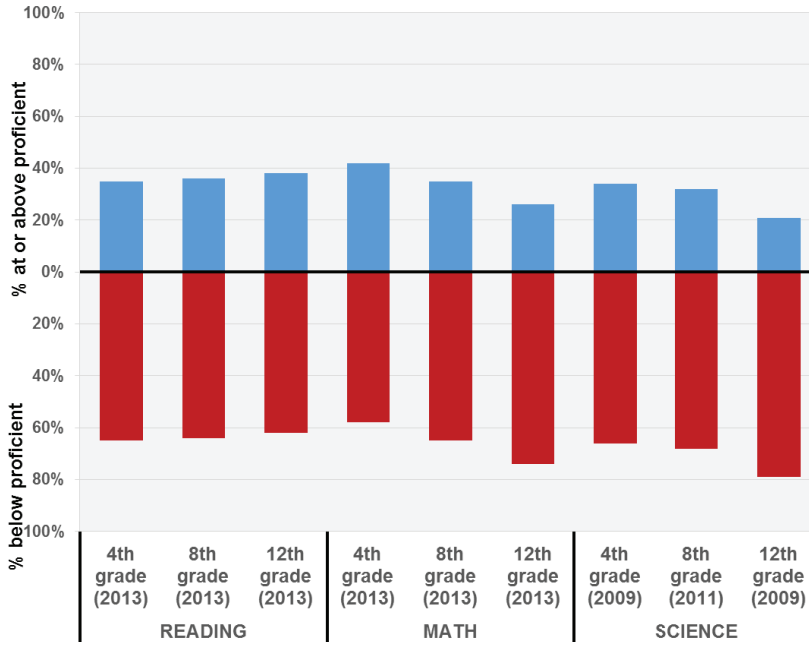

FIGURE 2-8 National Assessment of Educational Progress (NAEP) Reading, Math, and Science; 4th-, 8th-, and 12th-grade-level percentages of U.S. students "at or above" and "below" proficient.
NOTE: Presented in Kirsch slide 17.
SOURCE: Data are from U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, NAEP, accessed from the NAEP Data Explorer, September 3, 2015, by Kirsch.

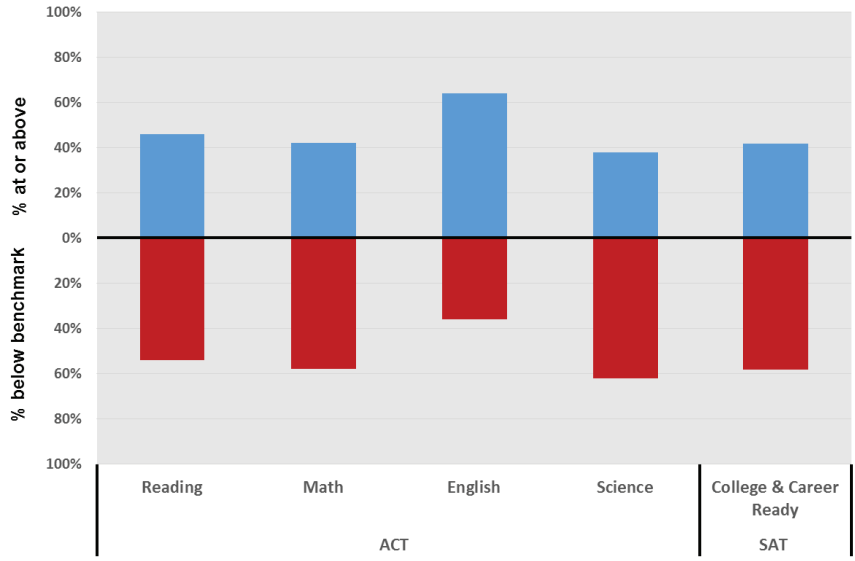

FIGURE 2-9 Percentage "at or above" and "below" established benchmarks, ACT and SAT, 2015.
NOTE: Presented in Kirsch slide 18.
SOURCES: ACT data are from: ACT. (2015). *The Conditions of College & Career Readiness 2015*. Available at https://www.act.org/research/policymakers/cccr15/index.html; accessed on January 26, 2016. SAT data are from: The College Board. (2015). *2015 College Board Program Results*. Available at https://www.collegeboard.org/program-results; accessed on January 26, 2016.

These results matter, said Kirsch, because education and skills are closely tied to earnings, employment, and other noneconomic outcomes. In fact, he said, over the past 3 decades the annual and lifetime earnings gaps of both U.S. men and women by educational attainment have widened considerably (Autor, 2014), contributing to substantial inequalities in earnings, incomes, and wealth (Figure 2-10). This growing inequality in family incomes has important consequences for the differential opportunities of children and their academic achievement, said Kirsch. "How do people participate in society with these levels of proficiency? This is not just a workforce issue," he said. He also noted that people are more likely to marry those with the same level of educational attainment, a change that has occurred over the past 3 to 4 decades and that amplifies the differences in family income and increases income inequality.

While some may doubt that this matters in the United States, the data tell a different story. "Not only do we see how these inequalities affect

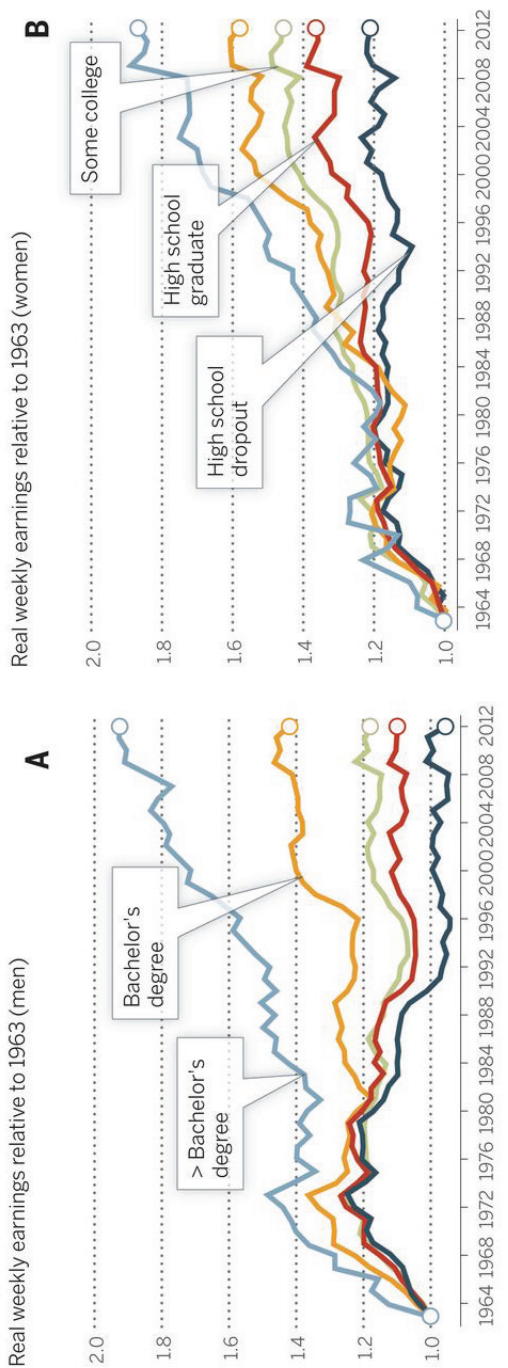

FIGURE 2-10 Changes in real wage levels of full-time U.S. workers by sex and education, 1963–2012.
NOTES: For both parts of figure, light blue indicates more than a bachelor's degree; orange, a bachelor's degree; green, some college; red, high school graduate; and dark blue, high school dropout. Presented in Kirsch slide 20.
SOURCE: Autor, 2014.

individuals and individual outcomes, and families and family outcomes, but the data are telling us this affects the transmission of opportunity to the next generation," said Kirsch. "This would be a big enough challenge to the country if it only affected the millennials. We could figure out ways to address this problem if we believed it would pass, but the data tell us just the opposite. The accumulation of advantages and disadvantages in one generation gets passed on to the next generation." To support this argument, Kirsch cited longitudinal data from an ETS colleague showing that where a student was as a teenager in 1997 in terms of family income and scores on the Armed Services Vocational Aptitude Battery (ASVAB) has a direct effect on whether they will have a bachelor's degree or higher in 2008. "Is this the America that we intend to be?" asked Kirsch.

One conclusion he draws from these data is the United States is becoming a country that is educated, but also one in which far too many students graduate without skills. "Our policies equate education and skills," said Kirsch. "Our policies are focused on keeping kids in school so they graduate high school, to get them to go to college, and to take on debt to go to college, but what the data show is far too many of these kids do not develop skills." According to the community college presidents he has spoken to, some 60 to 80 percent of students starting community college take remedial classes, so not only are they spending money on remedial classes but they are not accumulating college credits. In addition, the percentage of students who start at community colleges in remedial classes and graduate is low (Snyder and Dillow, 2011). "We have to think about our policies in terms of skills, not just credentials. It is not enough to get students to take classes if they are not acquiring skills. It is not enough to get them to sit in classes if they are not taking the courses that will develop needed skills and that we are passing them without those skills," said Kirsch. "The data show educational attainment is the single best predictor of where you go in life when you finish school, but it is your skills that take over and create much more monetary power as you progress in your time in the workforce. I would argue we need to focus on skills, not just attainment."

The enormity of the challenge the U.S. faces is twofold, Kirsch continued. On the one hand, the data show this problem is not limited to a single group or locale. "Our averages have to go up so that we have more people at the higher level and fewer people at the lower level of education so that we reduce the disparity in opportunity," said Kirsch. "But we also have to keep in mind these challenges are being driven by forces that continue to gain strength with little evidence they will pass by us on our own. Instead, they will get worse if we as a nation do not take action."

In closing, Kirsch mentioned ETS's Opportunity in America program. This program's goal is to build on the extensive literature on inequality and disparity and create a framework for moving the country forward. He

noted that, while there are many excellent programs that aim to address inequality and disparity, "the data suggest their effectiveness is attenuated because they are not stitched together in a way that maintains the growth attained in programs earlier in the development process," said Kirsch. He noted the importance of treating inequality and disparity as a systemic problem, not just one of U.S. schools not doing their job well. "Yes, schools play a critical role in educating children, but there are many programs outside of school with a big impact, and kids who come from better circumstances spend more time in these extracurricular learning environments," he explained. He also said that any successful program will have to be sustained for many years. "This problem did not develop overnight, and we will need several generations of work with clear indicators to measure progress," said Kirsch. "There is no magic bullet. The extent to which we as a nation commit to dealing with this problem will determine what we look like as a country and the quality of our democracy."

DISCUSSION

Following Kirsch's presentation, Richard Freeman, from Harvard University, claimed Kirsch underestimated the value of the data on skills. Freeman noted that PIAAC skills data relates more strongly to earnings than does education, suggesting that national efforts should focus on improving skills, not education per se, and that research should examine how students gain skills outside of the school system. He also noted that the United States is distinct among countries in the wide earnings distribution seen among people with the same exact PIAAC skill scores. Kirsch responded there is a set of skill use variables in the PIAAC dataset that looks at those who are employed and what they do in their jobs. He acknowledged that more of that type of measure needs to be included in future surveys.

Daniel Atkins, from the University of Michigan, asked Kirsch if his organization or others have looked at recent movements, such as connected learning, that try to establish more synergy between formal and informal learning settings. Kirsch replied he did not know of any efforts along those lines. He added there are conversations at ETS about devoting some of its research agenda to understanding these less formal educational environments given the recognition that informal educational venues are going to be important going forward. Kirsch noted it used to be true that when the U.S. economy recovered from downturns, people who had lost their jobs during those downturns returned to the same jobs. Those days are gone, he said, and the nation needs to think seriously about how to retrain those workers so they can fill the new jobs requiring new skill sets being created. He worries that online education and retraining assumes there is a baseline level of skills. "As we think about making all of these online courses available, we need to ensure we don't increase the gap because those individuals

with skills will get more and those who do not could fall further behind," said Kirsch.

Stephanie Teasley, from the University of Michigan, shared Kirsch's concern about growing inequality, but said the field should exercise caution about using standardized test scores as the means by which inequality is measured. "Poor kids who do not test well do not go on to college, but rich kids who do not test well can afford to get training to test better," said Teasley. "In fact, many colleges are going to test-optional admissions procedures to reflect the fact that these tests are inherently discriminatory. As we talk about skills and pathways, I think we need to be careful because standardized tests have been a major driver of pipelines." Kirsch, acknowledging that her point was well taken, reiterated that PIAAC is not a school-based test, does not use multiple-choice questions, and was developed with input from many countries. "What I was trying to show was we ignore the current status of U.S. adults at our peril," he said. "We do need to look for other measures, but we should not throw them out because they are standardized tests."

Debra Stewart, former president of the Council of Graduate Schools, asked if the PIAAC data provided any insights into the robustness of American Ph.D. programs given they are generally regarded as the international gold standard. Kirsch replied that Ph.D. holders are too small of a cohort to produce meaningful data in any nationally representative sample, but said the United States continues to be the envy of the world for higher education and particularly graduate and medical education.

Ted Childs Jr., from Ted Childs, LLC, made a number of points. First, he commented on the demographic shift occurring in the United States, one that over the next 30 years will produce a country in which 200 million people, about half of the U.S. population, will be people of color. He then noted there are several major U.S. cities in which the dropout rate exceeds 50 percent, and he also pointed to data for 15-year-olds from 60 countries showing that American students are not in the top 10 in math, science, or reading. In his opinion, the nation is "flushing our black and Hispanic kids down the tubes and that our best students come from the school systems where we make our most substantial investment," and he felt that this situation is a national security issue. Kirsch said he agreed completely with Childs and added that, while demographically the country has become less segregated residentially by color, it is becoming more segregated residentially by class for whites, Hispanics, and African Americans. "All of these forces are changing the opportunities in America, and we are leaving too many children behind, not just by color," said Kirsch. "We are becoming more of a caste-based system, where circumstances of birth determine so much of your outcome, and I do not think that is a situation we want to be moving toward as a country. This has to be a national priority, for the consequences of doing nothing are not acceptable."

3

The Student and Recent Graduate Voice

In the workshop's first panel, Thomas Rudin, director of the National Academies of Sciences, Engineering, and Medicine's Board on Higher Education and Workforce, moderated a discussion with two college students and a recent Ph.D. graduate on what does and does not work in workforce preparation. "Oftentimes, we have workshops about subjects that affect students, yet we rarely hear the student voice, and so we thought it important to start our workshop today by hearing from students who are directly influenced, and will be influenced, by the policy decisions that are made at the federal, state, and institutional level and ultimately by some of the work that we are beginning today," said Rudin. The three panelists were Kenneth Gibbs, who received his Ph.D. from Stanford University and is a Cancer Research fellow at the National Cancer Institute (NCI); Camila Ballesteros, a student at Montgomery College (Maryland) pursuing a degree in information technology (IT) cybersecurity; and Abby Estabillo, a junior at the University of Maryland, College Park, majoring in electrical engineering, who transferred from Montgomery College after receiving her associate degree. Estabillo is also a part-time intern at the National Academy of Engineering working on website development.

Rudin began the discussion by asking the panelists to describe the most and least effective aspects of their preparation for a science, technology, engineering, and mathematics (STEM) career. Gibbs replied that he benefitted from having outstanding educational opportunities starting with the great public schools in North Carolina, including a statewide residential high school for math and science. From there, he was a Meyerhoff Scholar at the University of Maryland, Baltimore County (UMBC), received his

Ph.D. training at Stanford University, served as an American Association for the Advancement of Science (AAAS) Policy fellow at the National Science Foundation (NSF), and would soon be starting his full-time position as a federal STEM policy analyst after completing a postdoctoral fellowship at NCI. He noted that his parents, the first in both of their families to go to college, instilled the importance of education in him from an early age and have been supportive throughout his education. "While this is not something we can turn into policy, it is important to recognize that home factors matter," said Gibbs. He also attributed the research internships he participated in starting in high school as playing an important role both in stimulating his interest in science and in preparing him for the workforce. "If I had not worked in laboratories, I would not have liked my science classes because they were taught as a series of facts disconnected from life," said Gibbs. The financial support he received from UMBC, the National Institutes of Health, NSF, and AAAS enabled him to pursue the many opportunities he had both within and beyond the formal educational system.

With regard to what could be done better, Gibbs said career development advice and opportunities are often in short supply in the biomedical sciences. "In the biomedical sciences, there has been a great increase in the number of Ph.D.'s relative to the number of jobs, so we need to pay greater attention to what we are actually preparing people for as they go through graduate school," he said. "We need to make sure students know the skills they are developing are applicable in a wide variety of jobs beyond becoming a professor." In his case, he would not have imagined 5 years ago he would be employed as a science policy analyst even though he now recognizes he has all of the skills needed to be successful in this field.

Ballesteros, who hopes to work for the Federal Bureau of Investigation or the Central Intelligence Agency after graduating from college, said Montgomery College provided both financial and advising support she finds invaluable. Faculty members there take an active role in ensuring students get help with academic challenges—though she does well in her IT classes, she struggles with math—and providing them with career advice. Regarding her successful transition to the University of Maryland, Estabillo credited a gateway program at Montgomery College and the strong partnership between Montgomery College and the University of Maryland that prepared her for the rigor of upper-level engineering courses she takes as a college junior. She also noted the value of the career fairs the University of Maryland holds, which have provided her with the opportunity to talk with the representatives of many potential employers and practice her interview skills.

Rudin asked Estabillo about any specific challenges she has experienced as a woman in an engineering program. One challenge she is facing now

is that, as a junior, her classes are small and of the 30 or so students in class only 3 are women. "It can be intimidating when the professor asks a question," she said. "I'm afraid to raise my hand because I'm afraid to say something wrong." Ballesteros had a similar response. "Being one of the few women in a class of mostly men is intimidating, and I'm afraid of giving the wrong answer and being laughed at," said Ballesteros. Speaking from the perspective of an African American and a member of an underrepresented group, Gibbs said during college he was surrounded by women and other students of color, but that was not the case when he went to graduate school. "In a building with 600 people, I was the only black person who was not a technician, mailman, or janitor," he said. "I used to laugh there were more black presidents of the United States than there were senior faculty in the Stanford School of Medicine," he added. That type of environment sends a message about who belongs in science, said Gibbs. In the case of women, he noted, 60 percent of the Ph.D. students in the life sciences are women, but the number of women faculty hires is not representative of that fact. He did caution, though, that there are different issues for women and students of color in different STEM disciplines. "We would do well to bring a level of finesse to this discussion instead of just calling it a STEM issue," said Gibbs.

DISCUSSION

Rudin then opened the discussion to the workshop at large, and Jodi Wesemann, from the American Chemical Society, asked the panelists if they could provide advice on how to take what is a personal process and build effective programs that could provide a foundation to the individual pathways that people take to STEM careers. Gibbs said making professional development skills part of the curriculum would be a big help. While he received great training in biology during his Ph.D. program, he was not prepared to create a resume or a cover letter or to interview for jobs. Estabillo said the University of Maryland has a group that e-mails engineering students weekly about job openings and internship opportunities and provides the opportunity to engage in mock interviews. She called this program particularly helpful. Ballesteros added that she benefited from similar programs both in high school and at Montgomery College that have helped her land internships, find mentors, develop interviewing skills, and create professional resumes and cover letters. The program at Montgomery College even provides advice on how to dress for interviews, said Ballesteros. Gibbs added that at the graduate student and postdoctoral level, there need to be incentive structures to allow students to pursue professional development opportunities, such as attending workshops and securing internships outside of the laboratory. "Depending on how you are

funded, you can have more or less freedom to pursue and explore these other experiences," said Gibbs. Rudin said this is an important point that warrants further examination in the context of those whom Ph.D. programs should benefit most—the student or the professor. He also noted the emphasis all three panelists placed on the importance of early exposure to the world outside of the classroom.

Returning to the remarks Ballesteros and Estabillo made regarding being a woman in classes filled with men, Crystal Bailey, from the American Physical Society, asked them if they would comment on what drew them to their respective fields and if they encountered any resistance from family or community members to their interest in male-dominated fields. Estabillo said both her brother and sister-in-law received nursing degrees in the Philippines and her father questioned why she wanted to be an engineer when nursing seemed a more suitable career, even though, as she put it, "I am better at math than with blood." He became more supportive when he realized she could make a better living as an engineer than as a nurse. She also noted the Society of Women Engineers provides a good support system for female engineering students. Ballesteros said her father is very supportive of her career choice—she was the family's computer expert and electrical repair person from an early age—but her mother regularly voices doubts she can succeed in this field. "I do struggle with this," said Ballesteros.

Kelvin Droegemeier, from the National Science Board, followed up on this question by asking the panelists about the factors that shaped their thinking about possible STEM careers and helped them maintain their interests in STEM up to this point in their lives. Gibbs replied that his parents stressed education and his dad would make up math facts for him and his sister starting from when they were children. They also encouraged his curiosity as a child—he wanted to be a meteorologist and his mother got him books on the weather. He also had many black teachers as a child, whom he believes were "in cahoots with my parents to encourage my interest in science." Estabillo said she was always good at math, but first became interested in engineering thanks to the Academy of Engineering at her high school in Silver Spring, Maryland. "There were many girls there, which made engineering attractive to me," she said. She credited the teachers at her high school with encouraging her to pursue engineering as a career, and in particular one female teacher who was her first mentor and provided good career advice.

Ted Childs Jr., from Ted Childs, LLC, then commented that when he worked for diversity at IBM, which like many technical organizations is the epitome of a male-dominated culture, he was approached by a group of women researchers at IBM who were concerned by the lack of senior women in the research organization. A discussion about possible activities ensued, and the group came up with the idea of what became called the Exploring Interests in Technology and Engineering (EXITE) program, an

international series of 1-week summer camps for eighth grade girls run by women at IBM. The curricula for these camps are designed by IBM women scientists and engineers, who also act as the camp faculty. He recounted that one girl arrived thinking engineers only drove trains, while a camp participant in Mexico was so engaged by her EXITE experience she went home and started her own online bakery business. "In every country where IBM has these camps there is a technology gap that can be heavily influenced by encouraging young women to think about what is possible," said Childs. He added that the nation must engage young women in science as part of its national talent strategy.

Estabillo said one obstacle in her pathway to a career has been the catch-22 of companies wanting to hire interns with technical experience beyond the classroom, but it is hard to get experience without first getting an internship. Ballesteros noted the same problem. "If we want women to work in these fields, we need to introduce them to STEM at an early age and provide the opportunity to get the skills and technical experience outside of the class," said Ballesteros.

Meredith Hatch, from Achieving the Dream, Inc., asked the panelists how they get their information about career opportunities and if there was any additional information they would like to have. Ballesteros said she gets information from her counselor and mentor at Montgomery College. Her professors have also been generous with career advice, offering to provide references and informing her about opportunities for internships and financial aid. Estabillo said that a program at Montgomery College that helped her was a learning community the school formed around students taking Physics 1 and Calculus 2. Students in these classes were kept together during their time at the school and almost the entire cohort transferred together to the University of Maryland. The members of this learning community not only support one another in their studies but also act as an extended information-gathering and dissemination community.

The final question to the panel came from Melvin Greer of Lockheed Martin, who asked the panelists if they had industry mentors and to comment on what age they thought would be appropriate to find such mentors. Ballesteros said she does not have an industry mentor and wishes she did. "That would be a great connection for me and provide me with insights into what goes on in the working world. I would be more prepared once I graduate," she said. In her opinion, she thinks students should have industry mentors before entering their senior year of high school so they can have some idea of the career options before applying to college. Estabillo and Gibbs agreed the younger the better, and Gibbs said such mentors could also come from the academic research world, depending on what subjects interest a student. He also thought that near peers can be important sources of support as well.

4

Key Challenges Facing U.S. Employers in High-Demand Fields

In the workshop's second panel, moderated by Greg Camilli, professor of educational psychology at Rutgers University's Graduate School of Engineering, four panelists gave brief statements about how they viewed the challenges facing U.S. employers in high-demand fields and then fielded questions from the workshop participants. The panelists were Ted Childs Jr., founder of Ted Childs, LLC; Melvin Greer, chief senior fellow and chief strategist at Lockheed Martin Information Systems and Global Solutions; Jennifer McNelly, president of the Manufacturing Institute; and Olivia Khalili, director of the Yahoo for Good Program at Yahoo, Inc.

As an introduction to this session, Camilli recounted some of the discussion that arose among the panelists when they prepared for the workshop, beginning with defining a "high-demand" field. "We are far from a policy consensus on what constitutes high demand, and we have not as a nation effectively addressed how to reorient the funding agencies to address a global knowledge-based economy or the flow of expert science, technology, engineering, and mathematics (STEM) labor across national boundaries," said Camilli. The discussion among the panelists noted the difference in preparing a student for a world in which computational approaches underlie much of the practice of modern engineering and science and of turning out graduates with a computer science degree, but with a limited view on how to apply that degree to other STEM disciplines.

This preworkshop discussion, said Camilli, also suggested it may be useful to contextualize STEM education with regard to specific industries so that educational investment can be targeted to develop critical thinking and analytic skills that could be used broadly within a specific

industry or across specific fields determined to be high demand fields. The panelists all agreed, he added, that students need to be exposed to both theory and real-world problem solving. One concern, though, is how to better connect employers and educators to increase the opportunities for project-based learning through the combination of revamped curricula and internships, cooperative education, and apprenticeships. "What incentives are there to align education and market needs?" asked Camilli. "How should employers and educators be engaged to ensure that education and training systems are preparing students with the skills that are in demand among employers?"

In his remarks, Childs noted that China, India, Russia, and Japan are all producing more engineers than the United States is, and if this country does not figure out how to get more women and people of color to pursue STEM training and STEM-enabled jobs, the United States will not be competitive in the global economy because it will not meet future demand for STEM-capable employees. Demographic projections, he said, show why women and people of color represent such an important talent pool: by 2043, the U.S. population will be nearly 400 million people, half of whom will be people of color and slightly more than half of whom will be women (U.S. Census Bureau, 2012). To reach these untapped groups, he suggested working with organizations such as the American Indian Science and Engineering Society, Society of Women Engineers, Society of Hispanic Professional Engineers, and National Society of Black Engineers, all of which have connections with networks of colleges. He added that there are 15 historically black colleges with accredited schools of engineering, which represent 4 percent of America's engineering colleges, but deliver 30 percent of America's black and Hispanic engineering graduates.

Greer, who introduced himself as the first and only African American senior fellow in Lockheed Martin's history, explained that his company partners with more than 250 universities across the country and has relationships with some 500 K-12 schools, which gives the company a good sense of what is happening in U.S. STEM education and how that translates into producing the people the company wants to hire. He said in his position he has observed a few dynamics that are changing the type of employee the company hires. For example, a key characteristic of Lockheed Martin's workers has changed in recent years so that they are now knowledge-enabled workers who have different problem-solving skills compared with when a worker had a designated job building a specific product, such as a plane, ship, or spacecraft. He also said global competition is having a significant impact on the company and its employees. "If anyone in the world does your job cheaper than you do, they are competing with you," said Greer, which means knowledge and problem-solving skills become important differentiators.

In response to these developments, industry's approach to STEM training is no longer philanthropic, but "is purely a business decision," said Greer. "When I go to work, my bosses are asking for business metrics such as return on investment—how many people are you going to hire with a particular investment—and if you are an educator who wants us to invest in your programs, you need to talk in those terms," said Greer. In fact, one metric in his annual performance plan measures his ability to support workforce and talent acquisition through his contacts at universities. Industry today, he said, looks for people with certain skill sets as opposed to specific degrees, but finding workforce-ready students is challenging. He cited one study, for example, showing that, while 96 percent of educators believe they are delivering workforce-ready students, only 11 percent of U.S. employers believe this to be the case (Busteed, 2014). At Lockheed Martin, STEM workers are expected to have some business and social acumen in addition to STEM knowledge. "You need to understand what customers are looking for and how they are going to pay for it," said Greer. He also said that while critical thinking and problem-solving skills are important, so too is the ability to apply those skills and knowledge to a number of different fields. "If you are working in biometrics or genomics and cannot apply that knowledge to energy or health care, we probably do not have a job for you," he said.

Greer predicted that, going forward, industry will increase its investments in new delivery models in education. It will also reach out to students as early as middle school, which is when students start to identify as being interested in STEM. Lockheed Martin, he added, has identified the top 20 jobs for the next 5 years that do not exist today and is going to take that knowledge and look at how it will impact curricula and how those curricula are delivered to students.

McNelly noted that in one survey of manufacturing executives in the National Association of Manufacturers 80 percent of respondents noted that they could not find workers who have the critical thinking and technical skills modern manufacturers need to succeed in today's global economy (Giffi et al., 2015). One reason for this shortage is the failure to provide students with career coaching that paints an accurate picture of the many occupational opportunities for STEM-trained graduates. "What is great about this nation is that you get to decide what you want to be and then create the path to get there, yet the majority of career guidance exposes students to very few of the available careers," said McNelly. She noted that programs such as Fab School Labs, which reaches out to girls in middle school and establishes a virtual mentoring environment, offer one approach to inspiring students. Another reason for the shortage of skilled workers, she said, is the lack of incentives for creating more real-world experiences for students interested in STEM or for those who are in the workforce to

gain additional STEM training without having to return to academia. What is needed are ways of applying learning where knowledge is happening and instilling in students that learning is a lifetime activity requiring flexibility and adaptability for lifelong career success. Today, however, academia is incentivized to teach to a point in time ending at graduation.

Khalili also stressed the importance of mentoring and career counseling as a means of introducing students to the breadth of opportunity in STEM. Companies can play an important role here through programmatic community outreach programs. The business sector also needs to get involved in efforts to plug what is known as the leaky pipeline, referring to the large number of students who lose interest in or drop out of STEM programs.

DISCUSSION

To open the discussion, McNelly pointed out that the large majority of U.S. manufacturers are small- to medium-sized companies that not only make valuable products but also serve as a training ground for the Lockheed Martins and IBMs of the world. "The odds are high that most of the experience the big companies are hiring comes from one of our small- and medium-sized manufacturers," said McNelly. Yet when she talks to leaders at community and technical colleges, their focus is on the few big employers that will recruit large numbers of graduates rather than on the many smaller companies that may hire one or two new workers at a time. She believes community and technical colleges need to build better relationships with small- and medium-sized companies not only because in sum they represent a large employment pool but also because local smaller manufacturers can often provide opportunities for work-based learning.

Commenting on the deficit in career counseling mentioned by both McNelly and Khalili, Rebecca Vieyra, from the American Association of Physics Teachers, said teachers could play a bigger role in addressing this problem, but teacher preparation does not include industrial experience, nor does it include the type of training in business matters that Greer noted. Greer responded that companies such as Lockheed Martin are now reaching out to K-12 educators, as well as those at colleges and universities, and creating opportunities to spend summers in industrial settings. Lockheed Martin's externship program, for example, enables teachers to spend a month in the company's laboratories to learn about the kind of metrics, processes, and tools it uses. This program has been a big success for the company in both influencing curricula and increasing the pool of well-trained workers from which it hires. Childs said such externship programs need to include more faculty from campuses that serve minority students so that they can better understand what their students will experience when they get into the workplace.

The National Association of Manufacturers, said McNelly, sponsors Manufacturing Day in early October. Manufacturers around the country open their doors and invite teachers, students, parents, and policy makers to learn about employment and career opportunities. She also said the National Association of Manufacturers is counseling employers on how to better use tuition reimbursement plans so that employees can be more purposeful in using these programs, which nearly all manufacturers now offer, to build career-enhancing skills.

Lida Beninson, an American Association for the Advancement of Science Science and Technology Policy fellow working at the National Science Foundation, said she was concerned there were not enough opportunities to reach every student who would benefit from such programs. "When I hear about summer camps and externships, I worry about all of the people who will not have access to these programs," said Beninson. McNelly suggested that while access to summer camp and externship programs is something that needs to be addressed, the real issue is why the nation has largely relegated project-based learning to summer camps and externships when research shows that mainstream STEM education should be delivered using project-based learning. Changing the way STEM education takes place is an area in which corporate America should exercise its influence, she said. Childs agreed, noting that companies are getting involved in education reform and training because they realize the talent they need tomorrow will not be there if the status quo holds. He also called upon the STEM education community to work with business to do everything possible to be the stimulant for all children to want to know more about STEM subjects. "We need to get these children motivated to want to be part of the STEM world," said Childs, who again pointed out that this is both an economic and a national security issue.

Dale Allen, from Quinsigamond Community College in Worcester, Massachusetts, reiterated the need to extend industry outreach efforts beyond the 4-year colleges that have been the focus of most programs, given that half of the nation's postsecondary school students, and an even bigger percentage of underrepresented populations, are enrolled at community colleges. He also called for the nation to increase its support of training programs at community and technical colleges so these institutions can produce the STEM-competent students that employers can then train to meet their specific needs. Greer agreed there need to be more outreach programs, but he also noted that academics across all of higher education need to do a better job of showing industry that what they are doing aligns with industry's needs. "It is unrealistic to expect someone in industry to be clairvoyant enough to figure out how to take what you are teaching your students and turn it into a workforce and talent plan," said Greer. Along those lines, Childs recounted how Freeman Hrabowski, from the University

of Maryland, Baltimore County (UMBC), suggested to the president of Boston Scientific Corporation that he invite the deans of the black engineering schools to spend the day at the company. The result was that 15 students from those departments were offered internships at the company and all 15 were invited back for the following summer. Hrabowski said his efforts to inform the National Security Agency (NSA) about how its programs were relevant to NSA's mission were a factor in the agency hiring many UMBC graduates.

Crystal Bailey, from the American Physical Society (APS), said she has found that a surprising number of academic physics departments are interested in including the types of educational elements that she has heard panelists say are important. APS has a program, Innovation in Entrepreneurship Education, that includes creating makerspaces,[1] increasing the amount of experiential learning, and relating learning to business concepts, and she encouraged any company with ideas on how to improve this program to contact her. Greer recounted how the mission to send a spacecraft to Pluto had such a large ripple effect through the physics, geoscience, and space exploration departments of every one of its academic partners. "They started to see a real application to the subjects they are teaching," he said, adding that the ripple effect included identifying a host of new projects relevant to the company's businesses. Greer also noted that he has seen the same thing with additive manufacturing and three-dimensional printing. "That is a technology that we can start incorporating into our curriculum to excite students," said Greer.

Camilli suggested the academic teams excited about Pluto might also start thinking about generalizing that interest to include searching for aquifers on Earth to benefit those who live in areas short of freshwater supplies. Greer then provided an anecdote about a 10th-grade student who was doing a research project on calderas and asked Lockheed Martin if she could access the data on calderas that the company had from its Mars programs. This young woman, who was quadriplegic, understood how to take an abstract idea, tie it to a specific industry target, and develop a fruitful research program. Not only did this result in a publication for this young woman, but it also netted her a job at Lockheed Martin when she completed her engineering degree.

Khalili commented that social media could play a role in increasing interest in STEM and awareness of STEM-related occupations. She noted, for example, there was a significant rise in the number of males enrolled in computer science classes the year after the release of the movie *The Social Network*, which depicted the phenomenal rise of Mark Zuckerberg, the

[1] A makerspace is a physical location where individuals can gather to share resources, tools, and knowledge to create, invent, and learn.

founder of Facebook. "How do we use the media to reverse the trend of women and minorities losing interest in STEM fields and to counteract the stereotypic message that they do not have the ability to compete in these fields?" she asked. Greer wondered if some of the new technologies, such as Siri (Speech Interpretation and Recognition Interface) and others, can be used to provide at least a cursory level of virtual assistance and mentoring to reach underrepresented groups of students. He said that while nothing can replace human interactions when it comes to mentoring and career coaching, the need to reach a broader audience will require new delivery methods of career information.

Khalili then commented on the recent announcement from the mayor of New York that all of the city's public schools will be required to teach computer science and the similar measures that Chicago and San Francisco are taking. "That is fabulous, but who is going to be teaching all of these computer science classes and how do we incentivize people to go into low-paying teaching jobs when they can go to Lockheed Martin, IBM, and Yahoo and make more money?" she asked. One possibility, she suggested, would be for companies to develop programs for their employees to work with local schools and for organizations such as Teach for America to increase the focus on STEM. Yahoo, for example, has an internship program that takes new college graduates, places them in programs to train teachers about computer science, and then brings them into the company workforce. Debt forgiveness could also serve as a powerful incentive to draw STEM-trained students into the education workforce.

Roy Swift, from Workcred, said he firmly believes the conversation should be more about learning than education. He noted that research shows that there is a return on investment from corporate efforts to facilitate continual learning among employees (Mallon et al., 2012; Brown and Duguid, 1991; Eurich, 1985), something companies are starting to embrace. On the other hand, he said, the education community has been reductionistic about how learning occurs, and these two factors combine to contribute to the problem. "How do we open industry more to talk about learning and continued competency of its own employees?" asked Swift. Sarah Simmons, from the Howard Hughes Medical Institute, turned this problem around and said educational institutions need to think about what skills their degrees confer and not just about education as a form of credentialing. "Can we talk about how to balance the need for institutions to be more responsive to industry's needs and still provide students with an education that enables them to be lifelong learners?" asked Simmons.

Greer responded that degrees are just outcomes, and today Lockheed Martin looks more for a specific type of individual, one who shows academic curiosity, critical thinking skills, business acumen, and an entrepreneurial mindset. McNelly added that the manufacturers she works with

need employees with a set of core competencies, so she has worked with programs to embed certifications of competency in the overall academic pathway. "The challenge is to take needed technical knowledge, map it into an academic pathway, and then surround it with all the other skills we've talked about today so that employers do not have to take students to square one when they hire them," said McNelly.

5

Maintaining Student Interest in STEM

Over lunch, the workshop featured a keynote address from Freeman Hrabowski, who has been president of the University of Maryland, Baltimore County (UMBC) for 23 years. He began his talk by recounting a conversation he had just minutes before with a young African American woman who was about to finish her Ph.D. in biochemistry. She told him she was considering taking a postdoctoral research position, but in all likelihood she would be pursuing a career in the science, technology, engineering, and mathematics (STEM) policy world. When he suggested she think about becoming a faculty member in an academic biochemistry department, she responded that she looks around in academia and does not see anyone like her in any faculty roles. That, said Hrabowski, is an important message: our bright, young students need to see a place for themselves in STEM if the goal is to get them to stay in STEM.

Many Americans, said Hrabowski, do not see themselves as being a part of the STEM workforce, either because they are afraid of STEM or are unaware or do not understand the career opportunities that exist in STEM other than those that require a Ph.D. Even those students who are in Ph.D. programs are unaware of the career opportunities that do not entail years of postdoctoral training with only a vague sense there may be a job sometime in the future. "I would say to the scientific community that we are so shortsighted if we continue to say to so many talented young people to have faith and maybe something will happen that is good for you," said Hrabowski.

He then challenged the workshop participants to start thinking that tomorrow can be different from today, that a field full of innovators should be able to think of new ways to get students excited about math and sci-

ence. As an example, he recounted how he became interested in math thanks to a professor at Tuskegee University who challenged him and the other high school students participating in a summer program sponsored by the National Science Foundation (NSF). "A professor came into the room, put a problem on the board that he said none of us could solve, and told us to come see him when we solved the problem. Everyone was upset, and yet I thought the guy was Superman. He felt that we had it in ourselves if we worked together to solve that problem, and that started me on this 40-year path," said Hrabowski.

After asking the workshop attendees to raise their hands if they love math, he said that when he asks that question of American audiences, it would be unusual if even 20 percent of the people raised their hands. One reason for this dismal response, he said, is that too many girls and children of color hear the message that math and science are not for them. "For large numbers of people in the United States, there is this notion that math and science are for the privileged few," said Hrabowski, with the result that too many students have decided by the 11th grade they are either math and science people or English and history people. "My point is we tend to be told in many ways you are either this way or that way, and we have to get away from thinking one group of children is smart and another group is not as opposed to thinking about the characteristics of people who achieve—hard work, discipline, and a belief in themselves," he said.

When he thinks about STEM in America, he continued, he thinks it is primarily an issue of attitude—that only smart people belong in STEM—and nowhere is this more of a challenge than at the university level where so-called weed-out classes do so much harm, even among well-prepared students. One of the surprising findings in the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2011 report *Expanding Underrepresented Minority Participation* (NAS-NAE-IOM, 2011), he said, was that while only 20 percent of blacks and Hispanics who started in STEM programs at 4-year institutions finished those degrees, only 32 percent of white students who started in STEM programs graduated with STEM degrees. "It was surprising to everyone because we had assumed this was a K-12 problem, but when we got to the bottom of it, we found the problem was us," said Hrabowski. Many students who did not do well in STEM courses, for example, had top scores on Advanced Placement exams, yet when they took their first quantitative courses and did not get an A or a B grade, they switched to fields in which they could get top grades. "Often, the best-prepared students start off in STEM and they become great lawyers," he said.

He then posed the question that, if even high-achieving students have bad experiences in university STEM courses, why is it a surprise when as adults they do not support STEM funding? In fact, he added, what he sees

in the faces of successful adults in their thirties, forties, and fifties when he asks if they started college as STEM majors but graduated in other majors is a look of embarrassment, guilt, and pain. His suggestion to remedy this situation is for NSF and other federal agencies to rethink how STEM is taught at the undergraduate level. "That is not to say we do not want to continue to strengthen K-12, but I am saying that if even the students who have done well in K-12 do not do well in the first year or two of work in college, this is a place we can increase the number of students who major in STEM. Even if they decide not to have a degree in STEM, at least make sure they have a positive experience and leave STEM not feeling they were a failure," said Hrabowski. What universities need to consider, he said, is the kind of knowledge all students, not just those interested in STEM majors, need to get from STEM courses. As suggested earlier, first-year courses could focus on having students work in groups, gain an appreciation for the larger context of the particular subject at hand, develop the ability to translate knowledge into marketable ideas, and even build emotional intelligence, something often lacking in first-year college students.

Regarding the STEM workforce, Hrabowski made several points. First, the number of STEM jobs will grow faster than the overall U.S. economy. Second, while those jobs will require some level of postsecondary school training, most will not need a Ph.D., and many will not require a bachelor's degree. He noted that he is a strong believer in the value of 2-year colleges and the programs they offer for those students who want STEM jobs, but added the STEM community needs to do a better job marketing those opportunities. As an example, he said Montgomery College has a superb 2-year biotechnology program, but there are few students of color enrolled in that program. "Why?" he asked. "Because families do not know about these opportunities." From his experience talking to high school students and their families, he believes that counseling departments need to stop telling students that the only option they have if they are of worth is to get a 4-year college degree.

Ten years ago, he admitted, he too believed everybody needed a 4-year degree, but after studying the opportunities available to students of differing backgrounds, he changed his point of view. While he heads a research university, he now believes there are different routes for people to take to careers that can change over their lifetimes. Today, he said, there are more than 100 companies working on his campus, and he has been fascinated that they have been able to reach out to young students of color and give them the opportunity to work in laboratories, to take courses at community colleges, and to nurture the idea that, one day, as these young workers become more mature and as they develop the skills they need to succeed, they can then have other opportunities to advance their education and their careers.

He noted, for example, that 54 percent of the STEM jobs that will be available in Maryland over the next few years will be for computer technicians, programmers, and scientists of varying levels of education and training. "We have to educate counselors, families, and communities about these opportunities and change the mindset that all students need one type of degree, and that a degree is limited to people who are 'smart.' We have to get away from this idea of smart," said Hrabowski. In his mind, what counts more than smart is grit or hard work. "On my campus, we say we are the House of Grit," said Hrabowski, "and if you want to talk about who is successful, it is the grit they have that makes the difference. It is those notions of grit, the intensity of curiosity, and persistence we should be talking about rather than smart."

Years ago, he said, he had the opportunity to be part of a trilateral study involving the United States, Germany, and Japan, and he was fascinated to see how Germany's apprenticeship program for high school graduates who were not going to college was producing workers who were better trained as chemists, for example, than Advanced Placement chemistry students. "What was clear was that chemistry for them was a part of what they saw as their future and not simply a course they had to get an A in," said Hrabowski. Here in the United States he sees this play out at UMBC, where math is a favorite subject of the student body. The reason for this, he believes, is that many of the students have worked in STEM-related jobs during high school and college, either in industry or at one of the national security agencies in the Washington-Baltimore corridor, and they have seen how math is relevant to their futures.

What is needed, he said, is to knock down the barriers that keep companies, national agencies, high schools, and colleges in their silos and instead create a culture of education and training that will give people at every level some vision of the possibilities for a rewarding and remunerative career in STEM. For those students who pursue a Ph.D., for example, there should be clear opportunities for them when they graduate beyond the vague idea of taking one or more postdoctoral positions until some unidentified job turns up. All students graduating high school should know about the different opportunities that await them with given levels of further education and training. They should also understand they will have to be lifelong learners, whatever degree or training they pursue after high school. "We need to focus on the future lives of students, with a STEM-prepared person being someone who has the skills required by different industries today, but who is prepared to continue to learn," said Hrabowski. "Whether we are talking about jobs requiring a 2-year, 4-year, or graduate degree, students need a broad education because what is clear is we really do not know how different the world will be and what specific skills students will need over their careers. People must be prepared to adapt to change and work in a

world of unknowns and to have the confidence that by asking good questions and working in collaboration with others, and with persistence, they can learn." He added what sets successful STEM-capable individuals apart is not just that they have certain quantitative skills but also the ability to collaborate with people from other disciplines, to get the larger picture, and to express the importance of their work.

In closing, Hrabowski said it is clear the public does not understand the importance of STEM for the future of the nation's children. Correcting this perception problem will require a change in culture across the entire U.S. educational system, but in particular at the nation's colleges and universities. He called on federal agencies to help university and college presidents to ask what they are doing to help their students get jobs at every level, not just in academia, and to help the academic and corporate worlds form partnerships that can produce the STEM-capable workforce needed to meet future job opportunities. "We need to start judging the success of institutions based not just on the science they do but on the futures of their graduates," he said. As a final comment, he called upon the workshop participants to practice encouraging curiosity in our nation's youth. "What's a STEM-capable person?" asked Hrabowski. "It's a curious person who never stops asking questions."

DISCUSSION

Jeff Livingston, from the McGraw-Hill Education Group, asked Hrabowski to comment on some of the alternatives to 4-year STEM degrees for students who want to pursue STEM careers. Community colleges, said Hrabowski, have long been more responsive to the needs of the business community, and there are lessons to be learned from the close relationships community colleges routinely build with the local business community. Boot camps, he added, can get students up to speed quickly, particularly in areas of high demand such as cybersecurity. While these boot camps do have a cost, students are able to repay that cost quickly given the salaries they then receive. "That is a more creative approach to meet demand than requiring everybody to get a major in computer science," said Hrabowski. He noted, in fact, that some of the most successful chief information officers he knows were English, history, and philosophy majors who then took courses in information technology management. The ability to communicate well and talk to colleagues in plain English enabled these individuals to climb the corporate ladder quickly, and today he encourages UMBC's computer science majors to take more classes that will help them learn to write and communicate effectively. One option, he said, would be to have NSF encourage institutions to help students integrate technology classes into a wide variety of majors.

Aprille Ericsson, from NASA Goddard Space Flight Center, noted she was someone who got bad grades in her first year and yet still completed her engineering degree thanks to programs at the Massachusetts Institute of Technology that nurtured first-year students. She then asked Hrabowski if he had any ideas on how the federal government could encourage more women and students of color to pursue STEM majors and STEM careers. He replied that the biggest obstacle is a lack of role models and mentors in the federal workforce. "I don't know a national agency in America, be it the National Institutes of Health, NSF, U.S. Department of Education (ED), NASA, or others, where even 1 percent of the practicing scientists are black and maybe 2 to 3 percent are Hispanic, and we need to say to ourselves as a community that we can do better than this," said Hrabowski. While noting he was pleased the new head of engineering at NASA Goddard was a black woman who graduated from UMBC, he also said the dream is not about black scientists helping black students, but about human beings helping other human beings understand the power of STEM to solve the major problems of humankind. "When we get all Americans to understand that dream, we will not be excluding anyone," he said.

As one example of how to produce change, he pointed out that the Howard Hughes Medical Institute has provided funds to replicate UMBC's Meyerhoff Scholars Program, which aims to increase diversity among future leaders in science, technology, engineering, and related fields, at the University of North Carolina at Chapel Hill and the Pennsylvania State University. The presidents and leading faculty at those institutions have spent time at UMBC to learn what they have to do to change the academic culture to support the aspirations of all students who show an interest in STEM. Another example Hrabowski cited was Project Lead the Way, a UMBC program providing faculty and K-12 teachers with the opportunity to work in engineering firms so they can better understand the career opportunities for their students. He did note there is a need for more data to get a better sense of what drives students to follow pathways into STEM and what happens to them after they graduate from STEM programs.

Ellen Lettvin, from ED, asked what role agencies other than those that directly fund science can play in nurturing STEM-capable workers. Hrabowski said there need to be mechanisms for rewarding mentors and advisers to not only make themselves aware of the career opportunities in STEM but also to follow them as they move through their careers. He recounted writing to Nobel Laureate Tom Cech to thank him for taking a number of UMBC graduates into his laboratory at the University of Colorado and having Cech reply that Hrabowski had failed to mention four additional students and telling Hrabowski where they had landed after leaving Colorado. "If a Nobel Laureate can do this, there is no excuse for

anyone else not to do it," said Hrabowski. "You can be a great researcher and a great human being, but it has to be practiced."

The only way there will be change, he continued, will be through a change in attitude and mindset. Companies are far more proactive than academia about inclusiveness and training. So, too, are the nation's security agencies. "When the National Security Agency tells me it wants people from all sorts of backgrounds because it needs to know how they think, that is a level of enlightenment that I do not often see in universities or other federal agencies," said Hrabowski.

6

Successful Strategies for Aligning Higher Education Programs, Curricula, and Lab Experiences with Workforce Needs

The workshop's third panel included three presentations on the nature of the learning experience within educational institutions and the mutually advantageous alignment with those industries that employ workers who are capable in science, technology, engineering, and mathematics (STEM). The three panelists were William Rudman, executive director of the American Health Information Management Association (AHIMA) Foundation,[1] vice president of education visioning for AHIMA, and a representative from the National Network of Business and Industry Associations; Sanjay Rai, senior vice president of academic affairs at Montgomery College; and Christine Ortiz, dean for graduate education at the Massachusetts Institute of Technology (MIT). A discussion moderated by Daniel Atkins, professor emeritus of information and professor emeritus of electrical engineering and computer science at the University of Michigan, followed the three presentations.

NEW APPROACHES TO UNIVERSITY EDUCATION

Before getting to the main subject of her presentation, Ortiz commented on two of the major changes that have taken place in MIT's doctoral training programs in recent years. One change has been the move from a binary apprenticeship model of one student working for one professor to one of global collaboration among laboratories and across disciplines and employment sectors. The other change has been the integration of

[1] A 501(c)3 charitable affiliate of AHIMA.

basic and applied research across the entire institution, though from MIT's perspective the actual translation of basic science into applications is still quite slow.

Today's students, Ortiz explained, do not want to be an electrical engineer or a physicist, but what they do want is to solve big problems. "They are problem-focused rather than goal- and degree-focused," she said. This desire on the part of students fits well, she noted, with the way in which research is now conducted at MIT. Today, research projects are interconnected, rapid, data-intensive, distributed, and focused on large, complex systems. As an example she noted that MIT is investing heavily on convergence and recently announced a new institute for data systems in society, the aim of which is to address societal challenges by integrating information science, statistics and data science, and social science. She also commented that the dissemination of research has advanced through the use of social media, RSS (Rich Site Summary) feeds, electronic publishing, and other novel channels, reflecting the fact that millennials are hyper-communicative and more globally minded.

This new focus on training beyond disciplinary boundaries has translated into a demand for personalized education with flexible degree programs at the undergraduate level, said Ortiz, which includes an increasing emphasis on massive open online courses (MOOCs), such as those offered on the Open edX platform. MIT, for example, now offers more than 50 residential classes using the Open edX platform as a means of experimenting with blended approaches to education. In her opinion, platforms such as edX are still in the nascent stage of development, akin to the old giant cell phones. Those developing MOOCs, she said, are starting to integrate learning in fields such as cognitive science, interleaved learning, self-pacing, and other fields into these platforms.

Turning to the challenges she sees for the nation's institutions of higher education, competition for the best students was first on Ortiz's list. She noted that many countries have built, are building, or are planning to build new science and technology institutes, some of them with MIT's guidance. "We are continually competing for the best students," said Ortiz, a competition made more difficult because of the many issues facing graduate students at U.S. universities. These issues include low levels of federal research funding, small graduate stipends, long training periods, stagnant availability of faculty positions, and poor preparation for careers outside of academia (Muindi and Keller, 2015). To address this last issue, MIT completed a survey of its alumni from the past 25 years to develop a better understanding of the skills that are a top priority today and is using that information to create curricula aimed at turning out graduates with those skills. She noted that at a recent workshop on the future of graduate and postdoctoral training, the participants listed several dozen ideas to enhance

graduate student training for careers outside of academia, including internships, site visits, job shadowing, individual development plans, informational interviewing, and student research sabbaticals. However, while there is a need for increasing the skills-based educational components of graduate education, Ortiz made the point that "it is critical to continue developing expertise-based education characteristic of doctoral education that pushes the frontier of science and technology."

She then identified four areas of opportunity for investment that would benefit U.S. research universities. The first would be to create interconnected, interoperable online metacurricula to foster personalized learning at all levels and the diversification of postsecondary educational models. The result, said Ortiz, would be to truly open on-the-ground curricula to higher-order, synergistic, creative, and generative discovery and accelerate the development of expertise in emerging fields. The second area of opportunity lies in creating interdisciplinary learning sciences that would merge fields such as linguistics, cognitive science, and educational technology with data and computer sciences to produce a scholarship of higher education.

A third area of opportunity comes from the significant advances in understanding the mechanisms of transformative research and creative thought using bibliometrics, case studies, and related methods. The goal, said Ortiz, is to develop curricula using the mechanisms of convergent and divergent thinking, creative effective skills, and self-evaluation to overcome what has been termed cognitive entrenchment. The final area of opportunity she listed is to invest in programs that aim to further collective intelligence, including crowdsourcing, citizen science, and MOOCs, and what she called MOORPs, or massive open online research projects. Such efforts would engage citizens with research universities, which would both reduce the isolation of the university and foster translational research.

COLLABORATIVE INNOVATION AT THE COMMUNITY COLLEGE LEVEL

As the cost of higher education has risen and students have accumulated $1.3 trillion in student debt, there is an obvious conclusion to be drawn, said Rai: the education many of these students received did not provide the opportunity to secure an economically viable job. The issue, he said, is a misalignment between the postsecondary education students are paying for and the STEM-based skills graduates need to fill jobs for which employers cannot find qualified candidates. To address this misalignment, Montgomery College, located in the Maryland suburbs of Washington, D.C., has worked with industry partners to create a number of STEM programs that meet the changing needs of the region's growing life sciences and cybersecurity industries.

In large part because of the success of the Human Genome Project, there are now some 300 biotechnology companies in the region employing approximately 60,000 people with a median income of $92,000, explained Rai, and most of the hires these companies are making today do not need Ph.D. degrees. With the local industry's participation and endorsement, Montgomery College developed a 2-year biotechnology program to produce laboratory-ready workers. Half of the students enrolled in this program have an undergraduate or master's degree, often in the life sciences area, but without the skills local industry requires. Students can complete this program, said Rai, at one-third the cost of getting an additional degree at other Maryland state schools and for much less than at for-profit schools. Montgomery College also offers a chief scientist program, which Rai characterized as a "mini-MBA program for scientists." Classes meet for 14 consecutive Saturdays and the program costs less than $1,000, he noted.

A third program, developed 3 years ago, prepares students to meet the growing demand for jobs in clinical research organizations (CROs), which conduct clinical trials for biotechnology companies. This is another 14-week program that meets for 3 hours every Saturday and, again, it costs less than $1,000. The students in the program, said Rai, include doctors, nurses, optometrists, and postdoctoral fellows from the National Institutes of Health. The students work in teams to develop real clinical trials with local CROs. Rai recounted how one chief executive officer from a local biotechnology company worked with two students on a project, and at the end of the course she hired her team members.

For the cybersecurity industry in Maryland and Northern Virginia, which Rai said currently has 30,000 posted positions (Restuccia, 2015), Montgomery College developed a 2-year cybersecurity program for novices in the field and a shorter cyber advantage program for current information technology workers who are seeking new opportunities. Many of the participants in the latter program, said Rai, formerly held jobs that were outsourced to other countries. The curricula for both of these programs were developed in collaboration with local industry. Rai also mentioned Montgomery College's 2-year engineering transfer program, the largest in the country. This program, which accepts anyone who applies, has graduated some 1,500 students who have then transferred to 4-year institutions that include MIT; the University of California, Berkeley; Georgia Tech; and the University of Maryland. He noted that Montgomery College follows these students once they leave and has been told that they do as well as the native students at these prestigious institutions. This is important, he explained, because 73 percent of the students in this program come from underrepresented groups. "We are helping to produce a STEM workforce that looks like the rest of the nation," said Rai.

In his final comments, he said U.S. higher education is still the envy of the world, and it will remain so because it has shown the ability to adapt to meet the needs of a dynamic global economy. "The spectrum of what we teach and how we teach is in good shape, and there are good conversations taking place about evolving curricula to meet the needs of the 21st century economy," said Rai. His biggest area of concern relates to the funding model for higher education. "We are addressing 21st century challenges with a 20th century funding model at the local, state, and federal levels that does not reflect the role that community colleges play today." He said 50 percent of the nation's engineers attended a community college, and 58 percent of women and minority member engineers came through community colleges. Yet for every $10 the federal government provides to 4-year institutions, community colleges get $1 in funding. "The funding model needs to be looked at differently," said Rai.

COMPETENCY AND SKILLS-BASED EDUCATION

Acknowledging that few people think of AHIMA and the AHIMA Foundation as being involved in education, Rudman explained that this association oversees curriculum development and implementation in health information management, informatics, and information technology at more than 400 U.S. colleges and universities. He noted, too, that AHIMA has a U.S. Department of Commerce grant to develop a global curriculum for 2-year, 4-year, and graduate programs in those areas, and the association will be sending staff to India, Saudi Arabia, the United Arab Emirates, and Brazil to conduct faculty training in health information technology in the coming months. "My role in academics colors the way I look at competency and skills-based education and the absolute need for academic programs to work with industry," said Rudman. "If we do not, we will fail, and I think we are seeing this across the U.S. and globally."

AHIMA and the AHIMA Foundation began their effort around competency and skills-based education some 4 years ago, and as Rudman recalled, it did not start on a positive note. "I remember presenting this to our academic faculty, and they booed," he said. Two years later, after bringing in people from the U.S. Departments of Labor and Commerce to explain how important it was to develop competency and skills-based programs, AHIMA Foundation's Council for Excellence in Education approved a curriculum, and at the end of 2015 it becomes mandatory for all academic programs in health information technology to adopt this curriculum for their graduates to receive AHIMA credentials. Rudman noted that the AHIMA Foundation worked closely with industry to develop its curriculum and the requirement to receive the AHIMA credential for employment. A recent AHIMA Foundation study, Rudman was pleased to note, found

that faculty are beginning to understand how important it is to work with industry to develop competency and skills-based training. Some 60 percent of faculty surveyed now see there is a disconnect between what industry leaders say they need and what academics believe they are providing as skills and competencies. According to business leaders, students are least prepared in leadership skills, but also in professional and technical skills, which Rudman said was a surprise.

One refreshing finding from this study, said Rudman, was that academic and industry leaders believe the remedy for these shortcomings is the same—experiential learning. Almost 90 percent of those surveyed from both industry and academia said professional practice experience was the most important thing to include in curricula, and such experience is now mandatory for credentialing. He noted there was a slight disconnect between academic and industry leaders in believing experiential learning should be mandatory at all levels of postsecondary education. The AHIMA Foundation, he explained, is developing a national apprenticeship program as part of a 5-year grant from the U.S. Department of Labor to address the reality that health information technology errors can kill people. Even with a college or graduate degree, an apprenticeship is necessary to ensure that those working in health information technology fields are sufficiently well trained. Apprenticeships for data analysts and business analysts will be open to someone with a bachelor's degree, but they are geared more to someone with a graduate degree, Rudman said. The AHIMA Foundation is also developing apprenticeship programs in cybersecurity and leadership, the latter of which will focus on women. In general, he added, the AHIMA Foundation's apprenticeship programs emphasize training for people of color and women, particularly single mothers. These apprenticeships will be run as boot camps and will come with a guarantee of a job at the completion of the program.

DISCUSSION

In response to a question from Jeff Livingston, from the McGraw-Hill Education Group, about AHIMA's effort to increase diversity in health information management fields, Rudman said approximately half of its members are people of color. He also noted health information management is the fastest-growing area of health care, and there are nearly three jobs for every student who graduates. However, even graduates of accredited health information programs are having a hard time getting jobs because they lack experience, and hence, the new emphasis on apprenticeship programs.

Aprille Ericsson, from NASA Goddard Space Flight Center, asked Ortiz how MIT was supporting minority students in its graduate programs. Ortiz said MIT recently received a large grant from the Sloan

Foundation to establish a university center for exemplary mentoring. This program will start with 36 Sloan Scholars who over 3 years will develop a professional development and academic mentoring plan to implement with incoming graduate students. MIT has also established a program, Common Values on the Graduate Student Experience, that generated a list of 11 best practices for graduate student mentoring and advising that are now part of MIT's official policy for advising and mentoring. Ortiz noted that 18 percent of new graduate students at MIT are now members of underrepresented minorities, up from 9 percent 5 years ago, and it has disseminated data from the Integrated Postsecondary Education Data System to all departments so they can target recruitment efforts on women and minority students. Any department at MIT, she added, can come to her office and procure fellowships for women and underrepresented minority students. She noted, too, that MIT's Summer Research Program had 80 participants in the summer of 2015.

Jodi Wesemann, from the American Chemical Society, said she appreciated the panelists' efforts in supporting curricular redesign and partnerships between industry and academia, areas the American Chemical Society and other disciplinary organizations have been struggling with in recent years, and she asked the panelists if they had any advice on how to build programs that get buy-in from academia, are sustainable, and include continuous improvement as a core feature. Ortiz said MIT has found having external visiting committees review its efforts every 2 years has worked well for obtaining faculty buy-in and creating a culture of continuous improvement. The members of these committees, half of whom are from industry, spend 2 days on campus, review "massive data analytics" that MIT departments generate, and interview employers of MIT graduates. She added that each department has to develop a strategic plan for improvement and MIT's administration articulates expected outcomes. "Continuous assessment combined with both qualitative and quantitative data analysis has helped quite a bit," said Ortiz. Rudman explained that all of AHIMA's curriculum development work is evidence based, includes revisions every 3 years, and is conducted in close collaboration with academia, industry, and government to ensure that curricula will help address projected trends in workplace demands. Rai agreed that collaboration with industry was imperative for developing successful curricula and suggested collaboration should include opportunities for faculty to spend time in industry and for industry representatives to spend time on campus. He also said faculty professional development is important given the dynamic nature of today's economy.

In response to a question from Roy Swift, from Workcred, Rudman said students who go through the AHIMA Foundation's apprenticeships receive professional certification. Swift then noted the industry certification community is often left out of discussions about STEM education and

asked the panelists if they could comment on the role such organizations can play going forward. Rai said that Montgomery College developed its cybersecurity program curriculum with substantial input from cybersecurity companies, so whether there is a formal certification or not, there is strong buy-in for this program from industry. The same is true, he added, for its biotechnology programs. Graduates of its clinical trials program, for example, receive a certificate signed jointly by the college and the company that sponsored the clinical trial project. He acknowledged, though, that a formal certification process is not yet in place for emerging STEM industries. "These are new disciplines, but if industry is at the table, if they are participating and collaborating, there is a good buy-in," said Rai. The proof, he added, is students in these programs are getting job offers before they even finish the programs.

In summarizing the session, Atkins noted the discussions highlighted the importance of apprenticeships, experiential learning, and mentoring, and wondered if any of the panelists knew of efforts that are using some of the new IT-based collaborative tools to expand the ability of students to engage in experiential learning in remote settings. He noted, too, that some faculty at MIT were creating robotics and wet chemistry laboratories for students as far away as South Africa to use remotely during off times. Ortiz said MIT is engaging in some of these activities, but they are difficult to scale and expensive to run. Virtual discovery, she said, is a more rapid trajectory for scalability and growth. Rudman said that AHIMA operates a virtual laboratory that is used to train more than 17,000 students a year. He said 40 percent of the health information management workforce is virtual or outsourced, and as a result, the AHIMA Foundation chose to include virtual mentoring and virtual training as part of its apprenticeships.

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Alternative Pathways and Alternative Providers

The workshop's fourth panel featured brief presentations from four innovators in postsecondary education, who discussed novel approaches for helping "non-traditional students" prepare for success in the science, technology, engineering, and mathematics (STEM) workforce, both outside of and inside traditional academic settings. The committee believed that it was important to understand the growing role and influence of online providers, computer "boot camps," and even traditional programs that are offering non-traditional pathways to undergraduate and graduate degrees in STEM fields. Such entities are enrolling increasing numbers of student at all age levels—including 18- to 24-year-olds and adult learners. These presentations, said session moderator Mary Alice McCarthy, senior policy analyst at the New America Foundation, challenge the notion of what STEM education can be in the United States. The four panelists were Liz Simon, vice president for legal and external affairs at General Assembly; Adam Enbar, president of the Flatiron School; Ruan Pethiyagoda, chief strategy officer at Hack Reactor; and Maureen Grasso, dean of the Graduate School at North Carolina State University. After their presentations the four panelists responded to questions from McCarthy and the workshop participants.

General Assembly, explained Simon, is building the education company of the future, one delivering skills-based training in the most in-demand fields of today and across the spectrum of new economy skills, including business design, data analytics, user experience, web development, product management, and digital marketing. General Assembly, which is not accredited, offers short, practical, practitioner-led courses at 14 campuses around the world and online, and is focused on the return on investment

for students. "We do exist outside of the landscape of the traditional educational system," said Simon, who added that "one of the reasons our model exists is it responds to the fact that people were educated but without [the necessary business-related] skills." General Assembly graduates about 4,000 students per quarter, she added.

Enbar said the Flatiron School, founded 3 years ago, delivers immersive, intensive programs with courses running from 3 to 5 months designed to provide people with little or no background in software engineering with the skills to become immediately employable in full-time software engineering jobs in a variety of industries. Flatiron School, which also trains K-12 teachers to teach computer science at the high school level, focuses on diversity and economic mobility. "We have partnered with organizations such as Google and the city of New York to provide programs exclusively focused on underrepresented groups in technology, such as women and minorities without 4-year degrees," said Enbar. Flatiron School graduates approximately 1,200 students a year.

Hack Reactor, which was also founded 3 years ago and also provides intensive, short-duration training in software engineering for people with no software engineering background, has evolved into an infrastructure company that owns and operates the systems supporting multiple schools, each having slightly different curricula and missions, explained Pethiyagoda. One such school is the Telegraph Academy in Oakland, California, which focuses on training underrepresented minorities for jobs in California's high-demand industries. Its New York school, in contrast, only accepts 10 percent of the applicants, but it also offers programs for those who are not quite ready for Hack Reactor's intensive courses and trains them for junior engineer positions that offer good salaries. Pethiyagoda said Hack Reactor's corporate focus is to develop a better understanding of the challenges that traditional 2- and 4-year institutions face in providing skills-based training and apply its systems to support those institutions. Hack Reactor graduates some 1,200 students annually from its programs around the country, he added.

Grasso noted that North Carolina State University is different from the other three organizations represented on the panel in that it is a research- and STEM-intensive institution. "STEM is in our DNA, and innovation and entrepreneurship are what our degrees are about," she said. Some 70 companies live and work on campus, offering students the ability to work and participate in internships on campus. Faculty work in partnership with industry employees, who also serve as adjunct faculty.

In 2012, Grasso had the opportunity to serve on the Pathways Through Graduate School and Into Careers Commission, jointly sponsored by the Council of Graduate Schools and the Educational Testing Service, which surveyed leaders in the corporate world to find out what their perception was about graduate education. Corporate leaders reported that graduate

schools were good at providing sound technical skills and training, but more work was needed on developing students' employment success skills, such as project management, professional communication, entrepreneurship, conflict resolution, intercultural cooperation, leadership, teamwork and collaboration, and communicating with the public. Based on those findings, North Carolina State University has developed the Professional Science Master's Program, an immersive internship program that features what Grasso called the most innovative curriculum that she has seen on her campus, one integrating training in both technical and employment success skills. She stressed this is not a "cookie-cutter model," but one that heavily leverages peer-to-peer learning through teamwork and focuses on applying practical knowledge. "The students learn by working on real-world problems using data from industry and standardized tools employed by the industry today," Grasso explained. "We augment this with instruction, one-to-one coaching that includes a writing coach, and continuous self-assessment and improvement." The final piece of the program is a practicum in which students work on real-life problems and at the end of the program report their findings at the corporate headquarters of the company that sponsored a particular project. "When students complete this program, they receive higher salaries and bonuses that produce a return on investment of 20 months," said Grasso.

WHAT KIND OF STUDENTS ENROLL IN THESE PROGRAMS?

Over 90 percent of the students who come to General Assembly have a bachelor's degree or at least some college background, said Simon. In general, they fall into two groups. The first are career changers, those who have some experience in the workforce and want new skills to secure the career they want and who are willing to immerse themselves full-time in gaining those skills. Typically, these students are around 30 years old. The second are the part-timers who enroll in General Assembly's night and weekend programs, and these are more likely to be incumbent workers who want to stay relevant in their current job, get a promotion, or explore the possibility of making a career change. There is close to a 50-50 gender breakdown, Simon noted, and while the students are ethnically and socioeconomically diverse, General Assembly has programs focused specifically on increasing diversity, including a scholarship program that has already produced 80 graduates.

Enbar explained that Flatiron School approaches the challenge of addressing the technology talent gap from two perspectives, one aimed at individuals with college degrees who can pay $15,000 for an intensive program to turn them into software engineers. "These people have a massive foundation of a college degree beneath them, and critical thinking skills,

and we can put them through this factory that turns out software engineers quickly," said Enbar. Flatiron School takes a different approach to address diversity and economic mobility issues through a program run in partnership with New York City. This program takes people with no college degree who are 18 to 26 and come from low-income backgrounds, and puts them through the same kind of training over a 5-month period while focusing on employability and professional development skills. "Everything about how we run that program is different, starting with the screening criteria. In our regular $15,000 program we can require long application essays and first and second interviews. But when you are targeting people who have no idea how to apply for a position or put thought into an essay, you have to approach the process differently," Enbar explained.

Hack Reactor's intensive program students have college degrees, and those that apply skew toward young, white males, said Pethiyagoda. Applicants undergo a single interview focused on identifying students who are tenacious and eager to learn, and have problem-solving skills, aptitude, and consistency of reasoning. He noted that Oakland's Telegraph Academy looks for the same traits in those who do not have college degrees and come from underrepresented minorities. There are some qualified students who cannot afford any program with a five-figure price tag, and Hack Reactor has been working to develop financing programs. "None of our programs are eligible for state or federal aid, and you cannot use college savings plans to pay for these kinds of programs," explained Pethiyagoda.

Grasso said the students in the Professional Science Master's Program have a college degree, though it may not be in data analytics, and may not even be a STEM degree, and the program receives more than 1,000 applications for approximately 100 slots. The most recent class was 41 percent female, and the students came from 18 countries of origin, with 85 percent being U.S. citizens or permanent residents. The age of the students ranged from 24 to 52, most are self-financed, and over half have a prior graduate degree. The interview process for acceptance in the program looks to build a cohort of students who can work together and identifies those points the students will have to work on in the self-assessment and self-improvement portion of the program, Grasso explained.

WHAT KIND OF OUTCOMES DO THESE PROGRAMS ACHIEVE?

General Assembly has found that 99 percent of the students who graduate from its full-time immersive programs have a job in that field within 6 months of completing the program, said Simon, and graduates see a 25 to 30 percent increase in salary. Students in the Opportunity Fund program are experiencing similar results, but the sample size is still small, she added. Hack Reactor's placement rates are also high, said Pethiyagoda, and though

the program is expensive, the return on investment is under a year given the salaries its graduates make. Flatiron School has similar outcomes for placement rates and salary increases, said Enbar.

Enbar noted that this niche of boot camps has exploded over the past few years, with 50 new schools launching within the past year. "This sector went from nothing to a multi-hundred-million dollar industry in a couple of years," he said, "and as you would expect, that can attract some bad actors, so it is important to understand what is behind a school's claims about outcomes." One school, for example, advertises that its students have not graduated until they have a job, which means it automatically has a 100 percent placement rate for its graduates. What Flatiron School has done, said Enbar, is release an independently audited report of its performance and it is working with Hack Reactor and General Assembly to create standards and benchmarks for audited performance measures. "It is important as this industry matures to set standards for transparency," he noted.

As far as whether these programs are delivering the right kind of skills, Pethiyagoda said that the only way to judge that is by knowing if companies are employing their graduates and how successful they are in subsequent years. That the graduates of all three of these schools are finding high-paying jobs argues that these programs are delivering on their promises, he said.

WOULD IMMERSIVE MODELS FOR SKILLS DEVELOPMENT WORK IN OTHER STEM FIELDS?

General Assembly offers a great breadth of programs that focus on technology, but not just programming and software engineering, said Simon. She noted that a study General Assembly conducted with Burning Glass Technologies (Burning Glass Technologies and General Assembly, 2015) identified a new type of job they called a hybrid job, one combining some sort of technical and business skills and that can be accessible to people without a technical degree. Examples of hybrid jobs include digital marketing and mobile developing, jobs that have risen 350 percent in number in just the last year, said Simon. "Those are jobs that if you break down the skills, it is not just a hard technical skill that you need." She said while there is a technical component in all of General Assembly's curricula, they also include the soft skills required for these hybrid jobs.

Enbar agreed these programs do not have to be about programming, but the key is to develop skills to fill a talent gap and to do so in a way businesses can evaluate. "If you are looking at a person with a degree from Princeton, you are going to interview that person, but how do you evaluate the graduates from our schools?" asked Enbar. Fortunately, in the software world there is a website called GitHub, a place where software engineers

can store the code they write and where prospective employers can review that code and evaluate an engineer's skills. "As employers realize what this kind of transparency makes possible, we're seeing more reception to the people who come out of our programs," said Enbar.

Pethiyagoda said the information technology world has been receptive to this kind of program because of the extreme shortage of qualified job applicants and because of sites such as GitHub that enable them to judge the skills of the graduates of these alternative approaches to skill building. "I don't think the rest of STEM is there yet. You still have to have the right degree to get the best jobs in most cases, but that is only going to last until other fields start seeing a reduction in the number of graduates or their needs outgrow the number of graduates," predicted Pethiyagoda.

Roy Swift, from Workcred, noted the military is a prime example of how immersion-type education is done on a daily basis in a wide range of disciplines. He recounted, for example, how he could not teach at the Army's Academy of Health Sciences until he had completed a 6-week immersion course on teaching and demonstrated teaching proficiency. "We forget about the military model, but it does work," said Swift.

DISCUSSION

McCarthy asked the panelists about the role the federal government, and the National Science Foundation (NSF) specifically, can play to create alternative pathways in a way that does not end up with the situation today where students take on a large amount of debt for an education that cannot get them a job that pays well enough to service that debt. Simon suggested the missing elements are equity and access, and the federal government can play the same role in education that it plays in the workforce in general. What she and her colleagues in this alternative pathway sector worry about, said Simon, "is having the doors flung wide open with respect to Title IV. We have seen how federal money going into the for-profit world can be disastrous." She encouraged the federal government to think creatively about how to use the platforms it has and how accreditation works, particularly regarding outcomes-based evaluations. "We need to think about alternative payment models, perhaps tax incentives to help employers pay for this kind of training and bolstering the balance sheet of private lenders," Simon suggested. The federal government might also consider increasing funding for workforce development, she added.

Grasso said she would like NSF to provide opportunities to study how these immersion models can be extended successfully to other areas of STEM and to help prepare future faculty through programs that connect teachers and future teachers with industry. Pethiyagoda seconded this idea, saying the lowest hanging fruit would be to share some of the pedagogical

lessons learned from these programs. Simon suggested NSF might be able to bring together coalitions of employers to work on curriculum development for immersive STEM education.

Grasso then noted that administrators at educational institutions can encourage and build relationships, but the disciplines need to get behind these efforts. "Students need to be out of the laboratory, but faculty have not bought into this idea yet," said Grasso. One suggestion she had would be to include provisions in NSF grants that would make faculty accountable for the skills development that industry needs. NSF could also carve out a part of every research grant that would go directly to the graduate school, which would then offer these kinds of programs and skills training.

Christine Ortiz, from the Massachusetts Institute of Technology (MIT), said she believes there is a disconnect between developing skills and forming a foundation of knowledge, with the latter taking much longer than the former. "If you look at the STEM workforce, some of the greatest challenges require extensive expertise," said Ortiz. For example, she can train someone in a month in how to use a three-dimensional printer, but one of the big challenges in this new field is creating a true multimaterial printer. Meeting that challenge requires a foundation of expertise in material science, molecular modeling, and other disciplines. "The STEM workforce needs people who have developed a full understanding of a domain of knowledge beyond being able to apply a skill," said Ortiz. "Skills in many cases refer back to selective portions of a network of knowledge that is built up over a long period of time."

Pethiyagoda agreed with Ortiz and said Hack Reactor is conscious of that difference. "It is easy to look at a job requirement and decide you can teach the skills needed for that particular job," said Pethiyagoda. Hack Reactor, in fact, stops teaching skills 5 weeks into a 12-week program, with the remaining time spent creating experiences and developing the student's mindset to succeed beyond those skills. As an example, students are frequently switched among multiple projects because that is the way the work world works. The goal, he added, is for graduates to come back and say the job is easier than school because that means they have had experiences beyond just skills development. Enbar agreed with Ortiz as well, but noted that for the 90 percent of Americans who just want a better job and to be part of the middle class, there are alternatives to spending 4 years at MIT. "We are not talking about the people who are inventing the new technologies and need that MIT education," said Enbar. "We are talking about the people who make sure your credit card works when you buy something at the grocery store."

Dale Allen, from Quinsigamond Community College in Worcester, Massachusetts, said in Massachusetts, community colleges will work with industry partners who come to them with a need to fill positions and a

curriculum in hand to train students for those jobs. With that model in mind, he asked the panelists if any of them would partner with a community college to deploy their curricula and provide technical assistance and faculty training. Simon replied that she and her colleagues at General Assembly have had many discussions with community colleges over the past year to do just that and would be happy to have the conversation with Allen. Pethiyagoda said Hack Reactor is in fact focusing on how to build a system for deployment anywhere and toward that end has started a remote-immersion model. "We provide the curriculum, you provide the big room, the Internet connection, and the coffee," he said. Local staff can take over the nontechnical skills portion of the curriculum if desired, and Hack Reactor faculty can teach the rest of the program. Early results, he added, show this approach producing similar outcomes to the in-house program.

To close this panel session, McCarthy highlighted two things she found interesting. The first was the failure of traditional credentials to reflect the value of these alternative pathways and the availability of venues such as GitHub to enable employers to evaluate potential employees regardless of their formal credentials. This new model opens a space for a new type of provider, she said. "This is something to think about for federal investment and federal policy and how it relates to the credentialing space," said McCarthy. The second thing she found interesting was the research opportunity to combine what is known about cognitive processes and learning with the interesting pedagogical lessons from these immersive programs to develop new ways of solving training problems.

8

K-12 STEM Education and Workforce Readiness

The workshop's fifth and final panel explored the question of how to lay the groundwork early for success in science, technology, engineering, and mathematics (STEM) careers. The three panelists were June Atkinson, North Carolina's superintendent of public instruction; Gary Hoachlander, president of ConnectEd: The California Center for College and Career; and Jeff Livingston, former senior vice president for education policy and strategic alliances at McGraw-Hill Education Group. The panelists then responded to questions from session moderator Russell Rumberger, professor of education in the Gevirtz Graduate School of Education at the University of California, Santa Barbara, and following that, from the workshop participants.

Rumberger began the session by recapping the key ideas he had heard during the day that could affect K-12 education, starting with the importance of mentoring and advising in influencing students' decisions to go into STEM fields and the role the arts might play in STEM education. The critical role of work-based learning was also a clear point of emphasis, as was the importance of math in getting students into STEM fields. Rumberger also referred to a landmark demographic study by the late John Clausen, who followed a cohort of children born in the Depression through life until age 70 and looked at the many factors that helped define their success over that period (Clausen, 1985). The features predicting successful, fulfilling lives turned out to be tied to what a person was like in high school. "This underscores in my mind the importance that K-12, and perhaps especially high schools, has in preparing students not just for STEM careers but careers in general," said Rumberger.

Atkinson then briefly described her most important roles as state superintendent, a position she has held for 10 years. One role is to guide the state board of education to develop the best policies for education. Another major role is to let the people of North Carolina know how the state is doing in public education and what needs to be done to improve and make changes that are beneficial to the state's children and its economic development. The third major role is to determine what the state needs to do to prepare policies and standards and licensing of teachers to ensure it can meet future challenges.

Hoachlander then recounted an experience he had the summer before entering 10th grade when his parents sent him to a science camp at Phillips Academy in Andover, Massachusetts, one of the most elite preparatory schools in the United States. His teacher at the camp was a research biologist who had him spend the entire summer studying the cricket as a thermometer. He had to read the original scientific work from the 1800s, design an experiment to validate earlier research that there was a mathematical relationship between the rate at which crickets chirp and ambient temperature, build the necessary equipment, go into the field and catch crickets, produce a research paper summarizing his results, and present and defend his findings to his teacher and fellow classmates. He even discovered something never reported before, that some crickets lack the ability to chirp and that these crickets do not have ears. "Developing the ability to understand the scientific method and enjoy the excitement of original discovery had enormous value," said Hoachlander.

He told this story, he said, for two reasons. The first was to point out the importance of changing the way teaching and learning are organized in the United States so that they focus on experiential learning, not only in K-12 but in postsecondary education. The second, and more important reason, was to raise the issue of equity. "We are talking about an approach to learning and teaching used 50 years ago in the most elite educational institution in this country, and it is still not present in the high schools of Detroit and Oakland and Los Angeles, or if it is, it is the exception, not the rule," said Hoachlander. "What is routine at places like Phillips Academy, and at the Massachusetts Institute of Technology, Princeton, and Yale, is missing from the K-12 systems serving the overwhelming majority of young people in the United States. Clearly, we need a new approach to STEM education." In California, that approach is called Linked Learning, and it integrates rigorous academics with career-based learning and real-world workplace experiences. There is no one right way to implement this type of program and introduce new pathways to college and careers, but there are wrong ways, said Hoachlander, so the Linked Learning program has worked hard to spell out what constitutes high-quality pathway design and implementation. The challenge, he said, is to build systems at the district,

community, and regional levels to support and sustain high-quality pathways. Linked Learning, which started in California, is now being implemented in Detroit, Rochester, and Houston.

Livingston, who was in charge of college and career readiness at McGraw-Hill for more than a decade, also told a story to make a point. His story was about a conversation he had with a Texas fourth grader named Maria. During this conversation, he asked Maria what she wanted for her future, and she said she wanted to be the first person in her family not to be poor. This was a startling statement, said Livingston, and it colored how he thinks about the advice to give a student like Maria. For starters, he would tell Maria to work hard to convince her mother to advocate forcefully for her to get into a school where other students go on to college, which in Texas is probably a charter school. He would advise her to go either to a college or university that has ever been ranked in the top 10 or go to the local community college and focus on a STEM career, and probably in technology and engineering because that is where the money is and she does not want to be poor. "I think the future of our economy, the quality of our society, rests precisely on how successful we are at helping Maria achieve what she wants for her life, which is to not be poor," said Livingston.

HOW CAN K-12 EDUCATION ENCOURAGE STUDENT INTEREST IN STEM?

Atkinson said she is optimistic about being able to make the shifts needed in public education, and an important step to take is to do a better job of training teachers about how to show students the many ways in which STEM knowledge is useful in real life, starting in kindergarten, and to provide career advice and mentoring. "Any policy that does not pay attention to the teacher is a policy destined to fail," said Atkinson. She noted that on her travels across North Carolina she is seeing a major shift in elementary education using many of the strategies being discussed at this workshop. "Teachers are integrating STEM concepts into the general lesson flow and not separating them out," she said. Based on what she has seen, she believes elementary school teachers are best prepared to do this kind of integration and to do the important priming that will get students interested in STEM. More work is needed, though, at the middle and high school levels when it comes to project-based learning, she added, and this will require different approaches than those that succeed in elementary school.

Hoachlander agreed that teacher training is a critical area needing attention because, as he put it, "the typical math teacher knows very little about how math is used in engineering or even in basic construction." One way to improve teacher training is to build the capacity of core academic teachers to apply their discipline outside of the classroom through engage-

ment with local industries. In the same way, it is important to give young people of all ages the opportunity to apply in authentic ways what they are learning, which also requires the opportunity to interact with professionals in STEM careers outside of the school environment.

Another point Hoachlander raised was that STEM is important in many fields that had yet to be mentioned during the workshops, such as agriculture, energy, environmental science, law and justice, intellectual property, and security, all areas of potential interest to students. He also noted how important it is to give Maria the STEM foundation that will enable her to succeed in any kind of economy, including an economy that few people today can even envision. "What is the strategy for ensuring that every Maria in every single school in the United States has the opportunity to get the kind of preparation she needs to be successful in lifelong education and career?" asked Hoachlander. Atkinson then reiterated the importance of thinking about the entire spectrum of occupations requiring STEM as a foundational skill. "As you get further up the ladder of education, the goal is to make sure all students have those foundational skills, and then with the career pathways framework, you give students the opportunity to delve further into what they are learning," she said.

Livingston said the concept of mindset should be part of all teacher preparation if the goal is to nurture Maria's interest in STEM. Nobody, he said, is born to be a mathematician, for example. Rather, there are things that families and teachers expect students to be good at and persist at until they master those subjects, and there are things that they give students permission to give up on. "The first thing we need to do is protect Maria from the assumption that she cannot become a scientist because her elementary school teacher does not think of her as a math person. We need to protect her from that mindset," said Livingston.

He then mentioned his current favorite school that follows a similar model to Linked Learning, P-Tech in Brooklyn. P-Tech was the first school in the nation—there are now 28 others in New York, Illinois, and Connecticut—to connect high school, college, and the world of work through college and industry partnerships. Students at P-Tech in Brooklyn graduate with a high school diploma and an associate's degree in one of three technology fields from New York City College of Technology, and Livingston noted in the first cohort of these students, six of them finished their high school and associate's degrees in 4, not 6, years. Four of these students, he added, are working at IBM today and have become the highest paid members of their families.

Hoachlander said he is a fan of the P-Tech schools, but cautioned he wants to make sure they are not just creating a new form of tracking that has dominated the American high school experience for more than a century. The P-Tech model avoids creating tracks better than most of the new

pathway models in that it prepares students for the full range of postsecondary school options. "What we do not want is a pathway for grades 9 to 14, another pathway for grades 9 to 16, and so on," said Hoachlander. Another good model, he said, is San Diego's ACE (architecture, construction, and engineering) program, where the large majority of the high school students participating in the program are Hispanic and eligible for free or reduced-fee lunch programs. This program, he explained, prepares students for many graduation options, including apprenticeships, 2-year college, and 4-year college, and it is up to the students to make the choice of the pathways to take after graduation. "It is not a choice being made by others based on presumptions of what students are or are not able to do," said Hoachlander.

Atkinson agreed the best approaches give students the opportunity to make choices. "Because a child took a sequence of courses in a career pathway should not determine whether or not they get into college," said Atkinson. "We should teach students in ways that engage them so they can have options after graduation." Her favorite schools in North Carolina, for example, expect all of their students from a variety of backgrounds to meet high standards in mathematics, science, and social studies, and all students take the same classes regardless of what career pathways interest them. These schools even have pathway departments in which teachers from the disciplines work together. The challenge, she said, is to replicate these schools so that every child in the state who wants to be in this type of program can be. As a final comment before the open discussion began, Atkinson added that schools need to do a better job in particular in helping students achieve in mathematics in the K-5 years. "The research I have seen says that if children get a deep understanding of mathematics by then, that will propel them to higher mathematics as they go on in school," she said.

DISCUSSION

Brian Mitchell, from the National Science Foundation, noted that teaching is a passion for many doctoral students and said while having a Ph.D. does not guarantee someone will be a good teacher, he wondered if there is a pathway to facilitate teaching careers in K-12 for doctoral students. He also posed the harder question of how to value that as a career choice for those who attain that highest level of education. Atkinson said those were two challenging questions, particularly regarding how to reward Ph.D.'s who want to teach in K-12. While rewarding them with higher salaries is not an option today in her state, what should happen regardless is for citizens and the business community to start acknowledging how important teachers are to the nation's economic development and letting teachers know they have the support of the community. She called on the

business community in particular to put pressure on legislatures to provide the funds to provide higher salaries for teachers.

As far as how to accredit Ph.D.'s to teach in K-12, Atkinson explained that North Carolina has a system where case managers will look at each individual's qualifications to determine what they need to do to become certified. However, she said, her department has found the best teachers are those who have come through a 4-year teacher preparation program and that it takes about 3 years with mentoring and professional development for Ph.D.'s to reach the same point as teachers who have gone through 4-year programs. Livingston added he would tell Maria that becoming a teacher is a good way not to be poor, but not to get a Ph.D. first.

Sarah Rowlinson, from Clemson University, told a story of when she moved with her family from New York to Florida as a middle school student and her parents were given the option of placing her in the regular, honors, or gifted program. Her parents, neither of whom had gone to college, picked the honors track, which Rowlinson said had a significant impact on her access to the most engaging science programs. Only those students in the gifted program dissected fetal pigs, for example. "The teachers were different and the resources were different for these different tracks," she recounted. "This is something we need to address because it greatly affects the STEM experience for students and tells those students who are not in the gifted track that they are not worth the money to get them interested in STEM."

Atkinson's response was, "You are exactly correct. When kids are exposed to experiential learning, we are halfway home to helping them gain those foundational skills and knowledge and employment success skills they need." She added she has seen countless examples of "regular students" being engaged through experiential learning and becoming interested in and pursuing STEM careers. Livingston commented that what has happened in public schools is that these three different tracks—the regular, honors, and gifted programs—are likely to be at different schools. "So depending on where you can afford to live, you have one experience or another," he said. Rumberger agreed with Livingston and said the United States has the most stratified educational systems of any country. "We have some of the best schools, but we probably have the worst schools, too," said Rumberger. Referring back to Freeman Hrabowski's earlier comments about grit, Atkinson said the nation needs to develop the grit to fix the problem schools in America's public school systems.

Christine Burgess, from the American Association for the Advancement of Science, asked the panelists if they could identify some of the features of successful educational pathways to careers in STEM. Hoachlander said college and career should have four critical components: an academic core of math, science, English, social studies, and a world language; a cluster

or sequence of career technical courses aligned and taught in concert with the academic courses in a way that engages students in multidisciplinary projects; a work-based learning component starting in 9th grade through 12th grade; and personalized student supports, which for most children means supplemental instruction in reading, writing, and math, combined with solid postsecondary and career counseling. He stressed that work-based learning does not mean work experience, which itself is also a good thing. As an example of a work-based learning experience, he described how students at the health careers academy at Palmdale High School in Palmdale, California, learn science. Every senior during the second semester spends three mornings a week in a group internship at various medical facilities in the area, with each group consisting of 25 students and their classroom teacher. On the morning he observed one of these groups, the teacher was working side by side with a physician assistant assigned to the class by Kaiser Permanente, and the two adults were showing the students how to perform an electrocardiogram. The students, with adult guidance, worked on real patients, operated the electrocardiogram, and learned to interpret the results. That afternoon, the students were back in their medical science class learning about the human cardiovascular system, the role that electricity plays in regulating the human heart, and how heart disease interferes with that electrical system, which is what the electrocardiogram is used to detect. "There was a direct and immediate connection between what students were doing in a real hospital with a real physician's assistant that very morning and what they were learning back in their medical science class that afternoon," said Hoachlander. "That did not happen by accident, and that is what I mean by work-based learning."

That is all fine when there are STEM professionals that are available to work with teachers and students, said Nicole Parker, from Johns Hopkins University, but where she comes from in Eastern North Carolina, those professionals do not exist. "How can we change training opportunities for those K-12 teachers to have that knowledge so that all schools can be teaching that way?" she asked the panelists. One way to address that problem, said Atkinson, is to use work-based learning for teacher preparation. Along those same lines, it could be a matter of policy that teachers would have to have some hours in work-based learning for their license renewals, and she thought the group-based learning experience Hoachlander described would be pertinent for teacher preparation and continuing teacher education. Livingston suggested the funding model for public institutions could include a requirement for engaging in work-based learning with public schools. "That could make a big difference and could scale if we got serious about it," he said.

As a final comment, Hoachlander pointed out that education is the third largest U.S. industry, and yet not many schools take advantage of

experience-based learning opportunities within their own walls. For example, he imagined the school systems in North Carolina probably operate the largest transportation system and the biggest computer networks in the state, yet he doubted that North Carolina's schools had work-based experiences connected with those systems. Not to single out North Carolina, Hoachlander wondered how many high school students had ever had internships at the National Academy of Sciences or the U.S. Department of Education.

9

Breakout Discussion Groups

The workshop's second day began with two rounds of six breakout groups, with each round lasting 75 minutes. Workshop participants were free to participate in the discussions in any of the six groups during either round. Discussion leaders led and guided the groups' conversations using a series of questions to draw out relevant ideas and issues. The intent of these groups was not to create a list of specific recommendations for workforce development investments, but to identify important issues and challenges related to workforce readiness, and to create a range of thoughtful options for consideration by federal agencies; research institutions; the National Academies of Sciences, Engineering, and Medicine (the Academies); and other stakeholders in science, technology, engineering, and mathematics (STEM) workforce development.

The six groups and the topics to be addressed by the groups were as follows:

1. **Exploring new/innovative pathways and effective articulation strategies.** What are examples of new and innovative pathways toward a STEM career beyond the more traditional 2-year and 4-year degree from an accredited institution? What is appealing about the new and innovative education and training providers that have arisen in recent years—and what are legitimate concerns about these providers? Which mechanisms are most effective in assessing the quality of innovative, nontraditional providers and the quality of all providers? What roles can federal agencies play in encouraging innovative pathways and innovative providers while ensuring integrity and quality among the providers? How can federal agen-

cies encourage stronger partnerships between traditional 2-year and 4-year colleges and the new, alternative providers?

2. **Professional skills or "employability" skills.** What are the types of nontechnical skills that institutions need to develop more fully in their students to prepare them for career success? How are these skills taught and assessed, both by educational institutions and by employers? Where are institutions doing a good job—and a poor job—of preparing students for career success with respect to problem-solving, creativity, teamwork, and communication? How can agencies foster the development of skills in these key "non-cog" areas as part of regular undergraduate coursework, lab experiences, and internships/fellowships? What new and innovative assessment tools need to be developed to account for the integration of multiple knowledge, skills, and attributes that graduates need for career success? How can a more multidisciplinary approach to grant making foster student development in all of these areas?

3. **STEM career awareness and participation.** How can K-12 schools and postsecondary institutions provide greater awareness of STEM career options and career pathways for students, and ensure their participation in STEM academic programs and careers—especially among low-income and underrepresented minority students? How can federal agencies support career awareness efforts among schools and institutions? How can each stakeholder promote the attainment of advanced degrees in STEM fields, especially for students from underrepresented groups? How can agencies do a better job of providing information and awareness about education and training options to the more than 24 million adult workers who need "upskilling" in our workforce?

4. **Faculty development.** Particularly in rapidly changing STEM fields, what can be done to overcome "faculty calcification" in postsecondary institutions? By what means can federal agencies incentivize more project- and problem-based learning and critical thinking at the undergraduate and graduate levels? How can faculty training support student preparation for nonacademic career pathways for STEM graduate students? What are examples of new and innovative strategies for giving faculty an opportunity to experience the STEM workplace and to bring industry scientists to campus to teach and work directly with students with support from federal agencies? Are faculty able to remain current both in their particular fields of study and in broader, multidisciplinary areas that reflect the increasing influence of "convergence" on STEM careers?

5. **Broadening participation and diversity.** Much has been studied and written over the past 50 years about diversity, access, and equity in STEM, but how much has changed? Where are there time-tested examples of successful interventions at the K-12 and higher education levels that have increased the participation and success of women, underrepresented

minorities, persons with disabilities, and veterans in STEM? What works and does not work in bringing those models to scale? How can business and industry be more directly involved in recruitment and retention of women and minorities in STEM careers? How can the new INCLUDES (Inclusion across the Nation of Communities of Learners that have been Underrepresented for Diversity in Engineering and Science) initiative at the National Science Foundation (NSF) leverage significant reform in this area?

6. **Emerging priority content areas**. What are the content areas that demand more significant focus for preparing the STEM workforce of the future? Are these areas considered particularly important: math/quantitative literacy, computational skills, cyberinfrastructure, analytics, data science, and convergence? What are other areas that need special attention? What mechanisms need to be put into place to create a strong "employer voice," as postsecondary institutions provide experiences that ensure students have broad and deep exposure to emerging content areas? Within these new and emerging content areas, how can NSF and other agencies support skills development, curriculum development, and faculty professional development?

BREAKOUT GROUP REPORTS

Group 1: New and Innovative Pathways

The report for Group 1 was made by four individuals. Dale Allen, from Quinsigamond Community College in Worcester, Massachusetts, said one topic of discussion was how to integrate into federal funding the ability to monitor contiguous labor markets and develop regional approaches to respond to changes in those labor markets. One suggestion from this group was for NSF to consider using its funding pools to incentivize K-16 partnerships for stackable programming to be delivered in concert with state agencies that focus on regional economic development. As Allen reported, the discussion in this group raised the point that there are likely to be common competencies and curricula that could be shared across a state or region, or even nationwide to some degree. One question in this regard, said Allen, was how to bundle NSF funding in a way that would build capacity so that local successes could be developed regionally. He added that NSF has begun to work together with other agencies and to move in that direction to some extent.

Katherine McClelland, from the National Manufacturing Institute, said another topic of discussion in Group 1 was how to make sure students, teachers, and parents understand the career opportunities available in their region and to create mechanisms by which employers can signal what openings will be available and to identify the job skills students will need to fill those openings. She noted, too, that it is important to understand

how to translate the skills students are developing to fit employer needs. Oftentimes, said McClelland, the words employers use to describe skills are not the same as schools are using, but the skills are the same. This group, said McClelland, discussed the importance of using labor market analyses and data to identify the jobs that are available today and those that will be available over the next few years and to then provide that information to parents so that they will be motivated to encourage their children to stay in STEM courses despite challenges they might have with algebra and other classes that often discourage students from sticking with STEM pathways.

Mary Alice McCarthy, from the New America Foundation, then reported that one of the big issues discussed in Group 1 was how to think about workforce as an outcome of workforce development. "If we think about what that outcome is, that could change how programs and pathways are constructed because we are thinking about preparing people for the workforce as a major goal," explained McCarthy. If workforce development is the desired outcome, she wondered what the effect would be on how NSF structures its programs and measures their success. "Are there outcomes we can articulate that can better reflect the workforce mission?" she asked. "We need to think about what those outcomes are and embed them in program structures."

Michelle Van Noy, from Rutgers University, concluded the Group 1 report by noting two additional points that were raised during the group's discussions. One point had to do with the alternative approaches to skills acquisition, such as massive open online courses, boot camps, gaming, extracurricular activities, and others, and the role NSF might play in incorporating these pathways into STEM education and STEM careers. NSF, she said, funds research, pilot programs, and evaluation of different approaches, and it was suggested during the group's discussions that these alternative approaches might be a space in which NSF could become involved in evaluation, particularly regarding access and equity. "It seems there is a great role for NSF to help this space mature and to see what works and what does not work in the K-12 area and in the postsecondary school area," said Van Noy. The second point the group raised was that NSF might develop some programs to help people who enter STEM through alternative pathways understand how their skills and knowledge translate across different domains and how to sell those skills to employers without the traditional credentials that come through more traditional pathways. The group said that NSF should not get involved in credential development, but rather in the area of skills translation, which it is already doing with some programs for military veterans. "This might help more of these outside spaces become inside spaces," said Van Noy.

Group 2: Professional Skills or Employability Skills

Rebecca Dernberger, from Manpower, reported Group 2's discussions, which began, she said, by noting that students need to be at the center of whatever approach is used to develop employability skills. "Whatever the desired outcome, it cannot be accomplished without involving the students because they will be the ones who will be motivated to get the job, get the higher income, and be successful," she said. This group also discussed the importance of developing a common language so that students, parents, and employers truly understand what employability skills are, and group members noted that active listening is one skill students need to develop along with the ability to change their behavior based on what they hear from employers. Other aspects of common language the group noted were project management, entrepreneurship, leadership, conflict resolution, and communication. Regarding communication, the group discussion raised the point that students need to be able to communicate with a wide range of people in the workplace. "You may be a scientist talking to a public relations person and you have to have the ability to make that connection," Dernberger said by way of example.

One challenge raised during the discussion was the need to keep up with ever-changing workforce demands. Industry wants results fast, said Dernberger, and so the speed with which the system can produce workers with needed skills will be a key part of how well the STEM educational enterprise can meet the nation's workforce needs. Group 2 also discussed data and assessment, and the suggestion was made that digital badging may be one solution. The group noted that certification may be a path for some industry skill sets, but credentialing efforts will only be impactful if led by industry. The discussion also raised the point that industry's needs can present a moving target: when unemployment is high, companies look for the "perfect fit," while when unemployment is low, companies become more adaptable and are willing to train new employees.

This group noted that the use of data is important for predicting demand and that social and behavioral scientists may be able to help with their tools for predictive behaviors and for assessing student soft skills. Educational and behavioral psychologists could also help standardize the assessment tools industry uses to judge a student's suitability for employment. Other points of discussion included the need for career centers and universities to develop strong connections with alumni and the suggestion that schools can provide useful data on the types of jobs their alumni hold, the career pathways they take, and perhaps going forward, on income and income growth.

Group 3: STEM Career Awareness

DeRionne Pollard, from Montgomery College, and Russell Rumberger, from the University of California, Santa Barbara, served as the rapporteurs for Group 3. Pollard reported the group spent time talking about the fact there is no simple way to share information about model programs that are occurring across the country for STEM awareness. "Each of us could talk about various programs that were happening in our area, but how do we gather information to share best practices so they can be scaled and replicated across the country?" she asked. The group also discussed the need for communities to assess the pool of local human capital and their capacity to form alliances between local business and educational institutions at all levels. One suggestion from the group was to think about what kinds of policies could motivate those types of evidence-driven partnerships and enable better information sharing across regions and the nation.

This group also discussed planning for career pathways and how such activities have become more deliberate. The group talked about the need to introduce students early to the idea of what it means to be STEM ready so that they can prepare thoughtfully for different options, both including and beyond academia. One way to broaden student perspective about STEM is through early work-based experiences through partnerships with industry that would expose students to some of these options. The group's discussions also noted the importance of situating education so that is has more of a purpose for students and helps them better understand what they have to do to prepare themselves for these opportunities.

Group 3 also discussed the need for STEM education programs to do a better job of branding to shift the perception of STEM from being something for the elite class to an avenue for economic development and the ability to secure rewarding careers for middle-skill STEM workers. The question was raised as to how the STEM community can partner with a wide range of community groups, including social services organizations, unions, and places of worship to get this message out to the broader community. "There needs to be an intentional campaign to do this kind of work," said Pollard. She also reported the group had a robust conversation about the value of the teacher (at all levels—middle school, high school, and college) in getting this message across to students and the need to develop programs to give teachers industry experience so that they can expose students to careers they may not have thought possible.

In his report, Rumberger noted the need to start early with any efforts to raise awareness of the wide range of STEM career opportunities as a major topic of discussion. Various members of the group pointed out there is a large body of information available about STEM careers and STEM career pathways, but the question is how the STEM community can do

better getting that information to students and teachers. One question that arose during the discussions was whether math and physics teachers know about the jobs that may be related to the subjects they are teaching, which led to the idea that there needs to be a mechanism for collecting and synthesizing information across the nation about successful approaches to raising awareness about STEM careers.

Rumberger mentioned a program he has been involved with that is being used with some success in California. This program starts with having ninth graders think about what they might want to do when they first enter the job market given their general interests and how those interests could translate into career pathways. The students then learn about the availability of different kinds of jobs they might like, how they would need to prepare themselves for those jobs, what kind of income they might realize in those jobs, and how that income translates into the ability to buy a house and car and support a desired lifestyle. The students then pick potential careers given their interests and desires and map an educational pathway to those careers. He also noted work being done in the field of behavioral economics, where information is shared using mobile phones and social media to get students to fill out Free Application for Federal Student Aid forms. "Perhaps we could take that kind of approach to build career awareness over time," said Rumberger. Along those lines, there was discussion within this group about using such methods to enlighten teachers about career options for their students.

There was some discussion about gender differences related to experiences in STEM classes and how to overcome gender stereotypes about different STEM careers. The group also noted the challenge of raising STEM career awareness in a fluid labor market. "We talk about mapping students to careers that exist now, but the real challenge is preparing them for jobs that do not yet exist," said Rumberger. "What kind of skills-based education do we provide them in that context?"

Group 4: Faculty Development

Debra Stewart, former president of the Council of Graduate Schools, provided a recap of Group 4's discussions on how the federal government could best invest in faculty development in ways that would help the nation's STEM workforce development efforts. From these discussions, the group identified three priority areas for investment. The first area had to do with how to encourage faculty at all levels to take seriously career development of their students, but particularly among college and research university faculty. The discussion raised the idea that NSF and other agencies should emphasize programs that explicitly recognize that many STEM students, and STEM graduate students in particular, pursue career pathways

outside of academia and need to receive encouragement to engage in professional development activities that will lead to success on those pathways. NSF training grants provide a straightforward mechanism for enabling a range of professional development activities, but as 80 percent of NSF funding goes directly to faculty, other mechanisms will need to be developed. Stewart noted there was strong interest within this group in building student career development into the broader impact statement associated with federal funding. "Faculty could demonstrate broader impact within the context of a grant by paying attention to the ultimate career outcomes of the students who benefit from a grant," Stewart said. Along the same lines, the group's discussions highlighted the need to encourage programs to track the career outcomes of their graduates and acknowledged the professional disciplinary societies are leading the way in this regard. Having said that, the discussions noted the importance of having NSF and other federal agencies encourage universities to collect data on student employment and career outcomes and then share those data with faculty.

The second priority area for investment to come from the group's discussions concerned mentorship development for faculty as part of broader professional development activities. One suggestion from the group was to create opportunities to include mentor training as part of NSF grants to faculty who will be supervising students. It was noted during the discussion that NSF grants already include the requirement to mentor postdoctoral fellows, but the group also acknowledged that adding graduate student mentoring obligations to grants could be seen as an unfunded mandate, so NSF would need to consider how to fund this kind of activity. Stewart said that Group 4 had an interesting conversation about the need to increase the faculty community's understanding and use of the proxy measures for teaching efficacy. "While there is evidence-based research on the efficacy of different strategies, it is not adequately disseminated, and the funding agencies need to begin to think about strategies for incentivizing the active utilization of what we now know about what works in teaching in the evaluation and promotion process for faculty," said Stewart.

The third priority area for NSF Group 4 discussed was to advance and improve faculty members' capability to more effectively utilize what is known about how students learn and embed that pedagogical knowledge into curricula. The group's discussions noted that NSF, with the help of disciplinary societies, should find ways of disseminating new effective ways of teaching and encouraging faculty to adopt those methods. There was some concern voiced during the discussions that pedagogy may differ among the various STEM fields, which might then reinforce what is happening today at universities, which is that the chemistry department teaches one way and the physics department teaches a different way. This discussion led to a suggestion that NSF should reflect on how to take advantage of what many dis-

ciplines are learning and doing with respect to implementing new pedagogy and embedding it in curriculum while doing it in a way that simultaneously spreads this new understanding across STEM disciplines within a university.

Group 5: Broadening Diversity

Holly Zanville, from the Lumina Foundation, and Shelley Westman, from IBM, were the rapporteurs for Group 5. Zanville reported that one key point raised during the discussions was that it will take a 10- to 20-year commitment to programs aimed at broadening the diversity of the STEM workforce to have a major and long-lasting impact, but grants do not go on for this long. She noted that foundation representatives who were present during this conversation suggested program guidelines could accommodate requirements for sustainability and the corresponding development of sustainability plans. Another point the group raised was that meeting the imperative to change the face of science so that it looks like the rest of society will require getting rid of the stigma of exclusion that science and technology have. It will also require getting out the message that STEM careers can include people with a broad range of education and training.

The discussions noted, too, that multiple approaches are needed to address diversity gaps, and funding will have to be spread out across many areas, including social media campaigns and joint efforts with industry, and across all levels of education, including adult education, to make real progress. Efforts to spread the evidence about the importance of developing STEM capabilities across all segments of our society will take tremendous attention from the entire STEM community, Zanville said. The group pointed out the important role that industry will have to play as part of the solution.

This group's discussions also raised the point that there are many innovative programs for mentorship, early engagement in research, and guided pathways that have demonstrated the ability to broaden diversity among students in STEM. The challenge now is to scale these programs to increase their impact. Regarding research, the discussions noted it is important to move beyond just counting heads and delve into what makes for a successful program. "We're going to have to get a little deeper into the weeds as students move through these programs to understand where people are falling out," said Zanville. Along the same lines, it is important to learn from programs that achieve near-zero rates of attrition and develop new pedagogical approaches for reducing attrition.

Other topics discussed included the need to better understand how to use social media more effectively and to get diversity models into the media, the need to use nontraditional and broadened pathways to broaden diversity, and the need to involve families more in efforts to encourage students to pursue STEM career pathways.

Westman added it is important to get across the message that diversity affects everybody, and particularly in STEM. "If you are a man and have daughters, diversity affects you," she said. She also reported there was discussion in the group about why some successful programs do not scale, and one reason suggested was there may not be the same level of involvement, passion, or sponsorship when programs are introduced in new places.

Group 6: Emerging Priority Content Areas

The rapporteurs for Group 6 were Daniel Atkins, from the University of Michigan, and Gregory Camilli, from Rutgers University. Atkins started his report by noting that the participants in this group's discussions were largely from academia, and they rejected the sweeping assumption that higher education was irrelevant to the future of STEM career pathways. "Higher education has and will continue to engage in transformative change in the nature of disciplines and related educational experiences," said Atkins. Participants in this group noted that new fields and new content demands emerge from research activities in academia as well as industry, and that public universities in particular are the largest source of STEM workers with college degrees. It was pointed out that the interdisciplinary activities taking place at the nation's large research universities have and continue to produce new fields and create new industries. One point made during this group's discussions was the difficulty NSF review committees have dealing with interdisciplinary proposals.

Another point of discussion was that the emergence of new fields and the demands for new content are intrinsically an organic process that can and needs to be nurtured, but cannot be prescribed or built. Along those lines, Atkins said an important insight to come from the group's discussions was that it is not NSF's role to specify the exact content of these new areas but to nurture the processes from which they evolve and are propagated and disseminated. It was pointed out that NSF works to encourage community engagement at workshops for visioning and developing new solicitations, with the findings from those activities serving as the basis for new solicitations. New fields then emerge from the intersections and white spaces of existing fields, and this group said that NSF needs to continue supporting those white spaces. The discussions identified a number of emerging areas that merit continued NSF support, including adaptive manufacturing, neurotechnology, autonomous systems, and "x-analytics," or big data, and also raised the point that when NSF identifies a new area of interest, it gets the attention of provosts and deans as well as other private funding agencies that also start investing in these areas. "The role of NSF is to support propagation and adoption of requirements for new

content and new educational experience that emerge from the research agendas that they help nurture," said Atkins in summarizing the group's discussions. "NSF encourages the engagement of researchers in educational innovation that promotes meaningful broader impact. At various times, this latter requirement gets taken more or less seriously, and lately NSF has been placing more emphasis on this."

It was noted during the discussions that the federal government could do more to engage the research community in curriculum development and equipment sharing with K-12 systems, but that the U.S. Department of Education is prohibited from developing curricula. NSF, it was noted, has fewer constraints on curriculum development, but its budget for doing so is limited. Some of the participants in Group 6 suggested NSF needs to be more flexible in its assessment of education and learning research, particularly for projects proposed by groups outside of the formal education area who want minimal funding to pilot a new idea without the need for extensive and expensive evaluation. At the same time, it was noted NSF has played a meaningful role in developing and propagating new content relevant to contemporary science and engineering, and it should study some of these programs with the goal of replicating those successes. As examples, Atkins pointed to the key role NSF played in nurturing integrated manufacturing, the digital library movement that led to Google, the concepts of distributed collaboration, and most recently data science.

Atkins recounted that the group's discussions did note there are some meta issues about how all of this will get done. "If you look at real innovations—open courseware at the Massachusetts Institute of Technology, the School of Information at the University of Michigan, the work in learning analytics coming out of the physics department at the University of Michigan—all of those trace back to leadership, people who stepped forward and took risks, people who were nurtured and supported by their management and who got venture funding," said Atkins. The group also pointed out there will always be questions in academia about incentives, mitigation of risk, faculty not being able to step outside of the norms of publish or perish, and the need for flexibility in terms of broader notions of impact. Another challenge with new areas is how to characterize the skills that they require in students. For example, today, individuals with training in user experience and interface design are in high demand, but it was only a couple of years ago that very few people knew what those were and what skills they required.

Camilli said another topic discussed was employer concerns for high-demand skills, which he said is different from employer needs in high-demand fields. One subject not broached, he said, was globalization, which he characterized as the elephant in the room, and he thought it might be interesting to compare the National Science Board reports from 2012 and 2014 and the

different pictures they portray of off-shoring of research and on-shoring of production. "If we don't take these issues into consideration, we're not preparing the workforce we think we're preparing," said Camilli. He also voiced his opinion that NSF and the Academies should have American interests at heart, and those are not always the interests of industry. "I believe industry should be concerned about the return on investment for shareholders—that is industry's moral imperative—but our moral imperative is to think about how globalization affects the kinds of skills and demand for those skills," said Camilli as a final comment.

DISCUSSION

Jodi Wesemann, from the American Chemical Society, highlighted that throughout the breakout groups that she participated in there was a compelling need for data collection to feed back to the research questions and inform ideas coming forward. Atkins added he heard an appeal for applying big data to the topic of how to approach issues such as diversity and meeting the demand for skills. "This suggests we need to think about what kind of infrastructure we could put in place that would allow for the aggregation and sharing of data," said Atkins. He noted that a coalition of Big Ten schools is cooperating on a system for sharing the output of learning management systems to inform learning research, and he suggested NSF might consider taking an inventory of projects such as this and making a modest investment to nurture cooperation, interoperability, and sharing between these projects. Along those lines, he noted NSF has started a regional data hub initiative that could grow and accommodate sharing of data relevant to learning research. "We have to not assume the infrastructure for data sharing actually exists and be intentional about developing that infrastructure," said Atkins. Thomas Rudin, from the Academies, suggested there are lessons to be learned from the health care and manufacturing industries, which have built systems to share data in a manageable and concise manner.

Earnestine Easter, from NSF, commented that the University of Michigan, with NSF support, has developed a new institute that is building an infrastructure to enable a variety of longitudinal studies dealing with workforce development issues. This institute, she said, is integrating existing data from a number of sources to enable studies that will include examining the economic impact of investment in STEM workforce development. She added that the University of Michigan will be making this infrastructure available to all investigators who want to do research using these data.

As a final comment, Aprille Ericsson, from NASA Goddard Space Flight Center, remarked that when talking about innovation, it is important to resist not moving ahead and not taking risks in the absence of data. Science and technology advance, she said, because people take risks and try new things in the absence of data.

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Potential Next Steps

The workshop's final activity was to engage in an open discussion, moderated by Thomas Rudin, director of the National Academies of Sciences, Engineering, and Medicine's Board on Higher Education and Workforce, on two sets of questions:

1. What can institutions, businesses, and federal agencies do *now*? What can you do now based on what you have heard over the past day and a half to take steps forward, either alone or in collaboration with others?
2. What are remaining research questions that need further attention?

WHAT CAN INSTITUTIONS, BUSINESSES, AND FEDERAL AGENCIES DO *NOW*?

Jennifer Davis, from Goodwill Industries International, pointed out her organization, as well as others such as Boys and Girls Clubs of America, Big Brothers Big Sisters of America, United Way of America, and Job Corps, is in every state and serves predominantly the underrepresented populations that the science, technology, engineering, and mathematics (STEM) community wants to reach. Goodwill Industries works in the public schools, operates charter schools, provides college navigators to help students be successful in college, and has partnerships with community colleges nationwide. "We could be your partner, but our degrees are in social work and anthropology," said Davis. "We are not skilled or prepared to talk about STEM, but our aspiration is for the people we serve to have great careers." She said Goodwill and other national nonprofit organizations are serving

the pipeline of individuals who want to move up the economic ladder. "We would love to partner with those of you who might be interested in reaching the people that we serve and building our capacity to deliver that support," said Davis.

Rudin asked Davis what Goodwill would need from industry and higher education to be successful. She replied that one approach, which the organization has used with other industries, would be to bring representatives from a STEM industry to Goodwill's headquarters for an all-day discussion about pathways, identifying the skills and credentials that are in demand. Goodwill would then bring in the local agencies that are interested in participating in the program and form an affinity group to enable peer sharing and peer learning. "We share what we learn nationally so that the local agencies can use that with local industry," explained Davis. "We also put together training programs, sometimes at Goodwill, sometimes in partnership with local community colleges."

Brian Mitchell, from the National Science Foundation (NSF), commented that some academic institutions are creating avenues for their students to get involved with local schools, such as through service-learning opportunities, and he noted there is now a Carnegie Classification of Institutions of Higher Education designation for such opportunities. "Many undergraduates now are civically engaged, and service learning is one mechanism by which you can connect academics through reflective observation and learning to make a difference in a community in partnership with local community nonprofit partners," said Mitchell. He added that these are structured activities, and there is information available on how to develop and structure such programs. "This is one way to connect what we are doing at the research level that goes to the broader impact discussion," said Mitchell.

Meghan Wills, from the National Governors Association, suggested state and local government and state and local workforce investment boards can play an important role in bridging what industry is looking for with what the education system is doing to prepare students. These boards are chaired by someone from industry, she explained, and they can bring that industry perspective to help ensure that the public workforce system is successfully preparing students for jobs. Those entities, she added, can serve as the convening bodies for these discussions. Rudin noted that states, and not the federal government, are often the main forces in supporting workforce training budgets and policies and that states need to play a central role in any effort on workforce development and education going forward.

Christine Burgess, from the American Association for the Advancement of Science, said one thing the STEM community can do now is think both about how to build diversity into all programs and about how to implement metrics to truly measure the impact of these efforts. It is important, she

said, to provide a framework organizations can take off the shelf and adapt easily to evaluate diversity to inform their efforts. Rudin asked Burgess what she thought about the impact of institutions creating new positions such as chief diversity officer, and she replied that if the chief diversity officer goes out and pushes people in the organization to look at what they are doing and provides resources and ideas to help them make the changes that will improve diversity, that is a positive step. "There has to be a commitment by the institution and the right person to be pushy," said Burgess.

Daniel Atkins, from the University of Michigan, made two suggestions on steps that could be taken in the relatively near future. Today, he said, there are many places where public schools are being converted to STEM or STEAM (science, technology, engineering, arts, and mathematics) schools, and the curricula at these schools are largely project based. He asked if anybody is looking at the landscape of these schools and identifying lessons that could be translatable or generalizable. His other suggestion is to think systematically about what might come from being more intentional at reducing the barriers between formal and informal learning systems and building synergy between the two to create a new ecology of learning. He noted this is the theme of a MacArthur Foundation effort on connected learning that is not focused on STEM but is not hostile to it either. Rudin, posing a rhetorical question, wondered why school districts create these alternative schools with project-based curricula to serve select groups of children—and not all children.

Beth Buehlmann, from the Council of Graduate Schools (CGS), said from her perspective of someone who was a congressional staff member for more than 20 years, one problem is that the NSF has a different taxonomy of STEM disciplines than does the U.S. Department of Labor, which has a different taxonomy than the one used by the U.S. Department of Education, and so on. "We cannot even talk about this problem across agencies unless we develop a common definition of STEM," said Buehlmann. She then commented from CGS's perspective that the STEM community is not doing a good enough job getting across the message that an investment in graduate education is an investment in a public good that benefits our local communities and society as a whole. "We are not getting that message out in a way that is understandable and that convinces the federal government to fund graduate student education," said Buehlmann. In particular, she noted that many high-demand middle-skills jobs are filled by individuals with master's degrees, yet federal agencies are not supporting the programs that would produce those middle-skills employees.

Meredith Hatch, from Achieving the Dream, Inc., said that when talking about the STEM pathway it is critically important for institutions, businesses, and federal agencies to think about pathways in terms of on-ramps and off-ramps and not as straight lines. "That is the way students are get-

ting prepared for STEM careers," she said. Community colleges, she added, play a growing role in providing those on-ramps. Rudin noted that half of all undergraduates in this country are at community colleges.

Celeste Carter, from NSF, reminded the workshop participants that her agency had funding from the American Recovery and Reinvestment Act of 2009 to offer an equivalent to the professional science master's degree in only 1 year, a program that she said was "wildly successful." The program that she runs today at NSF, the Advanced Technological Education program, has a request for proposals for projects that would infuse business and entrepreneurial skills into technician education programs and provide students with a better understanding of what working in industry entails and how they might start their own companies when they develop their own ideas. This program started as a community college innovation program that brought 10 finalists to NSF for a week-long boot camp that included meeting with venture capitalists and an evening reception at the Capitol that was attended not by staffers, but by representatives and senators.

Regarding building diversity, the Massachusetts Institute of Technology (MIT) took a different approach, said Aprille Ericsson, from NASA Goddard Space Flight Center. At the end of 2013, MIT aligned provost positions with diversity themes and women to create a new position that includes equitable treatment to empower and leverage diversity. While that represents an important step, Ericsson's concern is that it does not impact recruitment. She then made two suggestions: "If every person here mentored one student, think of the impact that would make," she said. "Imagine, then, if that became a national theme—if each STEM professional mentored a student." She proposed creating an inexpensive web-based infrastructure where students could select a STEM professional as a mentor and that would use e-mentoring via Skype and other technologies to expose students of all ages to the many careers available in STEM. Her second suggestion regarded all of the federal STEM employees who are projected to retire over the next decade: "What if these individuals went back to schools and taught something about their profession?" asked Ericsson. "If that brainpower would go into schools and help with things like robotics clubs and other activities, we would be infusing all of that brainpower back into our youth, giving them an experienced person to talk to about the relevance of their classes." Carter added that STEMconnector[1] has already collected 400,000 pledges toward its goal of signing up one million women mentors.

[1] STEMconnector is "a consortium of companies, nonprofit associations and professional societies, STEM-related research & policy organizations, government entities, universities and academic institutions concerned with STEM education and the future of human capital in the United States." More information is available at http://www.stemconnector.org/; last accessed January 06, 2016.

Lida Beninson, an American Association for the Advancement of Science Science and Technology Policy fellow at NSF, recommended a paper on collective impact that talks about the importance of cross-sector coordination and partnerships for enabling large-scale social change of the sort that this workshop has been addressing (Kania and Kramer, 2011). In this paper, the authors state there are a few factors that lead to a successful collective impact project: having consistent measurement across all of the involved partners; having a solid infrastructure with somebody overseeing the work that all of the organizations are doing; and having a project that is coordinated, not redundant, appropriate to the locale, and consistent with the project's mission.

WHAT REMAINING RESEARCH QUESTIONS NEED FURTHER ATTENTION?

One question that needs further research, said Debra Stewart, former president of the Council of Graduate Schools, is How are developments in technology going to transform the workforce in the future, including how many workers we will need? Some projections, she noted, say that within 20 years the workforce will only need to be 20 percent of what it is today, and as an example she wondered what the impact of the driverless car will be on future employment in the transportation industry. "What if the workforce of the future looks nothing like the workforce of today?" asked Stewart. Carol Van Hartesveldt, from NSF, added a corresponding question: What are the ways in which new technologies are going to change education and research and what will the impact be? She also noted that NSF, with a budget of $7 billion, can be catalytic in its funding but not sustaining.

Jodi Wesemann, from the American Chemical Society, proposed two questions that need further research: What is the strategy for taking what is happening in education research and our discipline-based education research and bringing it into classrooms, programs, and partnerships? What are the strategies for taking a successful program and translating it into different environments, across disciplines, and across all educational levels?

Matthew Wilson, from NSF, listed several questions in the National Science Board's most recent report: What are the barriers that people who get STEM degrees but do not go into STEM careers encounter, particularly for women and minorities? Is it in their interest to forge new pathways not yet characterized as STEM? What are the influences that motivate career pathway changes throughout a career? Where do people learn the "employability" skills that employers are saying they need? Given that degrees do not necessarily reflect skills, how does the federal statistical system measure skills and how can it adapt and update these measures to reflect skill levels?

Betsy Bizot, from Computing Research Association, posed these questions: What do career paths look like, since most are not linear? What do people do with their skills and how should data to answer this question be collected and used to better prepare people for careers?

Roy Swift, from Workcred, asked: What can we learn from other models of change? He cited the case of health care, which is moving from a hospital-based model to a community and population-based model. He suggested that STEM should develop a community education model and look at how to develop a learning community and have higher education interface with that learning community to produce a more integrated approach to education and skills development.

Greg Camilli, from Rutgers University, offered the final question, which addressed specific problems in information technology: What are the difficulties that computer science majors face in getting jobs after graduation? Computer science majors report that positions are not available, and so the problem may be market based, but it may be the result of the influx of workers from other fields into the information technology field. "We need to talk about this dynamic back-and-forth between jobs when we think about training and barriers," said Camilli.

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Appendixes

Appendix A

Workshop Agenda

NATIONAL SUMMIT ON DEVELOPING A STEM WORKFORCE STRATEGY

A National Academies of Sciences, Engineering, and Medicine Workshop
Funded by the National Science Foundation

September 21-22, 2015
Room 100
Keck Center
500 Fifth Street NW, Washington, DC

Board on Higher Education and Workforce

Themes for the Summit

- The exploration of new, innovative, and dynamic education and training pathways (and education providers) that lead to college and career success in STEM fields, in addition to the more traditional pathways and education/training providers.
- Understanding the "voice of the employer" and encouraging stronger college-business partnerships for more effective and sustained two-way communication between business and higher education.
- Understanding the role of K-12 education in preparing the workforce of the future, and understanding how stronger university-school partnerships can enhance STEM workforce readiness at all levels.

- Examining current and prospective developments in undergraduate and graduate education and their impact on STEM workforce readiness, including the encouragement of more hands-on, research-based learning, an increased emphasis on both interdisciplinary learning and "team science" at all levels, the desire for more internships, apprenticeships, and traineeships for undergraduate and graduate students.
- More clearly defining what we mean by a "STEM-capable workforce," including a recognition that many so-called non-STEM careers still require some level of STEM capability or STEM-savviness.
- Identifying innovative and effective ways in which federal investments in education and training can enhance STEM workforce readiness.

AGENDA: Day 1, September 21, 2015

7:30–8:00 a.m.	Breakfast and informal conversation (Lobby)
8:00–8:15 a.m.	**Rodney Adkins, Former Senior Vice President for Strategy, IBM Corporation. (Chair of the Summit Planning Committee)** Welcome, introductions, purpose of the Summit
8:15–8:30 a.m.	**Dr. France Córdova, Director, National Science Foundation** Welcome from the sponsor
8:30–9:15 a.m.	**Dr. Rush Holt, CEO, American Association for the Advancement of Science** The Link Between STEM Education and Workforce Productivity
9:15–9:45 a.m.	**Kelvin Droegemeier, NSB Vice Chair and Chair of its Science & Engineering Indicators Committee** "Revisiting the STEM Workforce" An overview of the new report of the National Science Board
9:45–10:30 a.m.	**Dr. Irwin Kirsch, Director of the Center for Global Assessment, Educational Testing Service** "America's Skills Challenge: Millennials and the Future"

10:30–10:45 a.m. Break

10:45–11:30 a.m. **Panel 1. The student voice and recent graduate voice: "what works—and what doesn't work—in terms of workforce preparation?"**
—Thomas Rudin, Director, Board on Higher Education & Workforce National Academies (Moderator)
—Abby Estabillo, Electrical Engineering Student at the University of Maryland, College Park.
—Kenneth Gibbs, Cancer Research Fellow, National Cancer Institute
—Camila Ballesteros, IT Cybersecurity Student, Montgomery College, Maryland

11:30–12:30 p.m. **Panel 2. Key challenges facing U.S. employers in high demand fields**
—Greg Camilli, Professor of Educational Psychology, Graduate School of Education, Rutgers University (Moderator)
—Melvin Greer, Chief Senior Fellow and Chief Strategist at Lockheed Martin Information Systems and Global Solutions
—Jennifer McNelly, President, Manufacturing Institute
—Olivia Khalili, Director, Yahoo for Good, Yahoo, Inc.
—Ted Childs, Jr., Founder, Ted Childs, LLC.

12:30–1:30 p.m. Lunch
Keynote Speaker: Freeman Hrabowski, President, UMBC
"What do we mean by 'STEM-capable' students and workers?"

1:30–2:30 p.m. **Panel 3. Successful strategies for aligning higher education programs, curricula, and lab experiences with workforce needs**
—Daniel Atkins, Professor Emeritus of Information, School of Information and Professor Emeritus of Electrical Engineering and Computer Science, College of Engineering, University of Michigan (Moderator)
—William Rudman, Executive Director of the AHIMA Foundation, Vice President of Education Visioning for AHIMA, and Representative from the National Network

—Sanjay Rai, Senior Vice President of Academic Affairs, Montgomery College, Maryland
—Christine Ortiz, Dean for Graduate Education, MIT

2:30–2:45 p.m. Break

2:45–4:00 p.m. **Panel 4. Alternative pathways and alternative providers—helping the *new* "traditional student" prepare for success in the STEM workforce**
—Mary Alice McCarthy, Senior Policy Analyst, New America Foundation (Moderator)
—Liz Simon, Vice President, Legal & External Affairs, General Assembly
—Adam Enbar, President, The Flatiron School
—Ruan Pethiyagoda, Chief Strategy Officer, Hack Reactor
—Maureen Grasso, Dean of the Graduate School, NC State University

4:00–5:00 p.m. **Panel 5. Focusing on K-12 STEM education and workforce readiness: How do we lay the groundwork early for success in STEM careers?**
—Russell Rumberger, Professor of Education in the Gevirtz Graduate School of Education, UC-Santa Barbara (Moderator)
—June Atkinson, Superintendent of Public Instruction, North Carolina
—Gary Hoachlander, President, ConnectEd: The California Center for College and Career
—Jeff Livingston, Former Senior Vice President for Education Policy and Strategic Alliances, McGraw-Hill Education Group

5:00–5:30 p.m. **Brief overview of six high priority themes for federal agency support and investment by the session moderators—to lay the groundwork for tomorrow morning's breakout group discussions (see details on the following pages and in your agenda books).**

Group 1. New/Innovative Pathways: Mary Alice McCarthy and Kim Green
Group 2. Professional Skills or Employability Skills: Rebecca Dernberger

Group 3. STEM Career Awareness: DeRionne Pollard and Russell Rumberger
Group 4. STEM University Faculty Development: Debra Stewart
Group 5. Broadening Diversity: Holly Zanville and Shelley Westman
Group 6. Emerging Priority Content Areas: Daniel Atkins and Greg Camilli

5:30 p.m. Adjourn Day 1

5:30–6:30 p.m. Reception

AGENDA: Day 2, September 22, 2015

8:00–8:30 a.m. Breakfast and informal conversation (Lobby)

(Pick up your tent card and go directly to your preferred breakout room at 8:30 a.m.)

8:30–9:45 a.m. **Concurrent Breakout Groups: To discuss, dissect and prioritize topics**
Breakout group sessions will be modestly structured to allow for a free-flowing discussion, but with the goal of surfacing key ideas that can guide both public policy strategies and institutional strategies.

Group 1. New/Innovative Pathways—Room 101
Group 2. Professional Skills or Employability Skills—Room 103
Group 3. STEM Career Awareness—Room 106
Group 4. Faculty Development—Room 201
Group 5. Broadening Diversity—206
Group 6. Emerging Priority Content Areas—Room 208

10:00–11:15 a.m. **Round 2 of Concurrent New Breakout Groups (same topics and rooms)**

11:15–11:30 a.m. Break

11:30–12:30 p.m.	**Report out from each breakout group on the topics, priorities, and strategies that surfaced during the discussions, as well as the key remaining questions that merit additional research/consideration**
12:30–1:15 p.m.	Lunch
1:15–3:00 p.m.	**Full group discussion of priority topics, considerations for federal investment, and identification of remaining questions that merit further research and analysis**
3:00 p.m.	Meeting adjourns

Appendix B

Biographical Sketches of Workshop Speakers and Planning Committee Members[1]

Rodney Adkins retired as senior vice president of Corporate Strategy from IBM at the end of 2014 after more than 33 years of service for the company. In this role he was responsible for leading continuous transformation across IBM and developing strategies that are linked to execution plans for a new era of computing, new markets, and new clients. Adkins was previously senior vice president of the systems and technology group, a position he held since 2009. In this role he was responsible for all aspects of IBM's semiconductor, server, storage, and system software businesses, as well as the company's integrated supply chain and global business partners organizations. Before heading the systems and technology group (STG) he was senior vice president of STG development and manufacturing, a position he held since 2007. Adkins has held a number of development and management roles in his IBM career, including general manager positions for the PC Company, UNIX Systems, and Pervasive Computing. Inducted into the National Academy of Engineering in 2005, Adkins is also a member of the Executive Leadership Council, and the National Society of Black Engineers, which in 2001 awarded him the Golden Torch Award for Lifetime Achievement in Industry. In 2011, *Black Enterprise* magazine chose Adkins as its Corporate Executive of the Year, and in 2002, *Fortune* magazine named Adkins one of the 50 Most Powerful Black Executives in America. He serves on the board of directors for United Parcel Service (UPS), the national board of the Smithsonian Institution, and the board of directors for the National Action Council for Minorities in Engineering.

[1] Names appear in alphabetical order.

Adkins also serves on the Georgia Tech Foundation, Rollins College Board of Trustees, University of Maryland Baltimore County Board of Visitors, and the University of Miami College of Engineering Visiting Committee. Adkins holds a bachelor of arts degree with an emphasis in physics from Rollins College, bachelor of science and master of science degrees in electrical engineering from the Georgia Institute of Technology, and honorary doctor degrees from both the Georgia Institute of Technology and the University of Maryland, Baltimore County.

Daniel E. Atkins is a professor in the school of information and in the department of electrical and computer engineering at the University of Michigan (UM), Ann Arbor. He holds a Ph.D. in computer science and M.S. in electrical engineering from the University of Illinois, and a B.S.E.E. from Bucknell University. He began his research and teaching career in the area of high-performance computer architecture, and led or participated in the design and construction of seven experimental machines. He developed high-speed arithmetic algorithms now widely used in modern computers. He did pioneering work in application-specific computer architecture, including interdisciplinary collaboration on medical image processing with the Mayo Clinic. In 1982 Atkins assumed academic leadership positions as associate dean for research and graduate programs and later interim dean of engineering at the University of Michigan. As part of a leadership team with James Duderstadt and Charles Vest, he presided over the rapid rejuvenation of the UM College of Engineering. The college, for example, replaced two-thirds of its faculty in 6 years. Atkins assisted in many aspects of this rejuvenation, but was specifically responsible for establishing one of the first and leading academic distributed computing environments, the CAEN (Computer-Aided Engineering Network), and for shifting the research culture to encompass more multidisciplinary, team-based projects often including industrial collaboration. The college's sponsored research volume more than tripled during this 5-year period. In the early 1990s, Atkins became the founding dean of the University of Michigan School of Information (www.si.umich.edu), also known as SI. This professional graduate school (M.S. and Ph.D.) is committed to learning, research, and societal engagement through a holistic, socio-humanistic-technical approach to "bringing people, information and technology together in more valuable ways." The UM SI has been the leader in defining and creating a new genre of "information school, or I-School" now emerging at many universities. Atkins also formed and directed an Alliance for Community Technology (ACT) sponsored by the W. K. Kellogg Foundation to support the innovative use of information technology in service of broader participation in civil society. Atkins also serves as a consultant to Kellogg on the innovative use of information and communication technology for enriching education opportunities for at-

risk youth in the United States, and for both rural communities and higher education in southern Africa. Atkins is now in the early stages of developing an international consortium to help align investment and collective action among the diverse stakeholders necessary to accelerate the creation and transformative application of cyberinfrastructure for enhancing learning, research, and societal engagement—and the synergy between them.

June St. Clair Atkinson is the state superintendent of public instruction in North Carolina and has served in that role since 2005. During her career in education, she has been a public school teacher, community college instructor, and state administrator. As a member of the North Carolina Department of Public Instruction, she has been a director of Career-Technical Education, director of Vocational-Technical Education, and director of Instructional Services. Atkinson has also served as president of the National Business Education Association and the National Association of State Directors for Career-Technical Education Consortium. She is currently serving as the president of the National Council of Chief State School Officers.

Camila Ballesteros is currently working as a cybersecurity intern for Montgomery College in Montgomery County, Maryland, where she is a second-year student pursuing an associate degree in software engineering. Ballesteros is a member of the student Cybersecurity Club. She is a team player with a great passion for cybersecurity, with good communication skills. Ballesteros has a capacity for learning new systems and processes quickly. She does volunteer work at Identity as a counselor/mentor working with Latino youth after school and on Saturdays to provide a safe environment where they are able to express how they feel and receive help with homework. She also volunteers for the Aces Program, helping with parent nights and after school.

Gregory Camilli is in the Graduate School of Education (GSE) as a professor in the Department of Educational Psychology at Rutgers University. Camilli was a professor in the Department of Educational Psychology at Rutgers for 23 years, and he was the chair of the department from 1996 to 1999 before joining the faculty at the University of Colorado Boulder School of Education in 2010. His research interests include early education interventions, school factors in mathematics achievement, and multilevel item response theory models. He has published many scholarly articles on topics including psychometrics, research methods and statistics, test fairness, and reading research. He is also the co-editor of multiple books about education research, and his most recent book is entitled *Handbook of Complementary Methods in Education Research*. He received special

recognition from the American Educational Research Association for the handbook. Camilli received his B.A. in psychology in 1975 and his M.A. and Ph.D. in education (research and evaluation methodology) in 1979 and 1980, respectively, all from the University of Colorado at Boulder. He believes that "good intentions need to be supported by evidence when designing practices, policies, or programs," and his research has focused on both methodological approaches and substantive issues. Currently, his research projects include Bayesian regression for meta-analysis and the effects of affirmative action in law school.

J.T. (Ted) Childs, Jr. retired from IBM in August 2006 after a distinguished 39-year career as a member of their corporate human resources team. Upon retiring, he founded Ted Childs™, LLC. The role of Ted Childs™ LLC is to serve as a global "strategic diversity advisor" to senior management and a client's workforce diversity team. While at IBM, he held a variety of human resource assignments, including 15 years of executive responsibility for global workforce diversity programs and policies. In addition, Childs served as executive assistant to Dr. Benjamin L. Hooks, executive director of the NAACP, on an IBM social service leave from March 1982 to September 1983. He is a graduate of West Virginia State University, a member of the board of directors and a past president of the university's foundation, and a life member of the West Virginia State University National Alumni Association. In December 1989, Childs was appointed by Governor Mario Cuomo to the New York State Governor's Advisory Council on Child Care. In 1992, he was named co-chair of the National Council of Jewish Women's Work Family Advisory Board and was presented with their Founder's Award for commitment to quality of life issues for U.S. families. Childs is a member of the Executive Leadership Council (ELC), The Families and Work Institute Board of Directors, and was installed as a fellow in The National Academy of Human Resources in 2001. He has received Honorary Doctorate of Humane Letters degrees from Pace University (2001), West Virginia State University (2003), and Our Lady of the Elms College (2005). Childs holds life memberships in the National Association of African Americans in Human Resources, the National Council of Negro Women, Inc., the National Organization of Women (NOW), Omega Psi Phi Fraternity, Inc., the NAACP, the Sierra Club, and the Bass Anglers Sportsmen Society.

France A. Córdova was sworn in as director of the National Science Foundation (NSF) on March 31, 2014. Nominated by President Barack Obama to head the $7.2-billion independent federal agency, she was confirmed by the U.S. Senate on March 12. Córdova leads the only government science agency charged with advancing all fields of scientific discovery, technological innovation, and science, technology, engineering and mathematics

(STEM) education. NSF's programs and initiatives keep the United States at the forefront of science and engineering, empower future generations of scientists and engineers, and foster U.S. prosperity and global leadership. Córdova is president emerita of Purdue University, where she served as president from 2007 to 2012. From 2002 to 2007, she led the University of California, Riverside, as chancellor and was a distinguished professor of physics and astronomy. Córdova was the vice chancellor for research and professor of physics at the University of California, Santa Barbara, from 1996 to 2002. From 1993 to 1996, Córdova served as NASA's chief scientist. Prior to joining NASA, she was on the faculty of the Pennsylvania State University where she headed the department of astronomy and astrophysics from 1989 to 1993. Córdova was deputy group leader in the Earth and space sciences division at Los Alamos National Laboratory from 1988 to 1989 and staff scientist from 1979 to 1989. She received her Bachelor of Arts degree from Stanford University and her doctorate in physics from the California Institute of Technology in 1979. More recently, Córdova served as chair of the Board of Regents of the Smithsonian Institution and on the board of trustees of Mayo Clinic. She also served as a member of the National Science Board (NSB), where she chaired the Committee on Strategy and Budget. As NSF director, she is an ex-officio member of the NSB. Córdova's scientific contributions have been in the areas of observational and experimental astrophysics, multi-spectral research on x-ray and gamma ray sources, and space-borne instrumentation. She has published more than 150 scientific papers. In 1997, she was awarded an honorary doctorate by Loyola Marymount University, Los Angeles. She is a recipient of NASA's highest honor, the Distinguished Service Medal, and was recognized as a Kilby Laureate in 2000. The Kilby International Awards recognize extraordinary individuals who have made "significant contributions to society through science, technology, innovation, invention and education." Córdova was elected to the American Academy of Arts and Sciences and is a National Associate of the National Academies. She is also a fellow of the American Association for the Advancement of Science (AAAS) and the Association for Women In Science (AWIS). She is NSF's 14th director, succeeding Subra Suresh who stepped down in March 2013.

Rebecca Dernberger was named vice president and general manager for Manpower's Northeast Division in 2008. In her role, Dernberger oversees all aspects of over 70 branches of the Northeast Division. Annual U.S. revenue of Manpower is $1.7 billion and $19 billion globally. Dernberger joined Manpower in 1984 and served on the frontline of the largest U.S. franchise; eventually she became president of the franchise in 2003. She served as president until 2008 when the franchise was sold to Manpower Group. Recognized as an expert in workforce trends, Dernberger is pas-

sionate about the manufacturing and skilled trades sectors. Active in the community, Dernberger currently serves as a member of The Committee of 200, the Manufacturing Institute Board, the Manpower Public Sector Board of Directors and on the Talent 2025 Board. She has served on chamber boards, economic development boards, hospital boards, diversity boards, and workforce development boards. A resident of Zeeland, Michigan, Dernberger earned her bachelor's degree in business and psychology from Hope College in Holland, Michigan.

Kelvin K. Droegemeier earned a B.S. with special distinction in meteorology in 1980 from the University of Oklahoma, and M.S. and Ph.D. degrees in atmospheric science in 1982 and 1985, respectively, from the University of Illinois at Urbana-Champaign. He joined the University of Oklahoma faculty in September 1985 and in 1987 was named a Presidential Young Investigator by the National Science Foundation. Droegemeier's research interests lie in thunderstorm dynamics and predictability, variational data assimilation, mesoscale dynamics, computational fluid dynamics, massively parallel computing, and aviation weather. An expert in aviation forensic meteorology, he has served as a consultant to Honeywell Corporation, American Airlines, Continental Airlines, the National Transportation Safety Board, and Climatological Consulting Corp. In 2004, Droegemeier was appointed by President George W. Bush to a 6-year term on the National Science Board, the governing body of the National Science Foundation that also provides science policy guidance to Congress and the president. He chaired the board's standing committee on programs and plans and task force on cost sharing, and co-chaired the Hurricane Research Task Force. In 2010, Droegemeier was nominated by President Barack Obama for a second term on the National Science Board. In 2005, Droegemeier was appointed associate vice president for research and in 2009, vice president for research at the University of Oklahoma. He is a fellow of the American Meteorological Society, former chairman of the board of the University Corporation Atmospheric Research, former member of the Microsoft Research Corporation External Advisory Board, and current member of the boards of Oak Ridge Associated Universities, Oak Ridge Associated Universities Foundation, Council on Governmental Relations, National Weather Museum and Science Center, and Norman, Oklahoma, chamber of commerce. He also is a trustee of Southeastern Universities Research Association.

Adam Enbar is CEO of The Flatiron School, which he co-founded to create a system of education that's accountable for student results. Flatiron School has trained thousands of software engineers and placed them into jobs at companies like Google, Intel, and The New York Times through intensive

3- to 5-month programs. Flatiron has also partnered with the City of New York to launch the NYC Web Development Fellowship, focused exclusively on students without college degrees, over 90 percent of which come from diverse and low-income backgrounds. In 2015, Flatiron School released the industry's first and only independently audited jobs report verifying 99 percent graduation rate with 98 percent job placement and $74,000 average starting salary for graduates. Enbar began his career as a real estate developer before moving to Boston where he worked at HubSpot, leading the National Accounts team while the company grew from 70 to 350 employees in 2 years. He then spent time working in venture capital with Charles River Ventures working with entrepreneurs in education, enterprise software, and connected devices. All the while, Enbar remained close to education, teaching first grade in Brooklyn, teacher assisting a marketing course at Harvard, and volunteer-teaching entrepreneurship at South Bay Correctional Facility in Boston. He received his B.S. from Cornell University and MBA from Harvard Business School.

Abby Estabillo is a junior electrical engineering student at the University of Maryland, College Park. She feels passionately about inspiring young girls to take interest in the STEM field. Her goals include working for an electrical engineering company and starting a platform for these young girls to express their interest in the engineering field. In the past, she interned at the National Academy of Engineering (NAE) for three summers where she worked on the EngineerGirl website. Abby continues to work for NAE as a part-time college intern. She was also an administrative assistant for a nonprofit organization called Commonweal Foundation for 3 years. In the future, Estabillo plans on looking for internships in engineering firms once she graduates college.

Kenneth (Kenny) Gibbs, Jr. is a cancer prevention fellow at the National Cancer Institute (NCI) in the Science of Research & Technology Branch. Gibbs conducts policy-relevant research aimed at strengthening the research enterprise. His work focuses on: biomedical graduate and postdoctoral training, workforce development and workforce diversity (specifically, understanding the mechanisms of career development among recent biomedical Ph.D. graduates and postdoctorates, and how they differ across lines of race/ethnicity and gender, so that strategies can be developed to promote inclusive excellence); and developing methodologies for evaluation and dissemination of best practices in "team science." Prior to NCI, Gibbs completed an American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellowship at the National Science Foundation in the Directorate for Education and Human Resources, Division of Human Resource Development. As an AAAS fellow, he contributed

to the federal government's strategic, science, technology, engineering, and mathematics (STEM) education plan by developing evidence-based recommendations for engagement programs, and initiated the Burroughs Wellcome Fund supported "STEM Ph.D. Careers" research project to identify the factors impacting the career development of recent Ph.D. graduates. Gibbs completed his Ph.D. in the immunology program at Stanford University, and received his B.S. in biochemistry and molecular biology summa cum laude from the University of Maryland, Baltimore County, where he was a Meyerhoff, MARC, and HHMI scholar. Gibbs serves on the board of directors for the National Postdoctoral Association. He has written about career development for *Science Careers*, and science diversity issues for *Scientific American*.

Maureen Grasso is dean of the graduate school at North Carolina State University. Over the past 14 years as a dean in graduate education, she has focused her research and strategic initiatives on enhancing student success from admission through completion. While at the University of Georgia, Grasso was instrumental in reducing time to degree and increasing completion rates, working with faculty to make program-level changes to improve mentoring, working with faculty to develop new and innovative interdisciplinary degree programs, and working with donors to endow fellowships for graduate students. She was an active participant in the Council of Graduate Schools' Ph.D. completion project. Grasso served as a member of the Council of Graduate Schools and Educational Testing Service's commission for *Pathways Through Graduate School and Into Careers* report. In 2009, she received the Award for Outstanding Contribution to Graduate Education in the Southern Region, USA. Currently she is working with faculty at North Carolina State University to enhance the success of students with a focus on best practices in mentoring. Prior to moving into graduate education, she served as a faculty member at the University of North Carolina Greensboro and began her academic career at the University of Texas at Austin. Her research has focused on the sustainable built environment with a focus on thermal and bidirectional solar optical properties of textiles. Grasso is a fellow of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers where she served as vice president and on the board of directors. She is a textile scientist holding a B.S. from Utah State University, an M.S. from Cornell, and a Ph.D. from the University of Tennessee.

Kimberly A. Green has worked extensively on federal policy impacting career and technical education (CTE) for the past 21 years. Working closely with Congress, the Administration, and a broad range of stakeholders, she represents the interests of and seeks support for CTE. In addition to this policy work, she helped establish, implement, and grow the national Career

Cluster® Initiative, the Common Career Technical Core, the CTE: Learning That Works for America Campaign and the Career Readiness Partner Council—all of which are designed to build visibility and support for CTE, while also raising the bar for CTE by ensuring consistency in the delivery of high-quality programs to students across the United States. Green represents the state directors on a variety of boards and committees, including the board of directors for the Manufacturing Skills Standards Council, the National Technical Honor Society, and the National Career Academy Coalition. She is also collaborating with the new National College and Career Readiness Center and the Great Teachers and Leaders Center and is partnering with multiple federally funded projects to expand the implementation of career pathways. She is an accomplished speaker, having presented in all 50 states and is considered a nationally recognized expert in CTE. With the support of Pell Grants and the federal work study program, she is a graduate of Cornell University's School of Industrial and Labor Relations.

Melvin Greer is senior fellow and chief strategist, Lockheed Martin. With over 29 years of systems and software engineering experience, he is a recognized expert in service oriented architecture, cloud computing, and predictive analytics. He functions as a principal investigator in advanced research studies, including nanotechnology, synthetic biology, and gamification. He significantly advances the body of knowledge in basic research and critical, highly advanced engineering and scientific disciplines. Greer has been awarded the BEYA 2012 Technologist of the Year Award, which recognizes his outstanding technical contribution and technical products that have a broad impact and high value to society as a whole. He has been recognized for his outstanding technical contributions to cloud computing and service-oriented architecture. Greer has been appointed fellow of the National Cybersecurity Institute where he assists government, industry, military, and academic sectors meet the challenges in cybersecurity policy, technology, and education. In addition to his professional and investment roles, he is founder and managing director of the Greer Institute for Leadership and Innovation, focused on research and deployment of a 21st century leadership model. Greer is fellow and adjunct faculty at the Institute For Enterprise Architecture Certification (FEAC Institute) and the University of Puerto Rico at Mayaguez, College of Engineering. He is also a member of the International Monetary Fund/World Bank, Bretton Woods Committee where he explores how deployment of enabling technologies relates to private sector development, commercial opportunities, global financial stability, and social responsibility. He is a frequent speaker at conferences and universities and is an accomplished author; his fourth book *21st Century Leadership* is his most recently published book. As a popular educator and board member at a number of Historical Black Colleges and Universities,

Greer is leading science, technology, engineering, and mathematics (STEM) research initiatives, directly trying to shape a more diverse generation of up-and-coming technical talent. He received his B.S. in computer information systems and technology and his M.S. in information systems from American University, Washington, D.C. He also completed the executive leadership program at the Cornell University, Johnson Graduate School.

Gary Hoachlander is president of ConnectEd: The California Center for College and Career. Beginning his career in 1966 as a brakeman for the Western Maryland Railroad, he has devoted his professional life to helping young people learn by doing—connecting education to the opportunities, challenges, and many different rewards to be found through work. Widely known for his expertise in career and technical education, high school improvement, Linked Learning, and many other aspects of elementary, secondary, and postsecondary education, Hoachlander has consulted extensively for the U.S. Department of Education, state departments of education, local school districts, foundations, and a variety of other organizations. He earned his B.A. degree at Princeton University and holds a master's and Ph.D. degree from the Department of City and Regional Planning, University of California, Berkeley. Prior to founding ConnectEd, he spent 30 years as the founder and president of MPR Associates, Inc., one of the nation's leading education consulting firms, with offices in Berkeley, Washington, D.C., and Portland Oregon.

Rush D. Holt, Jr. became the 18th chief executive officer of the American Association for the Advancement of Science (AAAS) and executive publisher of the *Science* family of journals in February 2015. In this role, Holt leads the world's largest multidisciplinary scientific and engineering society. Over his long career, Holt has held positions as a teacher, scientist, administrator, and policymaker. From 1987 to 1998, Holt was assistant director of the Princeton Plasma Physics Laboratory (PPPL), a U.S. Department of Energy national lab, which is the largest research facility of Princeton University and one of the largest alternative energy research facilities in the country. From 1980 to 1988, Holt served on the faculty of Swarthmore College, where he taught courses in physics and public policy. In 1982, he took leave from Swarthmore to serve as an AAAS/American Physical Society Science and Technology Policy Fellow on Capitol Hill. He also served as an arms control expert at the U.S. State Department, where he monitored the nuclear programs of countries such as Iraq, Iran, North Korea, and the former Soviet Union. In 1981, Holt was issued a patent for an improved solar-pond technology for harnessing energy from sunlight. Before coming to AAAS, Holt served for 16 years as a member of the U.S. House of Representatives, representing New Jersey's 12th Congressional District. In

Congress, Holt served as a senior member of the Committee on Natural Resources and the Committee on Education and the Workforce. On Capitol Hill, Holt established a long track record of advocacy for federal investment in research and development, science education, and innovation. He served on the National Commission on the Teaching of Mathematics and Science (known as the Glenn Commission), founded the Congressional Research and Development Caucus, and served as a co-chair of the Biomedical Research Caucus. Holt served 8 years on the Permanent Select Committee on Intelligence and, from 2007 to 2010, chaired the Select Intelligence Oversight Panel, which worked to strengthen legislative oversight of the intelligence community. His legislative work earned him numerous accolades, including being named one of *Scientific American* magazine's "50 National Visionaries Contributing to a Brighter Technological Future" and a "Champion of Science" by the Science Coalition. From December 2014 to February 2015, Holt was appointed a Director's Visiting Scholar at the Institute for Advanced Study in Princeton, New Jersey. Holt is a Phi Beta Kappa graduate of Carleton College in Northfield, Minnesota, and he holds M.A. and Ph.D. degrees in physics from New York University. He is an elected fellow of AAAS, the American Physical Society, and Sigma Xi, and he holds honorary degrees from Monmouth University, Rider University, and Thomas Edison State College.

Freeman A. Hrabowski, president of UMBC (University of Maryland, Baltimore County) since 1992, is a consultant on science and math education to national agencies, universities, and school systems. He was recently named by President Obama to chair the newly created President's Advisory Commission on Educational Excellence for African Americans. He also chaired the National Academies' committee that produced the recent report, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*. Named one of the 100 Most Influential People in the World by *TIME* (2012) and one of America's Best Leaders by *U.S. News & World Report* (2008), he also received TIAA-CREF's Theodore M. Hesburgh Award for Leadership Excellence (2011), the Carnegie Corporation's Academic Leadership Award (2011), and the Heinz Award (2012) for contributions to improving the "Human Condition." UMBC has been recognized as a model for academic innovation and inclusive excellence by such publications as *U.S. News*, which the past 6 years ranked UMBC the #1 "Up and Coming" university in the nation.

Olivia Khalili works with companies to design, implement, and evaluate social benefit initiatives. She leads Yahoo's social impact program, Yahoo for Good. Previously, Khalili worked with Ashoka to create employee engagement and brand building programs that connected social entrepre-

neurs with companies including American Express and Ben & Jerry's. In 2008, she founded CauseCapitalism.com, an online resource that helps businesses grow by incorporating a social mission. Her approach stems from cross-sector experience working with tech startups and nonprofits, and in international development in Micronesia. Connect with her on twitter at @OKL.

Irwin S. Kirsch is the director of the Center for Global Assessment at Educational Testing Service (ETS). He earned his Ph.D. in Educational Measurement, Reading/Literacy from the University of Delaware in 1982. Since joining ETS in 1984, he has directed a number of large-scale assessments in the area of literacy, including the National Adult Literacy Survey, and the National Assessment of Education Progress (NAEP) Young Adult Literacy Survey. He was also a key person in establishing the International Adult Literacy Surveys and has directed them for ETS since 1993. In 1987, he received the ETS Research Scientist Award for his work in the area of literacy and was named as an ETS Distinguished Presidential Appointee in 1999. Kirsch currently manages several large-scale surveys, including the Adult Education Program Study with the U.S. Department of Education and the Literacy Assessment and Monitoring Program with the UNESCO Institute for Statistics. Kirsch also chairs the Reading Expert Group for the Organisation for Economic Co-operation and Development (OECD), Programme for International Student Assessment and has been involved with several efforts aimed at defining and measuring information and communication technology (ICT) skills. In this area, he has directed an international panel for ETS that defined ICT literacy, has designed and conducted a feasibility study on ICT literacy for the OECD, and participates on an OECD advisory panel aimed at establishing a new survey of adult skills for the 21st century.

Jeff Livingston spent more than a decade as a senior executive at McGraw-Hill Education. Most recently, he was senior vice president of Education Policy and Strategic Alliances. During Livingston's time at McGraw-Hill, he variously held general management responsibility for intervention, career and technical education, supplemental publishing, advanced placement, adult basic education, workforce training, fine arts, and college readiness. Before being promoted to lead businesses, he served as vice president of marketing for the McGraw-Hill Learning Group. He also previously served as the vice president of urban markets, database marketing and inside sales. Before joining McGraw-Hill Education in 2004, Livingston was a successful entrepreneur with specialties in instructional technology and marketing to urban school systems. As co-founder, president, and chief operating officer of Achieva.com, he helped to build the largest provider of online test prep

and college prep for American high schools. In the early 1990s, he spent several years in investment banking and trading of financial derivatives for Merrill Lynch. In July 2015, Livingston left McGraw-Hill Education to begin a sabbatical focused on finding creative solutions to important educational problems. So far, his explorations have taken him to for-profit universities in Brazil, apprenticeship programs in Serbia and Spain, universal pre-K implementations in several American cities, Early College High Schools in New York and California, and Historically Black Colleges and Universities looking to reinvent themselves for 21st-century relevance. In addition to continuing to invest in and advise Edtech start-ups, he intends to visit low cost, private primary schools in India and Africa during his sabbatical. Livingston holds a baccalaureate degree in government from Harvard University. He has served as a director of the Association of Educational Publishers, the Association of American Publishers-Education Division, the Software and Information Industry Association, and the Harlem Educational Activities Fund. He is also an adviser to the ASU/GSV Innovation Summit and South by Southwest EDU.

Mary Alice McCarthy joined the Higher Education Policy Team at the New America Foundation, where she serves as a senior policy analyst and focuses on the intersection between higher education, postsecondary career and technical education, and workforce development programs. Most recently, she was a member of the Policy, Research and Evaluation Staff team at the Office of Vocational and Adult Education (OVAE) at the U.S. Department of Education. She is leading a variety of policy reform and evaluation efforts in the areas of postsecondary career and technical education, career pathways, credentialing, and competency-based education models. Since joining OVAE, she established the Interagency Working Group on Career Pathways, which is composed of staff from the U.S. Departments of Education, Health and Human Services, and Labor and works to better align federal investments and policy in education, training, and employment services to support career advancement. She also serves as OVAE's liaison to the U.S. Department of Labor's Trade Act Assistance Community College and Training grants programs, collaborating on the development of the grant solicitations and technical assistance strategies. Prior to joining OVAE, McCarthy worked in the Office of Workforce Investment in the Employment and Training Administration at the U.S. Department of Labor, where she specialized in improving training and employment services for adult and dislocated workers. She directed the Career Pathways Initiative, cosponsored by OVAE, providing technical assistance to nine states and two tribal entities on the development of career pathway systems. McCarthy has a master's degree in public administration from the Harvard Kennedy School of Government and a Ph.D. in political science from

the University of North Carolina. At Harvard, she was the 2009 fellow in philanthropy at the Hauser Center for Nonprofit Organizations, where she conducted research on the role of philanthropic organizations in supporting innovative approaches to workforce development and adult education.

Jennifer McNelly is the president of The Manufacturing Institute, the nonprofit affiliate of the National Association of Manufacturers. The Manufacturing Institute is the authority on the attraction, qualification, and development of world-class manufacturing talent. As president, McNelly drives an agenda focused on improving and expanding manufacturing in the United States through education, innovation, and research. Prior to joining the Institute, Jennifer, a member of the Senior Executive Service for the U.S. Department of Labor, also served as the senior vice president of Strategic Partnerships, LLC. She is currently chair of the World Economic Forum's Global Agenda Council on Advanced Manufacturing.

Christine Ortiz is the dean for graduate education and the Morris Cohen Professor of Materials Science and Engineering at the Massachusetts Institute of Technology. Ortiz earned her B.S. from Rensselaer Polytechnic Institute and M.S. and Ph.D. from Cornell University, all in the field of materials science and engineering, with a minor in theoretical and applied mechanics. After graduation, she was granted an NSF-NATO postdoctoral fellowship, which she used to carry out research in the Department of Polymer Chemistry, University of Groningen, in the Netherlands, where she worked in the area of single-molecule mechanics. Ortiz then joined the MIT Department of Materials Science and Engineering as a tenure-track faculty member and developed a research program that focuses on the multiscale mechanics of musculoskeletal and exoskeletal structural biological materials, with the primary goal being to quantify and understand new mechanisms, phenomena, and design principles and how they determine function, quality, and pathology. Ortiz has over 160 scientific publications in more than 20 academic journals. She has given more than 130 invited lectures on her research, over 35 of which were international, and at 9 topically different Gordon Research Conferences. Ortiz has supervised more than 80 students from 10 different academic disciplines. She has received over 30 national and international honors. Ortiz has served on the editorial boards of *Science*, *Advanced Biomaterials*, *Transactions of the American Society of Mechanical Engineers*, and *Applied Mechanics Reviews*. She has served as a reviewer for the National Science Foundation, the National Institutes of Health, NASA, and the U.S. Department of Defense. Ortiz is the founding and current faculty director of the MIT International Science and Technology Initiatives (MISTI)-Israel program. She has served on over 25 institute and departmental committees and in her current role as dean for graduate

education leads areas, which include fellowships, personal support, professional development, policies and procedures, educational innovation, academic performance, graduate admissions administration, diversity initiatives, immigration, community-building, and institute-wide data analysis.

Ruan Pethiyagoda is chief strategy officer of Hack Reactor Core, the leading network of data-driven educational programs. Pethiyadoa's role includes student outcomes, employer partnerships, public policy, compliance, and corporate development. His team supports and scales these critical functions at top schools in California, Texas, and the Midwest, training and placing over 1,000 engineers per year into the software industry. Prior to joining Hack Reactor, he worked as an investigative journalist covering war crimes, arms trafficking, corruption, and politics in and around Sri Lanka.

DeRionne P. Pollard, president of Montgomery College, is committed to empowering students to change their lives and enriching the life of the community. Montgomery College, one of largest undergraduate institutions in the state of Maryland, serves nearly 60,000 credit and noncredit students annually at its three campuses. Pollard assumed leadership of Montgomery College on August 2, 2010, following a national search by the college's board of trustees. Since her inauguration, she has spearheaded the development of a new Montgomery College mission and *Montgomery College 2020*, the institution's strategic plan. Other priorities have included partnering with Montgomery County Public Schools and the Universities of Shady Grove in the creation of Achieving Collegiate Excellence and Success (ACES), a support program designed to help students transition from high school to college completion. Pollard is passionate about providing higher education opportunities to all students and seeking innovative ways to increase their success. During 2012, the Montgomery College Board of Trustees voted to take a position in support of the ballot question on the Maryland Dream Act. Pollard served as a public advocate and vocal supporter for the law, which was passed by the voters of Maryland to provide in-state tuition rates to undocumented college-aged students. She recently served on the American Association of Community Colleges' 21st Century Commission on the Future of Community Colleges and the Commission on Academic, Student, and Community Development. Pollard is a member of the Community College Advisory Panel at the College Board and the Higher Education Research and Development Institute Advisory Board. Closer to home, Pollard serves on several boards, including Montgomery County Business Development Corporation, Montgomery County Chamber of Commerce, Universities of Shady Grove, the Tech Council of Maryland, IMPACT Silver Spring, and Generation Hope. Pollard formerly served as president of Las Positas College in Livermore, California. Her community

college career began at College of Lake County (Illinois) as a faculty member in English. Pollard received her Ph.D. in educational leadership and policy studies in higher education from Loyola University Chicago and her M.A. and B.A. in English from Iowa State University.

Sanjay Rai, senior vice president for Academic Affairs at Montgomery College, is an outspoken champion and ardent supporter of innovations that advance community college student success in academic, career, technical, and workforce development programs. He has provided leadership for the redesign of the general education and general studies programs, for curriculum alignment with K-12 and 4-year colleges and universities, ensuring that Montgomery College's programs reflect the impact of technology, globalization, and workforce alignment—critical factors in student success today. A strong advocate for professional development, Rai's leadership for 500 full-time and 1,000 part-time faculty has focused on ensuring that content and pedagogy are current in dynamic science, technology, engineering, and mathematics (STEM) fields such as cybersecurity, biotechnology, engineering, and health science. He has developed innovative partnerships with local and global businesses that have resulted in Montgomery College becoming a center for continuing education and training for already skilled workers, as well as an on-ramp for people starting or changing careers. He is currently serving as chair of the Maryland Council of Community College Chief Academic Officers (CAOs), an affinity group of Maryland community college CAOs, and is on the boards of the Tech Council of Maryland, the Indian Biomedical Association, and the Montgomery College Life Sciences Park Foundation. Prior to serving as the College's chief academic officer, Rai led the Germantown Campus as vice president and provost, and also served as the dean of science, engineering, and mathematics at the Rockville Campus. He has been successful in securing a number of nationally completive grants for programs in these areas. Preceding his tenure at Montgomery College, he was chair of the Department of Mathematics at Jacksonville University, Florida, where he also was a tenured full professor. Rai completed a Ph.D. in mathematics from the University of Arkansas in Fayetteville, an M.S. in mathematics from Dalhousie University in Halifax, Canada, and an M.S. in mathematics and a B.S. in statistics, physics, and mathematics from the University of Allahabad in India. He is a graduate of Leadership Montgomery's Class of 2009 and has served on the board of directors for Leadership Montgomery, the Gaithersburg Germantown Chamber of Commerce, Tech Council of Maryland, and the BlackRock Center for the Arts. His publications are in applied mathematics (modeling HIV using differential equations) and mathematics education. His most recent book, *Pathways to Real Analysis*, was published in April 2009.

William "Bill" Rudman is the executive director of the AHIMA Foundation and vice president of Education Visioning for the American Health Information Management Association (AHIMA). Before taking this job, Rudman worked for 20 years in academia as a professor in health information management. Rudman also served as the director of the Health Information Technology Core for the Delta Regional Institute and oversaw implementation of an electronic record exchange in rural Mississippi. He served on the state of Mississippi Task force for health information exchange and chaired the education committee. Rudman was the principal investigator (PI) on the HISPC grant for education and training for the implementation on electronic medical records for the state of Tennessee. In addition to hands on experience in the development, implementation, and training of those working in the field of HIM, Rudman has an extensive list of presentations, publications, and health information technology grants. Rudman has published over 70 scholarly articles, made 140 scholarly presentations, and received over $70 million in federal funded grants. Among those grants, Rudman served as either a PI or co-PI on funding for the Southern Mississippi health information exchange (at the time the largest operating HIE in the United States), a rural e-network of Mississippi hospitals, and a telemedicine grant to connect hospitals in the Delta Region in Mississippi.

Russell W. Rumberger is professor of education in the Gevirtz Graduate School of Education at the University of California, Santa Barbara. A faculty member at UCSB since 1987, Rumberger has published widely in several areas of education: education and work; the schooling of disadvantaged students, particularly school dropouts and linguistic minority students; school effectiveness; and education policy. In the fall of 2011, he completed a book, *Dropping Out: Why Students Drop Out of High School and What Can Be Done About It*, which was be published by Harvard University Press. He served as a member of the National Research Council's Committee on Increasing High School Students' Engagement and Motivation to Learn (2004), the Committee on the Impact of Mobility and Change on the Lives of Young Children, Schools, and Neighborhoods (2010), and the Committee on Improved Measurement of High School Dropout and Completion Rates (2011). He also served as a panel member for the Institute of Education Sciences' Practice Guide, *Dropout Prevention* (2008). From 2010 to 2012 he served as Vice Provost for Education Partnerships, University of California Office of the President, where he was responsible for the university's engagement in P-20 education in California, including policies and programs that produce high-quality teachers and promote achievement and college access for all students. He currently directs the California Dropout Research Project, which is producing a series of reports and policy briefs about the dropout problem in California and

a state policy agenda to improve California's high school graduation rate). Professor Rumberger received a Ph.D. in education and an M.A. in economics from Stanford University and a B.S. in electrical engineering from Carnegie-Mellon University.

Liz Simon is the vice president of Legal & External Affairs at General Assembly (GA), which is pioneering a new kind of education for a global community of entrepreneurs and professionals. Her responsibilities include leading the GA's legal affairs, government and regulatory interactions, public affairs programs, and social impact work. Simon joined GA from the Obama Administration, where she served as counselor to the director of U.S. Citizenship and Immigration Services and worked on policy issues at the nexus of immigration and entrepreneurship. Prior to that, she was an attorney at Hogan Lovells, a Washington, D.C.-based law firm. Simon holds a bachelor's degree in government from Cornell University and earned a J.D. from the University of Michigan Law School.

Debra W. Stewart, former president of the Council of Graduate Schools (CGS), became president of CGS in July 2000. She holds degrees from Marquette University, the University of Maryland, and the University of North Carolina, Chapel Hill. In 1975, she joined the North Carolina State University faculty and was professor of political science and public administration from 1984 to 2000. In 1983, she became associate dean of the graduate school at North Carolina State and dean of the graduate school in 1988. In 1994, she served as interim chancellor at the University of North Carolina, Greensboro. Prior to joining CGS, she was vice chancellor and dean of the graduate school at North Carolina State University. Stewart's service to graduate education includes chairing the GRE® (*Graduate Record Examinations*®) Board, the Council on Research Policy and Graduate Education, the Board of Directors of Oak Ridge Associated Universities, and the board of directors of CGS. She also served as vice chair of the ETS Board of Trustees, Trustee of the Triangle Center for Advanced Studies, and member of the American Council on Education Board and several National Research Council Committees. In November 2007, her leadership in graduate education was recognized by the Université Pierre et Marie Curie with an honorary doctorate. Her alma mater, the University of North Carolina, Chapel Hill, honored her in October 2008 with the Distinguished Alumna Award. Stewart is author, co-author, and editor of books and numerous scholarly articles on administrative theory and public policy. She lectures nationally and internationally on graduate education issues and challenges. Her research focuses on ethics in managerial decision making.

Shelley Westman is currently vice president, Operations & Strategic Integration Initiatives, which is a new role in the Security Business Unit designed to focus on overall operations as well as key projects and strategic initiatives across the newly formed unit. As part of this role, she also leads the University Programs for IBM Security and is involved in several IBM boards and committees on hiring and skills. Westman is the founder of "WISE"—Women in Security Excelling. Immediately prior to this role, she was vice president, Security Growth Initiatives & Operations, Security Services. Prior to this she spent 15 years in IBM's System and Technology Group (STG) where her most recent assignment was vice president, Strategy. In this role Westman was responsible for leading and guiding STG's overall strategy, with a focus on transforming the strategy to a market-centric strategy, addressing opportunity and performance gaps, and driving alignment between strategy and execution. Westman's previous roles in STG included the vice president and business line executive, Systems Software and Security, where she had responsibility for the STG strategy, revenue growth, and execution around Systems Software and Security. She has held a number of other key roles at IBM including director of Power Systems, director of development operations and roles in alliance management, procurement, forecasting, and contracts. Prior to joining IBM, Westman practiced law in Raleigh for 5 years. She concentrated her practice in the area of civil litigation. She has a J.D., with honors, from the University of North Carolina, School of Law. Her undergraduate degree is from the University of Massachusetts, Amherst where she graduated cum laude.

Holly Zanville is a strategy director at Lumina Foundation where she leads the development of plans and strategies to help create new systems of quality credentials and credits defined by learning and competencies rather than time, clear and transparent pathways to students, high-quality learning, and alignment with workforce needs and trends. Her portfolio includes a focus on improving outcomes of developmental education, increasing degree completion for returning adults with prior college/no credential, and statewide approaches to reverse-transfer degrees through the national Credit When It's Due initiative. Zanville's work experience spans the educational pipeline with prior service in K-12, community colleges, universities, and higher education governance systems. Most recently, Zanville served as coordinator of Oregon's Joint Boards K-20 Redesign Initiative; senior academic officer, Washington Higher Education Coordinating Board; and associate vice chancellor for Academic Affairs, Oregon University System. Zanville received her Ph.D. in educational administration from the University of Minnesota; M.A. in English from the University of Wisconsin-Madison, and B.A. in English and biology from Lindenwood University.

Appendix C

Anonymous Participant Responses to the Pre-summit Question

What should be the top investment priorities for federal agencies (including NSF, NIH, U.S. Department of Education, U.S. Department of Labor, and others) to support the education and training of the STEM workforce of the future? In other words, how should federal education and training dollars be invested in ways that will yield the greatest impact to ensure that our STEM workforce has the skills, knowledge, disposition, and ingenuity required to excel and innovate over the next generation?

Move away from the heavy focus on bachelor's degrees and advanced degrees. Invest in community colleges, apprenticeships, and employer-based training.

There should be a renewed funding emphasis on graduate education and training. The level of support for basic research on graduate education is not commensurate with that at the K-12 and undergraduate level.

1. Increase the affordability of college.
2. Provide incentives for a livable salary for K-12 teachers and university faculty.

The top investment priorities should include funding for tech bootcamps and other trade institutions that focus on pathways to gain practical skills. Investing in web development and user experience design training at educational institutions like General Assembly, Dev Bootcamp, and more would

be a great way to ensure that students are able to gain access to practical skills within the tech field without taking on burdensome levels of student debt.

All work (where possible) would benefit from being "openly licensed" which aligns with the Administration's Open Government Directive. If this could be required of all (most) educational materials it would open up valuable STEM learning opportunities to all.

Since departments are the crucial units for change in higher education, federal agencies should develop programs that encourage and support departments as they enhance their programs to prepare students for diverse careers.

Investment earlier in the pipeline and in out-of-school time are both key. Engaging underserved groups in STEM so they can be STEM literate, if not pursuing STEM careers, is also critical.

STEM education must be contextualized appropriate to the industry being studied. STEM is not an occupation and is a means to an end. We need to have a better understanding regarding the relationship of STEM knowledge to "work performance." Funding should not be given for just "STEM Education" that leads to nowhere.

Agencies should invest so as to support critical and analytical thinking in specific fields or on specific topics.

- Target funding toward models and programs that have demonstrated effectiveness in leading to STEM skills.
- Advance a vision for a skilled STEM workforce at multiple levels, including middle-skill job opportunities that can serve as springboards for further educational attainment and career advancement.
- Connect STEM education and training investments to in-demand STEM occupations at the state and regional level.
- Prioritize access and completion for underserved or underrepresented populations.
- Prioritize programs that have meaningful engagement from employers in STEM industries.

Require that projects demonstrate and provide evidence to be tracked over time of integrative and cumulative approaches to learning and assessment that do not stop with content knowledge but that do include psychosocial and noncognitive approaches to teaching, learning, and assessment. Get beyond STEM content knowledge, which is necessary but not sufficient.

Based on my experience as an instructor in a community college, most students learn faster with scenarios. The scenarios help develop their problem-solving skills. I'm suggesting embedding scenarios into curriculum development will college's graduate students with both knowledge-based and skilled- (hands on) based scenarios.

Understanding the realities and the complexity of workforce needs to support STEM education in the right areas in the right labor markets. This is a moving target but better understanding will lead to better use of resources.

- Investment in the learning sciences, in particular interdisciplinary teams (cognitive science, neuroscience, data science, computer science, gamification, machine learning, artificial intelligence, education, etc.) to carry out pedagogical experiments, in particular assessment methods, personalized education, mastery-based education, Edtech and blended learning, metacurriculum, etc.
- Funding of new pedagogical experiments and assessment methods and Edtech and Education startups (SBIR), both for-profit and nonprofit
- Supporting discovery and research-based experiences for K-12 and undergraduates, as well as the public (citizen science and crowdsourcing)
- Researching the fundamental mechanisms of transformational science, engineering, and scientific engineering creativity (combination of quantitative and qualitative) with the goal of developing training method programs
- Implementing professional development programs for graduate students
- Recognizing a wider array of postsecondary providers, new ways to earn credentials, levels of learner recognized
- Funding more interdisciplinary and team research and graduate programs

More focus on preparing home grown workforce for knowledge industries "Skilling" of all postsecondary education curriculums that reflect needs of today's industries and contemporary global society. A reorientation/reorganization of funding agencies and priorities that address global knowledge-based economy and changing demography of our nation.

Supporting alternative pathways into STEM education programs (credentialing nonacademic experience), learning analytics (demonstrate value while addressing privacy concerns).

High-quality STEM preparation and professional development (PD) for K-12 classroom teachers—too many teachers are unprepared to provide high- quality, open-ended STEM experiences/activities in their classrooms. Often, local PD experiences are lacking. RET programs are wonderful; however, many teachers cannot exit their day to day lives to participate

in such in-depth experiences. Hybrid programs (face-to-face and online instruction) and online support coupled with high expectations of outcomes might help bridge the divide and open up experiences to many teachers. Teachers should also receive graduate credit in addition to PD hours for participating in such programs. Coupling these experiences with connections to industry would be very valuable for teachers to fully understand what STEM workforce preparation truly involves. Equipment is needed for teachers and students to perform hands-on STEM activities—many schools are lacking modern equipment (or enough equipment)—to allow students to participate in fruitful activities, which promote a deeper understanding of STEM principles, beyond simple regurgitation of facts. Again, coupling industry into this issue might be helpful. For example, industries with certain foci could provide equipment packages (coupled with curricula) that schools could purchase—or win through grants—to promote a suite of STEM skills. However, the impact of this type of program would be very dependent on evaluation and longitudinal tracking of students.

I believe that the majority of funding should go toward teacher training. Only by making sure our teachers (especially K-12) are equipped with the most relevant STEM concepts and skills can we ensure that the right foundation is being provided in the early years of schooling. We should also be thinking about how to connect education institutions with local businesses. Most concepts learned in school should match real world applications in the workforce. Creating a more collaborative environment in local communities will enable the right skills to be identified and taught, which in turn will create opportunities for a smoother transition into future employment. Funds should also be allocated to actively match and mentor students as they transition into the workforce, especially after completing studies in the highest demand skills.

- Early childhood and K-12 interventions
- Early childhood education and year-round school to support equitable learning opportunities
- Build STEM training for all teachers regardless of subject—there should be ways to bring STEM into any subject
- A set standard for teachers to meet regarding their knowledge and ability to effectively utilize a STEM curriculum
- Infrastructure investment in public K-12 schools, early education program campus/facilities. Teachers can be trained, curriculum can be integrated, incentives for STEM integration—all are ineffective without meaningful capital investments in in-classroom technology so that students learn STEM concepts in the environment that drives its usefulness.
- Invest in STEM-focused school counselors (grades 3-12); create STEM

learning tracks that are very similar to advanced placement learning tracks for students

- Bring more awareness to STEM opportunities by doing public service announcements, commercials, ad space on job seeking, and labor and workforce development websites.
- Provide financial assistance for specific subject matter training.
- Provide financial assistance for learning an agile business process.

Employer Engagement

- Provide more funding for experiential learning opportunities (K-beyond).
- Promote National STEM Career Day events with businesses that can host an open house for students to learn and "see" STEM careers in action.
- Develop employer engagement strategies that facilitate employer outreach to the education and workforce development systems. Employers can be guest speakers at schools and colleges; create regular internship slots; provide funding for training and work experience opportunities.
- Provide paid-for-performance options to local/regional job placement/developer organizations.
- Provide financial incentives for organizations/companies that place interns into Internships that utilize the knowledge gained from the training.
- Provide financial assistance to the participating organizations/companies for any tools/software necessary to manage the process to make this endeavor successful

Inclusion and Equitable Access

- Build inclusion and diversity incentives for local school districts.
- Make more investment in STEM specific academies in minority/low income neighborhoods. There is a lack of Black/Hispanic enrollment in the STEM fields. Make schools like the North Carolina School of Science and Mathematics more diverse and welcoming for students of color. The New Brunswick Health, Sciences and Technology High School is an outstanding magnet school for academically talented students from very low income neighborhoods in New Brunswick, NJ. Schools like these could help foster and groom more talented minorities in neighborhoods that fail to have the proper facilities and the in-classroom technology that Brad mentioned.
- Create smaller magnet STEM schools specifically for girls to help encourage their participation in the field.
- Concentrate, build, or place some of these facilities in the inner-ring suburbs of our large cities. Gentrification and the rising cost of housing in city neighborhoods are driving many minorities to suburbs right outside of cities.

Motivate university and college leadership to improve their campus climate to promote diversity in STEM. This could include requiring principle investigators to include references of on-campus programs that offer mentorship, informal learning opportunities, student grants, and student societies to promote retention in STEM fields:

1. STEM career awareness, particularly in underserved communities, such as providing hands-on/real world activities to students, so that they better understand what a career in STEM looks like
2. Providing opportunities for students to meet with STEM professionals and/or experience career opportunities (i.e., internships, apprenticeships, mentoring or similar activities)

Better coordination is needed between the agencies listed to ensure a more strategic federal investment approach to the issue of training the STEM workforce; there are many duplicative and disparate programs that almost undermine the broader effort to address the challenge.

It is critical to fund programs that enable young people to enter the array of STEM opportunities from a certificate to a Ph.D. We often focus on the top academic performers going on to graduate education, but fail to engage other students who would love to get involved in hands-on STEM opportunities.

There needs to be a cultural shift in how undergraduate research is approached. Through the NSF I-Corps L program, my team has investigated this landscape and would like to share insights and themes that emerged through over 100 interviews conducted from across the country. Incentivizing a holistic approach to undergraduate research opportunities is needed to ensure STEM workforce preparedness.

Investments in quantitative training across undergraduate education

Dollars should be allocated to organizations that have demonstrated an ability to deliver a clear return on investment.

Investment in students and programs that support them—not just stipend levels but funding to implement innovative ways to teach the noncognitive skills that are as important, if not more, than the discipline skills

I would like to see greater emphasis in encouraging women to enter into STEM fields.

1. Apprenticeship
2. Tuition support for underserved populations and working learners
3. Additional skills training (common employability skills)

Employer engagement to ensure that education and training systems are preparing students with skills in demand by employers. Support stronger alignment between K-12, postsecondary, and workforce systems to ensure that all systems are connected and aligned in preparing the future STEM workforce.

Adoption/scaling of known effective practices across all the topics identified for this summit

Each of the key topic areas to be discussed at the summit is of interest to stakeholders across the STEM community. A systemic approach—supported by research-based methods—is needed to design, implement, and assess plans and build capacity for addressing these key topic areas. Facilities, equipment, curricula, and professional development are all needed for effective hands-on laboratory experiences that inspire students to further their education and prepare them for high-technology careers. Aligning the investments being made by the different stakeholders and sustaining those investments over the coming decades will help us make progress. Federal agencies, which are often supporting initial investments, can foster this alignment by increasing programs and activities that

- scaffold the level of investments, such as designing grant programs to support projects of varying size and scope;
- support partnerships of various types among a range of stakeholders;
- encourage proposals that are based on and contribute to the research base;
- increase and assess the effectiveness of broader impacts activities; and
- facilitate the propagation of project outcomes.

Federal agencies can demonstrate how their programs and activities contribute to the portfolio of STEM education and workforce activities. The resources and activities of disciplinary societies and education associations should be leveraged by federal programs and those supported by federal grants. Federally funded projects should inform and enhance the resources and activities of disciplinary societies and education associations, which may be positioned to extend and sustain investments. The American Chemical Society has a series of public policy statements focused on science education and the scientific workforce (http://www.acs.org/content/acs/en/policy/publicpolicies/invest.html). The Science Education Policy outlines key aspects for strengthening and improving science education at all levels. Some additional specific areas of opportunity include the following:

- Strengthening the math and science partnerships
  - — Increasing the capacity
  - — Encouraging matching funds from the states
  - — Developing and expanding public-private partnerships
- Updating the Perkins Act
  - — Renewing the legislation to reflect current workforce needs
  - — Expanding the state-industry communications called for in the Workforce Innovation and Opportunity Act to include agencies
  - — Identifying ways to extend and leverage the Career and Technical Education program
- Optimizing the system of financial support for graduate students
  - — Decoupling student-support funds from specific research projects in order to provide students the opportunity for better balance between training in research and training in other career skills, without significantly impacting the research productivity of faculty
  - — Experimenting with training grants providing greater support for innovation in the educational program.

Work-based learning opportunities targeted toward STEM subjects:

1. Early childhood through high school exemplary curriculum development
2. High-quality professional development to manage exemplary curriculum
3. Teacher preparation pathways—professional development for those who prepare teachers so they can better prepare them
4. Policy changes in STEM endorsement programming in states
5. Value-based externships with industry partners for teachers of STEM
6. Engaging teachers within industry for professional development experience with the intent of offering a broader perception of real-world applicability
7. Education/Business engagement STEM programming (i.e., Iowa BEST, Waukee APEX, Blue Valley CAPS) that integrate innovative STEM education while at the same time offering program or project-based learning

1. Increasing the diversity of the STEM workforce, particularly in areas such as IT, where there are large discrepancies between the demographics of the field and the demographics of the local population
2. Developing ways to integrate technical education with other critical skills necessary to enter the workforce; for example, providing Ph.D. candidates with management training during the course of their studies
3. Providing robust and regional information on STEM sub-workforces so students can make informed choices when selecting training programs

Youth summer/weekend employment in STEM Fields—helps to address

getting students to work to build employability skills while also learning more about the industry. Investing in recruiting and developing minorities in STEM. Other under-represented populations—people with disabilities, incarcerated. What if what some of what incarcerated populations did as they work in prisons supported STEM fields (manufacturing etc.) while gaining a credential from the apprenticeship or some college credit? and also reform principles. The following research-based reform strategies are guiding principles for building pathways to middle-skill STEM credentials and jobs:

1. Program design and curriculum is based upon current regional labor market information and analysis that is fine grained, up to date, and informed by employers and regional workforce institutions.
2. Career-focused programs provide a clearly defined and well-structured pathway to jobs and careers that are in demand in the regional labor market.
3. Students entering below the necessary level of proficiency receive basic skills support that is accelerated and contextualized for STEM fields, with the goal of minimizing students' enrollment in stand-alone developmental education courses
4. Students understand their options through advising upon enrollment and are expected to select a broad pathway of study (e.g., STEM, liberal arts) early in their college experience, so that they can move quickly and efficiently to completion.
5. Early warning systems, frequent and ongoing advising, and career guidance are routine components of student supports and college experience.
6. Low-income students are connected to effective academic, social, and financial supports that promote retention and persistence through STEM programs.
7. Associate's degree courses and programs are aligned with those of public 4-year institutions in the state, so that transfer to senior institutions to pursue higher-skill STEM programs is seamless and credits transfer easily.
8. Student enrollment, persistence, completion, and labor market outcomes are continually monitored—and analyzed by college and major/program-and used for continuous improvement of curricula and support systems.

Developing understanding throughout K-16 of the basics of computing, statistics, and data science and their applications to other fields. Continued support for research experiences for undergraduates, especially members of underrepresented groups. Support for scaling up and implementing innovative forms of curriculum and pedagogy as well as for their development. Longitudinal research on students' career choices and influences, and post-baccalaureate choices, career development, and satisfaction.

1. Increasing diverse participation in STEM, ensuring that everyone has the opportunity to participate in the scientific enterprise
2. Providing STEM education that is hands-on, inquiry-based, and relevant for all students
3. Preparing students for a world in which computational approaches underlie much of the practice of science and engineering

Federal investments need to encourage clear connections and collaborations between industry, organizations, and universities to help prepare the future workforce realistically allowing for the development of the much needed professional skills and an understanding of the career opportunities available after graduation and into the future.

Partnerships between colleges and business/industry to open student opportunities; faculty development in instructional strategies that merge cognitive and noncognitive or employability skills to support student retention and completion.

At the K-12 level, enticing high-quality teachers to the highest-needs schools.

Appendix D

List of Workshop Registrants

Ashante Abubakar, Director, Workforce Development, Prince George's Community College
Rodney Adkins, Former Senior Vice President, IBM
Susan Albertine, Vice President, Association of American Colleges and Universities
Dale Allen, Vice President for Community Engagement, Quinsigamond Community College
John Angevine, Executive Fellow for Veterans Affairs, The Brookings Institution
Tom Arrison, Director, InterAcademy Council, National Academies of Sciences, Engineering, and Medicine
Daniel Atkins, Professor, University of Michigan
June St. Clair Atkinson, Superintendent of Public Instruction, North Carolina
Jessie Azrilian, Director, Education Partnerships, Association of Chamber of Commerce Executives
Laurie Baefsky, Executive Director, Alliance for the Arts in Research Universities
Crystal Bailey, Careers Program Manager, American Physical Society
Alberta Baker, Evaluations Specialist, U.S. Department of Labor
Juliane Baron, Director of Government Relations, American Educational Research Association
Christine Barrow, Dean, STEM Division, Prince George's Community College
Tali Bar-Shalom, Program Examiner, Office of Management and Budget

Mike Bartlett, Policy Analyst, National Governors Association
Cynthia Bauerle, Assistant Director, Howard Hughes Medical Institute, Science Education
Chelsea Baum, Admissions Producer, General Assembly
Sarah Beaton, Senior Program Manager, U.S. Department of Education
Tony Beck, Director, Office of Science Education/Science Education Partnership Award, National Institutes of Health
Lida Beninson, Science & Technology Policy Fellow, American Association for the Advancement of Science/National Science Foundation
Gary Bertoline, Dean and Distinguished Professor, Purdue University
Betsy Bizot, Director of Statistics and Evaluation, Computing Research Association
Sally Blake, Professor, Flagler College
Donna Boston, Project Officer, U.S. Department of Health and Human Services/Office of the Assistant Secretary for Preparedness and Response/Biomedical Advanced Research and Development Authority
Nina Boston, Research Associate, National Academies of Sciences, Engineering, and Medicine
Alfonso Bravo, Education Programs Producer, General Assembly
Crystal Bridgeman, Senior Director, Workforce Development Programs, Siemens Foundation
Melissa Brodeur, Program Manager, National Ocean Sciences Bowl
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Beth Buehlmann, Vice President Public Policy and Government Affairs, Council of Graduate Schools
Karen Burg, Vice President for Research, Kansas State University
Christine Burgess, Project Director, American Association for the Advancement of Science
Greg Camilli, Graduate Professor of Educational Psychology, Rutgers University
David Campbell, Program Director, National Science Foundation
Aissa Canchola, Legislative Aide, Senate Committee on Health, Education, Labor, and Pensions
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Celeste Carter, Program Director, National Science Foundation
Amy Chang, Education Director, American Society for Microbiology
Ida Chow, Executive Officer, Society for Developmental Biology
Shanaz Chowdhery, Admissions Manager, General Assembly
Rita Colwell, Distinguished University Professor, University of Maryland College Park and Johns Hopkins University School of Public Health

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Sue Cui, Associate Program Officer, Helmsley Charitable Trust
Jan Cuny, Program Officer, National Science Foundation
Jennifer Davis, Vice President, Mission Advancement, Goodwill Industries International
Rebecca Dernberger, Vice President and General Manager, Manpower's Northeast Division
Stephen DeWitt, Deputy Executive Director, Association for Career and Technical Education
Catherine Didion, Senior Program Officer, National Academies of Sciences, Engineering, and Medicine
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Earnestine Easter, Program Director, Division of Graduate Education, National Science Foundation
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Dean Evasius, Division Director, National Science Foundation

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Paul Gleger, Regional Director, General Assembly
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Melvin Greer, Chief Senior Fellow and Chief Strategist, Lockheed Martin
Jade Grieve, Senior Director, America National Achieves
Emily Grumbling, Program Officer, National Academies of Sciences, Engineering, and Medicine
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Mary Harrill, Associate Director of Programs and Policy, Achieving the Dream

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