Promising Practices for Strengthening the Regional STEM Workforce Development Ecosystem

DETAILS

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**Committee on Improving Higher Education's Responsiveness to STEM Workforce Needs:
Identifying Analytical Tools and Regional Best Practices**

Board on Higher Education and Workforce

Policy and Global Affairs

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

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IDENTIFYING ANALYTICAL TOOLS AND REGIONAL BEST PRACTICES**

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Preface

This report summarizes an 18-month study by the Committee on Improving Higher Education's Responsiveness to STEM Workforce Needs: Identifying Analytical Tools and Regional Best Practices, organized under the auspices of the Board on Higher Education and Workforce at the National Academies of Sciences, Engineering, and Medicine. The report's primary audiences are business and university leaders, key intermediary organizations such as chambers of commerce and regional economic development groups, and state and local government policy makers who seek to create and/or sustain partnerships based on mutual understanding and a shared commitment to regional economic development. We hope the recommendations offered here can serve as a set of promising practices that can enable both sectors to collaborate in sustainable ways that benefit students, universities, companies, regional economies, and national competitiveness.

The committee was composed of a group of experts on subjects related to science, technology, engineering, and mathematics (STEM) education, workforce development, university-industry partnerships, and university leadership and administration. The committee's charge was to explore the effectiveness of selected higher education institutions in educating STEM-trained workers who can meet regional workforce needs. To fulfill this charge, the committee organized five regional workshops around the nation—Phoenix, Arizona; Cleveland, Ohio; Montgomery, Alabama; Los Angeles, California; and Fargo, North Dakota.

In each location, the committee convened leaders and employers from the business community; administrators, faculty, and students from 2-year and 4-year colleges and universities; regional economic development experts; chambers of commerce; state and county policy makers; government officials; and philanthropic foundations. The committee reviewed evidence on effective practices for creating and sustaining university-industry partnerships, including interventions known to improve student retention in STEM majors. The committee also commissioned analyses to look at real-time labor market information in the regions it visited.

In addition to the five regional workshops and commissioned analyses mentioned above, the committee met twice and studied prior efforts addressing STEM workforce development, relevant research findings, and other promising programs and practices not featured in the geographical regions visited by the committee. Beyond the gathering and synthesis of this information, this report reflects the professional and personal judgments and experiences of the committee members.

We are grateful to the staff of the committee: Libby O'Hare, Tom Rudin, Nina Boston, and Irene Ngun with the Board on Higher Education and Workforce. We also acknowledge the invaluable technical assistance of Daniel Bearss from the National Academies' Research Center.

Acknowledgments

The committee gratefully acknowledges the support and assistance provided by the organizations and institutions that hosted the series of workshops described in this report. These include Arizona State University, the Ohio Aerospace Institute, Alabama State University, the Los Angeles Area Chamber of Commerce, and North Dakota State University. The committee is grateful to the staff of these organizations who worked tirelessly to plan the workshops. The committee is also indebted to the many participants who attended each workshop—this report is a reflection of their inputs and efforts. We also acknowledge and appreciate the generous support of Lockheed Martin Corporation, which provided a grant to help underwrite the Montgomery, Alabama, workshop.
The committee gratefully acknowledges the contributions of Karin Matchett and Maria Lund Dahlberg.

ACKNOWLEDGMENT OF REVIEWERS

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 objectivity, evidence, and responsiveness to the study charge. 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: Martin Abraham, Youngstown State University; Oscar Barton, George Mason University; George Boggs, Palomar College; L. Berkley Davis, GE Power and Water; Joseph Francisco, University of Nebraska-Lincoln; Valerie Greenhill, EdLeader 21; Edward Hill, Ohio State University; Matthew Hora, University of Wisconsin-Madison; Collins Jones, Montgomery College; Peter Larson, Boeing Defense, Space, & Security; David Longanecker, Western Interstate Commission on Higher Education; Ronald Painter, National Association of Workforce Boards; David Rattray, Los Angeles Area Chamber of Commerce; Daniel Restuccia, Burning Glass Technologies; and R. Michael Tanner, University of Illinois at Chicago.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Cora Marrett, University of Wisconsin and Helen Quinn, Stanford University. Appointed by the Academies, they were 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 authoring committee and the institution.

Richard Celeste, Cochair Teresa Sullivan, Cochair

Committee on Improving Higher Education's Responsiveness to STEM Workforce Needs: Identifying Analytical Tools and Regional Best Practices

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Summary

U.S. strength in science, technology, engineering, and mathematics (STEM) disciplines has formed the basis of innovations, technologies, and industries that have spurred the nation's economic growth throughout the last 150 years. Universities are essential to the creation and transfer of new knowledge that drives innovation. This knowledge moves out of the university and into broader society in several ways—through highly skilled graduates (i.e., human capital); academic publications; and the creation of new products, industries, and companies via the commercialization of scientific breakthroughs. Despite this, our understanding of how universities receive, interpret, and respond to industry signaling demands for STEM-trained workers is far from complete.

While our economy is increasingly global in nature, it remains true that most of the responsibility for—and actions required to enhance—economic growth are local. It is incumbent upon individual communities to become self-reliant economic engines operating on four "cylinders—residential, business, public sector, and nonprofit."[1] This principle reflects the notion that local talent and human capital is an essential driver of a community's economic vitality, and suggests that colleges and universities—and their graduates—have an important role to play.

Educators, policy makers, industry leaders, and others recognize the importance of strong college-university-industry collaboration in preparing the STEM workforce of the future. Two recent reports from the President's Council of Advisors on Science and Technology (*Engage to Excel*, 2012) and the National Science and Technology Council (*Federal STEM Education 5-Year Strategic Plan*, 2013*)* emphasize the importance of encouraging stronger university-industry partnerships as vehicles to enhance student learning and diversify pathways to careers in STEM. The landmark National Academies report, *Rising Above the Gathering Storm* (National Research Council, 2007), also examined the essential relationships between university-industry collaboration and regional economic growth. The report suggested that partnerships among academia, governments, and industry succeed when all members of the partnership see the collaboration as in their best interests, and further, pursue these relationships in the spirit of mutual trust and appreciation of the value that each partner brings to the table.

To explore common and proposed practices in establishing such partnerships, a committee organized under the auspices of the Board on Higher Education and Workforce of the National Academies of Sciences, Engineering, and Medicine undertook an 18-month study

[1] Robbins, C. (2014). All Economies Are Local: A Jobs and Growth Strategy for Cities and Towns. *Municipal Advocate* 27, no. 4:22–23.

of the extent to which universities and employers in five metropolitan communities (Phoenix, Arizona; Cleveland, Ohio; Montgomery, Alabama; Los Angeles, California; and Fargo, North Dakota) collaborate successfully to align curricula, labs, and other undergraduate educational experiences with current and prospective regional STEM workforce needs.

The key topic for this study was as follows: How to create the kind of university-industry collaboration that promotes higher-quality college and university course offerings, lab activities, applied learning experiences, work-based learning programs, and other activities that enable students to acquire knowledge, skills, and attributes they need to be successful in the STEM workforce. The primary area of focus was on whether universities give students both the breadth and the depth of experiences in STEM courses, labs, and applied learning activities—and in the totality of their undergraduate experiences—to ensure that they move into their careers with the skills and competencies to be successful workers and learners prepared to meet a region's STEM workforce needs. Given that recent work that has demonstrated that a region's economic prosperity is related to the educational attainment of its inhabitants, this study focused on the link between universities and employers at local and regional levels.[2]

Three overarching findings emerged from the study:

- Significant numbers of university students are graduating with STEM degrees, but many lack the right combination of technical and employability skills needed to thrive in the workplace. In short, we have many students with credentials, but fewer with the requisite skills to succeed early in STEM careers. This situation is particularly acute with minority students and female students, who are still significantly underrepresented in the STEM workforce and in STEM degree fields in most 4-year universities.

- Employers are increasingly focusing on the skills and abilities new hires possess, rather than the specific field in which an individual has obtained a degree or credential. While there is a need for STEM graduates who will work as professional research and development scientists and engineers (so-called STEM narrow skills), there is a growing need for individuals who apply STEM knowledge and skills in technologically sophisticated occupations that require a facility with STEM concepts, but not necessarily a bachelor's degree (so-called STEM broad skills). There is also a growing need for students with a breadth of skills outside of their core STEM discipline, including skills that are perhaps best developed through a well-rounded liberal education that includes STEM courses, humanities courses, and experiences in the arts. These include problem solving, critical thinking, teamwork and

[2] In its analysis of the five regions, the committee examined the nature and scope of collaboration among 2-year colleges, 4-year colleges and universities, research universities, and local employers (including local business and industry, local nonprofit and government agencies, local utilities, and others). The primary focus of this study, however—and therefore the primary focus of the findings and recommendations of this report—is on collaboration between universities and local employers.

collaboration, communication, and creativity.

- A robust and effective STEM workforce development ecosystem requires proactive steps on behalf of university leaders, local employers, and intermediary organizations to build and sustain alliances that benefit students and regional economic development. Most of the concrete and high-impact strategies that surfaced during the course of the study—including those recommended in this report—do not require extensive policy change by governing boards, but rather can be undertaken at the classroom, department, or program level within a college or university, often in collaboration with a local employer.

The committee offers many additional findings as well as a detailed set of recommendations—all included in Chapter 5 of this report. We summarize the key recommendations here in the form of specific action steps that individual leaders and partners can take in a region to create and sustain the types of higher education–employer partnerships that can create significant opportunities for STEM students, as well as encourage stronger economic development in a region:

BUSINESS LEADERS

- Foster a spirit of collaboration with local and regional higher education institutions so that employees are empowered to engage in collaborative workforce-building activities.
- Reach out to university presidents and deans and offer to build over time a university-business partnership that strengthens the local economy, enhances business operations, and creates more learning opportunities for students—many of whom will be the future employees of the business.
- Designate a high-level executive to serve as the initial point of contact with one or more local universities, and give this individual the power and authority to enter into formal relationships with local institutions (and, where appropriate, with third-party intermediaries). Make this effort a high-profile, high-priority activity of the business. The position should be established within the chief executive officer's office as a business development function, rather than in the company's human resources division.
- Work with one or more local higher education leaders, government officials, or third-party intermediaries to conduct a regional assessment of the economy that includes multiple sources of labor market data and employers assessment of the current and future workforce needs, and identifies the specific steps that are under way (and/or that need to be launched or expanded) to support stronger collaboration among partners—with the dual goals of enhancing the local economy and strengthening student preparation for success in the regional workforce.
- Prioritize the development of as many work-based learning opportunities as possible for students and faculty—including paid internships, apprenticeships, and other experiences that provide hands-on, experiential learning at the worksite.

Ensure that these opportunities include stipends or wages and emphasize diversity and the inclusion of groups traditionally underrepresented in STEM fields.

- Reach out to other businesses in the region with the same technical skill needs and develop collaborative programs to enlarge the region's STEM-capable workforce. Consider joining or creating sector-focused consortia.
- Encourage employees to serve as mentors to local college and university students—especially to underrepresented minority students and female students who may not have exposure to many role models pursuing this career pathway. Urge mentors to meet regularly with students, and even bring them to the worksite regularly to participate in meetings, projects, and other activities.

UNIVERSITY PRESIDENTS

- Foster a spirit of collaboration with local and regional businesses, including empowering faculty to engage in cooperative and workforce-building activities.
- Work with one or more local business leaders, government officials, or third-party intermediaries to conduct a regional assessment of the economy that includes multiple sources of labor market data and local employers assessment of the current and future workforce needs, and identifies the specific steps that are under way (and/or that need to be launched or expanded) to support stronger collaboration among partners—with the dual goals of enhancing the local economy and strengthening student preparation for success in the regional workforce. Make this a high-profile exercise to work with local business leaders and others to "take stock" of local employer workforce needs, and make a public commitment to better aligning the university's education programs, labs, curricula, and applied learning experiences to future STEM workforce projections.
- Designate a high-level administrator or faculty member to serve as the initial point of contact with local businesses and give this individual the power and authority to enter into formal relationships with them (and, where appropriate, with third-party intermediaries). Among the responsibilities of this individual should be coordinating departmental STEM advisory boards. Make this effort a high-profile, high-priority activity of the university.
- Organize and host a regional meeting on campus involving prospective partners, including business leaders, government agencies, chambers of commerce, individual entrepreneurs, and civic associations—focused on creating and sustaining a "regional STEM workforce development ecosystem" that shares the common goals of improving the local economy and strengthening human capital resources in the region.
- Encourage the creation of one or more STEM advisory boards on campus—housed in various academic departments and coordinated by the individual with responsibility for serving as the point of contact for business—for the purpose of regularly and deliberately engaging the local employer community in discussions about current and prospective workforce needs, collaboration, engagement, and mutual support. Ensure that these advisory boards are sufficiently diverse, and emphasize the importance of broadening participation in STEM.

- Using student migration analyses, track attrition in STEM courses and majors in the first 2 years of undergraduate education, and create a plan for increasing completion rates in STEM majors, especially for female and underrepresented minority students. Make use of the variety of evidence-based interventions known to improve student retention and persistence in STEM majors and occupations.

UNIVERSITY DEANS AND FACULTY

- Work with third-party intermediaries to create a regional advisory board that involves both business leaders and employees to ensure that the knowledge, skills, and attributes that students are gaining through their educational experiences are aligned with current and future workforce needs. If necessary, involve local industry officials in the redesign or creation of curricula, labs, and other campus-based experiences.
- Seek out opportunities for both faculty and students to secure internships, apprenticeships, and other work-based learning experiences in local industry and government agencies and labs. In addition, bring local business leaders and employees into the classroom and campus labs as visiting instructors on how industry works to remain current in rapidly changing fields.
- When internships and apprenticeships are limited, create simulated real-world applied learning experiences on campus that mirror the experiences in local work sites, so that students have exposure to workplace conditions and challenges and ensure that accreditation requirements do not become a barrier to the development of innovative applied learning experiences. Recognize that the workplace is often characterized by challenging multilayered problems that require teamwork and collaboration and good interpersonal relationships to identify possible solutions.
- Remain vigilant with efforts to recruit and retain underrepresented minority students and females into STEM majors and pathways. Provide support systems that enable minority and female students to engage regularly with mentors and peers who might have faced, or are currently facing, similar challenges in meeting the demands of the curriculum. Create an "early warning" system to monitor student progress and alert faculty to challenges that students are facing and may have difficulty addressing themselves without some kind of intervention and support.
- Track enrollment and attrition in STEM courses and majors in the first 2 years of undergraduate education, and create a plan for increasing completion rates in STEM majors, especially for female and underrepresented minority students. Make use of the variety of evidence-based interventions known to improve student retention and persistence in STEM majors and occupations.
- Ensure that appropriate incentives are in place for faculty who champion collaborative partnership activities: tenure, salary, summer funding, and infrastructure and personnel resources as needed. Consider grants for workforce development activities as having similar levels of prestige as those for research activities.

STATE AND LOCAL GOVERNMENT AGENCIES

- Work with a third-party intermediary to organize and facilitate a rigorous data collection and analysis effort that attempts to understand the current and future workforce needs in the region, and communicate the findings with both university officials and local businesses.
- Collaborate with third-party intermediary organizations focused on the creation of university-industry partnerships.
- Use legislation and, where possible, funding to incentivize partnerships, collaboration, internships, and other activities that bring students and faculty into regular and sustained contact with local employers. Even relatively modest investments of federal, state, or local dollars can encourage employers and institutions to dedicate time and resources to fostering creative partnerships that can then be sustained over time.

THIRD-PARTY INTERMEDIARIES (e.g., Chambers of Commerce, Workforce Investment Boards, Economic Development Organizations, Industry Consortia)

- Prioritize the importance of broadening participation in STEM education and workforce development pathways by helping to organize, support, and sustain cross-sector partnerships for workforce preparation.
- Facilitate the creation of effective workforce development partnerships among local employers and universities by
    - Bridging some of the cultural and communication barriers that can present obstacles to partnerships;
    - Establishing lines of communication between partners;
    - Organizing convening events;
    - Helping employers and universities understand the region's competitive advantages by addressing data and information needs;
    - Bringing promising partnership activities to scale; and
    - Assisting with securing outside sources of funding, as appropriate.
- Fulfill strategic functions of planning, convening, connecting and brokering, and measuring and evaluating collaborative efforts to promote the development, maintenance, and long-term sustainability of the STEM workforce development ecosystem.

Chapter 1
Introduction and Overview

U.S. strength in science, technology, engineering, and mathematics (STEM) disciplines has formed the basis of innovations, technologies, and industries that have spurred the nation's economic growth throughout the past 150 years.[1] Despite this, our understanding of how universities receive, interpret, and respond to industry signaling demands for STEM-trained workers is far from complete. While there is anecdotal evidence that regions differ in their ability to link STEM degree production with local workforce needs, there has not yet been a systematic examination of how to measure effectiveness or to identify the best practices for accomplishing this goal. In response to this challenge, a committee organized under the auspices of the Board on Higher Education and Workforce of the National Academies of Sciences, Engineering, and Medicine undertook a 1-year study of the extent to which institutions of higher education and regional businesses and industries in five metropolitan communities (Phoenix, Arizona; Cleveland, Ohio; Montgomery, Alabama; Los Angeles, California; and Fargo, North Dakota) collaborate successfully to align curricula, labs, and other undergraduate educational experiences with current and prospective regional STEM workforce needs.

The committee sought to identify the current state of higher education's responsiveness to regional workforce needs at the five target sites, identify barriers to stronger collaboration between universities and regional employers, and identify a number of promising practices and model programs that have fostered university-employer partnerships for aligning educational resources with STEM workforce needs. In particular, the study had two key objectives:

- To the extent to which such signals are available, understand how colleges and universities receive, interpret, and respond to industry signals regarding their demand for STEM-educated and STEM-trained workers.
- Understand the nature and scope of local and regional interactions among employers, nearby colleges and universities, and intermediary organizations focused on regional economic development.

It is worth noting at the outset that colleges, universities, and businesses are not entities that can engage with one another; rather, it is the *people* employed by those institutions who initiate, continue, and in some cases halt those interactions. As such, this study

[1] National Research Council (2012). *Research Universities and the Future of America*. Washington, DC: The National Academies Press.

examines the conditions under which such interactions are *most likely* and *least likely* to take place, the conditions and circumstances that make those interactions most and least productive, and the types of obstacles that individuals and groups of individuals on campuses and in industries must overcome to create true and sustainable partnerships between their organizations. In addition to examining the importance of individual initiative and entrepreneurship, however, the committee looked at organizational structures, institutional cultures (both on campuses and in businesses), and the characteristics of leadership in seeking to identify what was most likely and least likely to facilitate effective partnerships and alliances.

The outcomes of the study are detailed in this report. The hope of the committee is that the experiences and actions of the universities and employers at the selected sites can serve as models that could be adapted and/or scaled in other communities, regions, and states across the United States.

CHARGE TO THE COMMITTEE

This study sought to explore the effectiveness of educational institutions in producing STEM-trained workers in response to regional workforce needs and to identify promising practices in achieving this goal. The study's statement of task is outlined in Box 1-1. To address the issues described in the statement of task, the committee organized five fact-finding regional workshops to gather information and ideas on challenges and strategies in building effective workforce development partnerships.

BOX 1-1 Statement of Task

An ad hoc committee will explore the effectiveness of selected higher education institutions in educating STEM-trained workers in response to regional workforce needs and identify effective practices in achieving this. In this context, effectiveness will be judged, in part, on the number of STEM graduates and the extent to which these individuals graduate from educational programs with degrees that address local STEM workforce needs. The committee will conduct a series of regional meetings, commission work to analyze data on STEM degree production, convene a concluding workshop, and produce a report that compiles insights from all these sources to address the following questions:

1. What data and measurements are available to assess the effectiveness of higher education institutions in educating STEM-trained workers in response to regional labor market needs, and what do such measurements say about differences in effectiveness across regions?

2. To what extent can regional profiles be created that link STEM educational

resources and postsecondary degree pathways with workforce needs, including retraining of professionals in order to meet current, in-demand needs in STEM fields? Is there sufficient resolution in the data to specify regional STEM degree needs by discipline or degree level?

3. What practices and policies are educational institutions adopting to respond to local industry STEM workforce needs, both individually and as part of regional coalitions, and which effective practices and policies are replicable and scalable? What barriers, if any, exist that inhibit educational institutions from meeting regional STEM workforce needs?

4. What further actions are needed to assist higher education institutions, industry, and state or federal policy makers in fostering improved linkages between higher education resources and STEM workforce needs at the regional level?

While the main focus of the study will be on 4-year STEM degrees, the role of community colleges and graduate institutions in meeting regional STEM workforce needs and transitions between institutions will also be examined.

STUDY PROCESS AND METHODOLOGY: ASSUMPTIONS AND CONSTRAINTS

As described in the Statement of Task, the main focus of the study was on 4-year STEM degrees and the colleges and universities that grant these degrees. However, 2-year institutions are critical in the nation's STEM education landscape, with nearly 50 percent of individuals receiving bachelor's degrees in science and engineering having attended a community college at some stage of their education.[2] Furthermore, within the context of a regional metropolitan area, local community colleges and universities are likely to have existing partnerships (whether formal or informal), and populations of students must navigate transitions between 2-year and 4-year institutions during the course of completing their undergraduate education. Community colleges also tend to have more of a workforce orientation than 4-year colleges and universities, given their critical role in upskilling adult learners, as well as providing terminal associate degrees. This career and technical orientation has resulted in many community colleges developing innovative career preparation programs and workforce development partnerships with industry—some of which are profiled in this report. Given these considerations, and the expectation that the committee and the 4-year community could learn from the important work being done at community colleges, 2-year institutions were included as active planning partners at every regional workshop, and community college administrators and faculty were well represented on workshop panels and in other agenda roles (see Appendix C). Because of this extensive involvement, this report contains many examples of innovative initiatives

[2] National Research Council (2012).*Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit*. Washington, DC: The National Academies Press.

and practices occurring in the 2-year sector and also includes findings and recommendations drawn from these examples.

Among the primary sources of information for this study are the five regional workshops that the committee held around the country. As described below and in more detail in Box 1-2, the committee worked with partners in each region to identify key stakeholders, plan agendas, identify panelists, and invite a broad array of participants. As with any project of this nature, it is impossible to include every relevant stakeholder at every workshop—scheduling and logistical constraints will always present themselves. Because the absence of certain stakeholders from the five regional workshops may alter the content and conclusions of the committee, it is important to note some of the additional groups we endeavored to include at one or more workshops, but who were unable to participate for various reasons. These include nontraditional education providers, including adult upskilling organizations, representatives of professional and scientific societies, higher education accreditation organizations, and undergraduate students themselves (see Appendix C for more information on workshop participants).

The committee notes that its primary focus was on addressing questions 2, 3, and 4 as described in Box 1-1. In addressing question 2, the committee discovered that it was difficult to systematically assess how professionals already in the STEM workforce were being retrained, due to a lack of available data on the prevalence and scope of the job "upskilling." Although continuing education and training may be especially important for incumbent workers in fast-evolving, highly skilled STEM fields, some reports have suggested that this kind of training is not very common in the United States.[3] Regarding the Statement of Task's question 1, the committee initially planned on commissioning analyses that would use an econometric approach known as stochastic frontier analysis to identify the efficiency with which institutions of higher education in a defined region produced undergraduate degrees in STEM (question 1 in Box 1-1). Using the Integrated Postsecondary Education Data System (IPEDS)[4] data, these analyses calculate "effectiveness," or the degree to which institutions produce greater or fewer STEM degrees than expected, given the financial and human capital available to them.[5] Unfortunately, it became apparent that determinations of effectiveness require a larger number of colleges and universities as inputs to the analyses than are typically available within a given region.

To identify those institutions most effective at producing undergraduate STEM degrees, these analyses must consider all of the nation's colleges and universities, not just the handful of colleges and universities within a metropolitan statistical area, or even an entire state.[6] Furthermore, the committee found that, for purposes of understanding issues of STEM education and workforce preparation at the regional level, data are inadequate. There is confusion about how to define a region and its boundaries: is it a metropolitan

[3] National Science Board (2015). *Revisiting the STEM Workforce: A Companion to Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.
[4] National Center for Education Statistics, U.S. Department of Education.
[5] Hurtado, S., A. Ruiz Alvardo, and K. Eagan (under review). *Metrics, Money, and Degree Attainment: Identifying Engines of Social Mobility*. Los Angeles, CA: Higher Education Research Institute, UCLA.
[6] Ibid.

statistical area (as defined by the U.S. Census Bureau and used by other federal agencies) or something else? The U.S. Department of Education tracks graduation rates through its IPEDS system, and some institutions track subsequent employment of graduates, but there is not a systematic way to link disparate data sources to provide universities and employers with the rich and robust data they need to help meet local STEM workforce needs. For these reasons, the committee commissioned real-time labor market information (RTLMI) analyses to characterize the key occupations and skills that employers in a given metropolitan statistical area are seeking in new hires. The committee commissioned RTLMI analyses for four of the five regions[7] it visited. These results and their implications for workforce development partnerships in each region are described in the report.

At the outset, the committee took stock of current efforts to examine the effectiveness of educational institutions and programs in producing STEM-trained workers and how educational outputs are coupled with workforce needs. Given that recent work has demonstrated that a region's economic prosperity is related to the educational attainment of its inhabitants,[8, 9, 10, 11] the committee took a regional approach to understanding these issues. The committee identified educational institutions and geographical regions within the United States that appear to be effective in producing STEM-capable workers in response to local industry signaling—settling on five regions to undertake its investigation and analysis: Phoenix, Arizona; Montgomery, Alabama; Cleveland, Ohio; Los Angeles, California; and Fargo, North Dakota. The rationale for selecting those sites is outlined in Chapter 3. Briefly, regions were selected based on the committee's evaluation of the complement of higher education institutions (both 2-year and 4-year colleges and universities), the diversity and strengths of various industries (i.e., some regions have stronger representation in aerospace or advanced manufacturing, others in health care or agriculture), the region's population size, and whether it was urban (Phoenix, Cleveland, Los Angeles) or rural (Montgomery, Fargo). The committee opted to use an inclusive

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[7] The committee commissioned the nonprofit organization Jobs for the Future (JFF) to conduct RTLMI analyses for Phoenix, Cleveland, Montgomery, and Fargo. RTLMI is a form of labor market intelligence that is drawn from online job postings. Vendors such as Burning Glass, The Conference Board, Help Wanted OnLine, and Geographic Solutions "scrape" these data from the Internet daily. RTLMI is distributed by vendors and is purchased by a variety of companies, governments and non-profits that desire access to the data to perform any number of analyses. JFF has no special or unique relationship with any vendor that would make the data it uses different from what any other organization would receive. For purposes of the committee's report, the data that JFF staff used to help frame the conversations at each regional workshop were the same data that any subscriber could have pulled. In fact, several vendors would have likely provided similar analyses for their clients

The committee joined with the Los Angeles Area Chamber of Commerce to plan the Los Angeles workshop, and due to logistical constraints, it was unable to include JFF analysis in that workshop. Workforce and occupation data for Los Angeles was analyzed and presented by the consulting firm Beacon Economics.

[8] DeVol, R. C., I-L. Shen, A. Bedroussian, and N. Zhang. (2013). *A Matter of Degrees: The Effect of Educational Attainment on Regional Economic Prosperity*. Santa Monica, CA; Washington, DC: Milken Institute.

[9] Rothwell, J. (2013). *The Hidden STEM Economy*. Washington, DC: The Brookings Institution.

[10] Abel, J. R., and R. Deitz (2011). *The Role of Colleges and Universities in Building Local Human Capital*. Federal Reserve Bank of New York, *Current Issues in Economics and Finance* 17, no. 6.

[11] San Diego Regional Economic Development Corporation (2015). *The Economic Impact of San Diego's Research Institutions*.

definition of *region*, so as to capture the differences in how industry and higher education partners interact in the different communities visited.

The committee then worked with regional partners—starting with one or more universities or intermediary organizations in each region—to organize a workshop to highlight examples of promising practices and policies that institutions and industries are using to align curricula, labs, and other educational experiences with the needs of local employers, particularly those practices that might be scalable and sharable (see Box 1-2 for more details on the methods used to plan each regional workshop). The committee identified and invited key regional stakeholders to participate in each meeting, including higher education institutions, scholars, local industry representatives, regional economic experts, regional and state policy makers, and local foundations. Appendix C contains the agenda and participant lists for each regional workshop.

BOX 1-2 Planning Process for Regional Workshops

The overarching goal of each workshop was to convene key stakeholders that contribute to the creation and maintenance of regional workforce development partnerships. These stakeholders included faculty, administrators, and students from local colleges and universities, business leaders and company employees (small, medium, and large regional companies and national and global corporations), economic development professionals, policy makers (local, county, regional, and state), and philanthropic organizations. The following list details the key steps in planning each workshop.

1. Identify a motivated regional partner interested in helping to coordinate logistical and programmatic details in the selected city and region. For three workshops, this primary partner was a university (e.g., Arizona State University, Alabama State University, North Dakota State University); for the remaining two workshops, this partner was an intermediary entity interested in facilitating collaborative activities between higher education and industry in the service of regional economic development (e.g., the Ohio Aerospace Institute, the Los Angeles Area Chamber of Commerce).

2. Identify organizations interested in regional economic planning and development. These included city, county, or state chambers of commerce; city, state, or regional economic development organizations; state departments of commerce; and county or state workforce investment boards. Early in its study, the committee learned that these organizations are frequently key connectors and facilitators in their communities and in many instances were critical in helping the committee identify the appropriate individuals to invite to the workshop. These insights, and others, led the committee to make findings and recommendations about these critical intermediary organizations.

3. Using insights from intermediary organizations, identify and recruit key stakeholders to serve as speakers and panelists (see Appendix C for workshop agendas and participant lists). Most often, these individuals were deans and faculty from community colleges and universities, chief executive officers and department heads from industry (representing firms of all different sizes), economic development professionals, and philanthropic leaders.

4. Using the networks and insights from intermediary organizations and speakers/panelists, advertise the workshop and invite participants. Importantly, the committee viewed all workshop attendees as integral to an effective convening, and agendas were designed to solicit comments and suggestions from all workshop participants via ample discussion time and small breakout group sessions.

During the course of the study, it became apparent that a concluding workshop would likely not add any additional insights or observations that would help the committee meet its charge, and so was not held. This report represents the culmination of the committee's effort, and the findings and recommendations contained in this report represent a call to action for the industry and academic sectors—especially 4-year universities and research universities—to improve their responsiveness to local and regional STEM workforce needs. It is important to note the benefits and limitations of taking a regional perspective when looking at issues of STEM education and workforce development. As described above and in more detail in Chapters 2 and 3, universities can have real economic impact in their communities and the production of educated individuals who contribute to the region's economy is just one of the public goods universities produce. The regional perspective has value to employers and industry, which have long recognized the importance of human capital, and many of the most productive regional economies in the United States are located in close proximity to some of the country's top educational institutions. However, it is difficult to systematically track graduates who are mobile and may leave the immediate region where they obtained their degree to take a job elsewhere. This difficulty is due to uncoordinated data systems between universities and the various federal agencies who track educational attainment, wages, and migration, namely the U.S. Departments of Education, Labor, and Commerce, and the U.S. Census Bureau. A recent study was among the first to examine this issue, looking at employment and earnings outcomes for Ph.D. recipients by combining university administrative records with confidential data files from the U.S. Census Bureau[12]. Given that mobility may be different for different types of graduates, depending on degree field, institution type, or other characteristics, the committee believes that this is an important area for future study.

STRUCTURE OF THE REPORT

The remainder of this report focuses on the activities, findings, and recommendations from the five workshops. Chapter 2 provides context for the study and reviews the literature on STEM workforce development strategies. Chapter 3 provides an overview of the five regions and the rationale for selecting each region as a workshop site, and also provides demographic and labor market information about each site. Chapter 4 summarizes the observations gathered at each workshop and identifies the STEM workforce needs articulated by industry leaders in each region, the barriers to successful partnerships, and promising practices used by both universities and employers to overcome the barriers and establish strong partnerships. It includes the specific mechanisms used by employers and universities to align college and university curricula, courses, labs, and internships/mentorships with the current and anticipated knowledge, skills, and attributes of workers. Chapter 5 includes the committee's recommendations for actions, practices, and policies among all partners to improve higher education's responsiveness to regional workforce needs. It also includes a discussion of remaining issues and questions that merit

[12] Zolas, N., et al. (2015). Wrapping It Up in a Person: Examining Employment and Earnings Outcomes for Ph.D. Recipients. *Science* 350(6266):1367–1371.

further study to determine even more effective ways to build and sustain strong partnerships between institutions of higher education and regional employers.

Chapter 2
Project Context and Background

CHARACTERISTICS OF THE STEM WORKFORCE

Ensuring a robust and diverse science, technology, engineering, and mathematics (STEM) workforce is a critical element of our nation's competitiveness strategy, because individuals with STEM knowledge, skills, and abilities drive the innovation that leads to new products, industries, and economic growth.[1, 2] There is no consensus definition of the STEM workforce—in general, these individuals either possess a STEM degree (or other credential) or are employed in a STEM or STEM-related occupation.[3] Recent reports have described the heterogeneity of the STEM workforce, which typically includes professional scientists and engineers working in research and development (R&D), workers who apply STEM knowledge and skills, and workers in technologically sophisticated occupations who need a facility with STEM concepts to excel in their occupations, but not necessarily a bachelor's degree.[4, 5, 6] The STEM workforce also varies based on educational attainment, the STEM or STEM-related field in which the degree or credential was obtained, and the occupational field in which an individual works after completing his or her education.

Despite the complexity associated with defining and classifying the STEM workforce, the number of occupations requiring STEM capabilities is growing. According to the National Science Board's *2014 Science and Engineering Indicators*, between 2003 and 2010 the number of workers reporting that their job requires at least a bachelor's-degree level of facility in STEM increased 28 percent, from 12.9 million to 16.5 million.[7] When the definition of STEM workers is broadened to those outside the traditional STEM industries and those with subbaccalaureate credentials working across all fields, by the year 2011, 20 percent of all jobs in the United States (26 million) required a high level of knowledge in any one STEM field.[8]

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[1] BHEF/ACT Policy Brief (May 2014). Building the Talent Pipeline: Policy Recommendations for The Condition of STEM 2013.
[2] National Science Board (2015). *Revisiting the STEM Workforce: A Companion to Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.
[3] Ibid.
[4] Ibid.
[5] Rothwell, J. (2013). *The Hidden STEM Economy*. Washington, DC: The Brookings Institution.
[6] Oleson, A., M. Hora, R. J. Benbow (2014). *What is a STEM Job? How Different Interpretations of the STEM Acronym Result in Disparate Labor Market Projections*. The Center on Education and Work, University of Wisconsin–Madison.
[7] National Science Board (2015). *Revisiting the STEM Workforce: A Companion to Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.
[8] Rothwell, J. (2013). *The Hidden STEM Economy*. Washington, DC: The Brookings Institution.

Given its charge, as reflected in the statement of task, the committee elected to use its series of workshops to explore the implications of different operational definitions of a region's STEM workforce for better aligning educational resources with regional workforce needs. The committee was interested in focusing more on how STEM skills are used in the workplace, rather than on degree attainment or occupational classification. The U.S. Department of Labor's Occupational Information Network Data Collection Program (O*NET) surveys workers to document the characteristics and knowledge required for their occupation. A recent report used O*NET data to advance a classification framework based on the knowledge and skills individuals need to perform their jobs, rather than simply their job function.[9] This report suggested that there are two STEM economies—one closely linked with 4-year undergraduate and graduate-level education in the sciences, engineering, and medicine and the R&D processes that lead from university-based basic research to innovations and new products and technologies in the private sector. The second STEM economy comprises individuals with community college and vocational educational backgrounds whose jobs require a high level of knowledge and/or skill in a scientific or technical domain, but do not require a bachelor's degree. Nonetheless, individuals in this economy are critical to the implementation and commercialization of innovations stemming from university-based research and contribute to the prosperity of regional economies by boosting wages. These subbaccalaureate, STEM-knowledgeable workers are a critical component of the modern STEM economy.[10]

Additional research has considered how different interpretations of the STEM acronym result in different definitions of a STEM profession. Box 2-1 contains definitions of *STEM-core* versus *STEM-related* jobs and careers according to two classifications—one by the U.S. Bureau of Labor Statistics' Standard Occupational Classification Policy Committee and one by the National Science Foundation (NSF). While there are some differences in the classifications, there are many similarities in professions that require education in core STEM fields versus those that require a less intensive but still important set of education and training experiences in STEM. Moreover, the NSF definition has a general distinction in which science and engineering occupations will typically require a bachelor's degree in a science and engineering field, while the science- and engineering-*related* occupations may not.[11]

[9] Rothwell, J. (2013). *The Hidden STEM Economy*. Washington, DC: The Brookings Institution.
[10] Ibid.
[11] Oleson, A., M. Hora, R. J. Benbow (2014). *What is a STEM Job? How Different Interpretations of the STEM Acronym Result in Disparate Labor Market Projections*. The Center for Education and Work, University of Wisconsin–Madison.

Box 2-1 Comparisons of Core-STEM and STEM-Related Occupations as Classified by Two Federal Agencies[a]

	Department of Labor*	National Science Foundation
Core-STEM	Science, Engineering, Mathematics, and Information Technology Occupations: • Life and physical sciences • Engineering • Mathematics • Information technology • Social science (Types of occupations: research, development, research design, research practitioner; technologist and technician; postsecondary teaching; managerial, sales)	Science and Engineering Occupations: • Biological, agricultural, and environmental life scientists • Computer and mathematical scientists • Physical scientists • Social scientists • Engineers • Science and engineering postsecondary teachers
STEM-Related	Science- and Engineering-Related Occupations: • Architecture • Health (Types of occupations: research, development, research design, research practitioner; technologist and technician; postsecondary teaching; managerial, sales)	Science- and Engineering-Related Occupations: • Health • Managers • Precollege teachers • Technicians and technologists • Architects • Actuaries • Science- and engineering-related postsecondary teachers

*Within the U.S. Department of Labor, the U.S. Bureau of Labor Statistics' Standard Occupational Classification Policy Committee developed this classification scheme.

[a]Table adapted from Oleson, A., M. Hora, and R. J. Benbow (2014), *What is a STEM Job? How Different Interpretations of the STEM Acronym Result in Disparate Labor Market Projections*. The Center for Education and Work, University of Wisconsin–Madison.

Leveraging these prior studies, the committee employed the nomenclature of *STEM broad* versus *STEM narrow* to classify occupations in each of the five regions. The nonprofit organization Jobs for the Future (JFF) worked on behalf of the committee to develop a method for defining and identifying professions in each of those categories. Under the JFF system, STEM narrow included careers in the Sciences (biology, chemistry, physics);

Technology (including computer sciences); Engineering; and Mathematics (including analytics)—with jobs in this category typically requiring at least a bachelor's degree. The STEM broad category included all occupations that exhibit a high degree of STEM knowledge, based on the O*NET Knowledge Survey, but often did not require more than an industry certification or a 2-year associate's degree.[12]

The heterogeneity of the STEM workforce and lack of consensus on how to define it has spurred debates about the level of current and future demand for STEM workers (see Box 2-2). Although this debate continues among academics and policy makers, many occupations requiring 2- or 4-year STEM degrees are growing rapidly.[13, 14] According to a 2012 President's Council of Advisors on Science and Technology (PCAST) report,[15] the United States will need approximately one million more STEM professionals, relative to the number that it is currently producing, if the nation is to retain its international competitiveness in science and technology and meet these workforce demands. To meet this goal, the nation needs to boost the number of students completing STEM bachelor's degrees by about 34 percent over current rates. Critically, while fewer than 40 percent of students entering higher education STEM programs complete a bachelor's degree in a STEM field (either switching majors or leaving higher education),[16] increasing this retention rate by just 10 percentage points would itself generate three-quarters of the targeted one million additional STEM degrees needed to remain competitive.[17]

[12] Defining STEM and STEM related will always be a subjective enterprise. The committee opted to use the O*NET Knowledge Survey to assess whether certain occupations required STEM skills and knowledge, as this tool directly surveys incumbent workers to obtain information on training, education, experience, and skill-related work requirements. As such, occupations can be classified as to the level of STEM skills and knowledge they require.

[13] Carnevale, A.P., N. Smith, and M. Melton (2011). *STEM: Science, Engineering, Technology, and Mathematics*. Washington, DC: Georgetown University Center for Education and the Workforce.

[14] Carnevale, Smith, and Strohl (2010). Help Wanted: Projections of Jobs and Education Requirements Through 2018. Washington, DC: Georgetown University Center for Education and the Workforce.

[15] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduate with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President. Note that the analyses of STEM higher education enrollment, persistence, and completion included in the PCAST report (Appendix C) only include STEM bachelor's degrees.

[16] Ibid.

[17] Understanding patterns of degree completion is more complicated for students enrolled at community colleges, as they may have variable intentions and credential goals—they may be seeking a terminal 2-year degree or certificate or transfer to a 4-year institution without earning a degree. With this caveat, data suggest that about 20 percent of STEM community college students attained any STEM credential 6 years after enrollment. See: National Academies of Sciences, Engineering, and Medicine (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways*. Washington, DC: The National Academies Press.

BOX 2-2 Is there a STEM Workforce Shortage? Excerpt from the National Science Board 2015 Report, *Revisiting the STEM Workforce*

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

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

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

Research suggests that the first 2 years of college represent a critical period during which students, especially women and underrepresented minorities, are most likely to change majors and leave STEM fields.[18, 19] The most effective interventions for increasing the persistence of students in completing STEM degrees are targeted to the first 2 years of college and involve redesigning introductory STEM courses to provide more active learning and real-world problem solving, more and earlier exposure to authentic research

[18] Ibid.

[19] Chen, X., and M. Soldner (2013). *STEM Attrition: College Students' Paths Into and Out of STEM Fields*. National Center for Education Statistics, U.S. Department of Education.

experiences, earlier and better access to role models and mentors, and a suite of support services (e.g., campus learning communities, bridge programs).[20, 21, 22]

Educators, policy makers, industry leaders, and others recognize the importance of strong college-university-industry collaboration in supporting and promoting these interventions to increase the retention of STEM majors and better prepare the STEM workforce of the future. The Business Roundtable, an association of chief executive officers of leading U.S. companies with a combined $7.2 trillion in annual revenues and almost 16 million employees, has called for more universities and employers to partner so they may better understand regional labor market needs and create or redesign curriculum and programs organized around those workforce needs. A recent report from the Business Roundtable notes the critical importance of employability skills and the role that applied learning experiences such as internships and apprenticeships play in strengthening pathways to STEM jobs.[23] Similarly, PCAST has recommended the development and expansion of public-private partnerships to diversify and expand pathways to STEM degrees and occupations. Finally, several recent reports from the National Academies have described the need for the business community and universities to work together to ensure that universities are producing graduates with the depth of skills and knowledge required to maintain America's competitiveness in the 21st century.[24, 25] There is a clear role for the business community to play in developing and supporting several of the interventions described above. Specifically, firms can provide opportunities for applied learning in the form of internships, role models, and mentors, and can assist education partners in redesigning curricula by sponsoring capstone and other real-world problem-solving projects, serving as adjunct faculty or guest lecturers, and serving as active advisors through revamped advisory boards. These collaborative activities—as the committee observed them at the five regional workshops—are described in more detail in Chapter 4.

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[20] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President.
[21] Business–Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.
[22] National Academies of Sciences, Engineering, and Medicine (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways*. Washington, DC: The National Academies Press.
[23] Business Roundtable (2014). *Closing America's Skills Gap: A Vision and Action Plan*.
[24] National Research Council (2007). *Rising Above the Gathering Storm*. Washington, DC: The National Academies Press.
[25] National Research Council (2012). *Research Universities and the Future of America*. Washington, DC: The National Academies Press.
[25] Ibid.

WORKFORCE DEVELOPMENT ECOSYSTEMS

Institutions of higher education are drivers of regional economic development, and their presence and productivity is linked to the prosperity of the surrounding community.[26, 27] Universities are essential to the creation and transfer of new knowledge that drives innovation. This knowledge moves out of the university and into broader society in several ways—through highly skilled graduates (i.e., human capital);[28] academic publications; faculty consulting efforts; and the creation of new products, industries, and companies via the commercialization of scientific breakthroughs.[29] Universities do much more than train workers, but providing skilled workers is one of their key functions. This is especially true for many STEM-related occupations, of which universities and colleges are the sole providers.

Colleges and universities can enhance regional economic development via their roles as an employer, purchaser (i.e., procurement of goods and services), real estate developer, workforce developer (i.e., educational programs), and through technology development and its commercialization.[30, 31] There is evidence to indicate that the presence of a university in a community increases the supply of educated and skilled local college graduates who can meet the workforce needs of the region. One study, for example, suggested that the presence of a land-grant university in a metropolitan area results in 25 percent more college graduates and significantly higher wages,[32] although it is important to note that human capital can be mobile and not all graduates will become part of the regional economy. Importantly, it is not the mere presence of a university that is beneficial for regional economic development. Universities must actively engage and partner with other stakeholders concerned with regional economic development; they are "most effective at shaping a local economy when they are part of a larger ecosystem of innovative activity."[33] The federal government recognizes the value and impact of these partnerships, and supports a number of programs designed to strengthen them, including the NSF's

[26] Porter, M. (2007). *Colleges and Universities and Regional Economic Development: A Strategic Perspective*. Forum for the Future of Higher Education. Cambridge, MA.
[27] San Diego Regional Economic Development Corporation (2015). *The Economic Impact of San Diego's Research Institutions*.
[28] Abel, J. R., and R. Deitz (2011). The Role of Colleges and Universities in Building Local Human Capital. Federal Reserve Bank of New York, *Current Issues in Economics and Finance* 17, no. 6.
[29] National Research Council (2012). *Research Universities and the Future of America*. Washington, DC: The National Academies Press.
[30] Ibid.
[31] University Economic Development Association and Association of Public and Land-Grant Universities (2015). *Higher Education Engagement in Economic Development: Foundations for Strategy and Practice*.
[32] Moretti, E. (2013). *The New Geography of Jobs*. Boston, New York: Mariner Books, Houghton Mifflin Harcourt. 197.
[33] Ibid.

"centers" programs, such as Engineering Research Centers and Industry University Cooperative Research Centers.[34]

The term *ecosystem* captures the elements of effective, regionally focused workforce development partnerships. Each individual partner is interconnected with others in a symbiotic relationship that is able to adapt and evolve as both inputs and desired outcomes change. A recent report that details the STEM Learning Ecosystem approach for K-12 education notes that these ecosystems "encompass schools, community settings, science centers and museums, and informal experiences at home and in a variety of environments that together constitute a rich array of learning opportunities for young people."[35] STEM Learning Ecosystems pursue several strategies that have also been shown to improve STEM retention and increase the participation and persistence of underrepresented groups at the postsecondary level.[36] These include leveraging strong leadership, employing educational interventions known to be effective at strengthening STEM learning and retention, providing applied learning opportunities, and implementing a suite of support and wrap-around services for students and their families.

The committee believes that the ecosystem concept can be applied to cross-sector partnerships between business and higher education in the service of STEM workforce development and regional economic growth, a so-called STEM Workforce Development Ecosystem. In this ecosystem, actors include colleges and universities, local employers, and intermediary entities whose objective is to facilitate regional economic development. These intermediary bodies might be state or county government agencies, economic development organizations, chambers of commerce, and philanthropic foundations.
Community colleges have been the first, and thus far the only, sector (to the committee's knowledge) to apply the ecosystem approach to STEM workforce development at the postsecondary level. In 2013 Jobs for the Future and Achieving the Dream launched the Regional STEM Collaboratives Initiative, which is supporting three regional collaboratives in Ohio, Florida, and Connecticut. Each collaborative is centered on a community college and brings together local employers, state partners, community organizations, and the college's leadership, faculty, and staff to build more effective middle-skilled STEM pathways and meet the high demand for these workers in regional labor markets.[37]

Importantly, these collaboratives: (1) champion the use of interventions that help students persist and complete STEM degrees and (2) have committed leaders who recognize the importance of focusing efforts on strengthening those education and career pathways to meet specific regional workforce needs in STEM. The collaboratives are using real-time labor market information (RTLMI) to help them identify their region's most pressing STEM

[34] National Research Council (2012). *Research Universities and the Future of America*. Washington, DC: National Academies Press.
[35] Traphagen, K., and S. Traill (2014). *How Cross-Sector Collaborations Are Advancing STEM Learning*. Los Altos, CA: The Noyce Foundation.
[36] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President.
[37] Jobs for the Future and Achieving the Dream (2014). *STEM Regional Collaboratives: The Opportunity*.

workforce needs. RTLMI can reveal new and emerging trends in occupations for a region and offer insights into the skills, abilities, and credentials sought by regional employers. Importantly, RTLMI can identify occupations for which a given region has a competitive advantage, or those occupations for which there is a larger labor market share within the region relative to the national average.[38, 39] These data are useful for both partners, as they help higher education institutions understand the immediate needs of employers and they provide businesses with the opportunity to confirm that their self-reported workforce needs reflect the skills and occupations they are seeking to fill with new hires. The central importance of RTLMI for effective STEM workforce development partnerships and ecosystems is described in Chapter 4.

The Business-Higher Education Forum (BHEF) has developed a model that details five strategies that business and higher education can use to move from transactional relationships to strategic partnerships that advance economic development. BHEF has had success in applying its model to building the cybersecurity workforce in Maryland and to assisting the U.S. Navy in identifying the most effective strategies it can use to build its civilian STEM workforce. Importantly, the BHEF model leverages many of the principles described above as essential to a robust STEM workforce development ecosystem. Specifically, the five major strategies of the model include engaging and deploying corporate and academic leadership, focusing on corporate philanthropy, identifying and exploiting core competencies and expertise, facilitating employee engagement, and providing real-world research and learning opportunities.[40, 41]

APPLIED LEARNING EXPERIENCES: INTERNSHIPS, COOPERATIVE EDUCATION PROGRAMS, AND EMPLOYABILITY SKILLS

The focus of our study was not on whether colleges and universities were preparing their students and graduates to move into particular jobs, but rather whether they were giving students both the breadth and depth of experiences in STEM courses and laboratories—and in the totality of their undergraduate experiences—to ensure that they would move into their careers ready to be successful, adaptable, and agile workers and learners. A workforce development ecosystem approach highlights the need for employers and

[38] We define *competitive advantage* (as measured by location quotient) to mean the following: a location quotient (LQ) is a way of quantifying how concentrated a particular industry, cluster, occupation, or demographic group is in a region as compared to the nation.

[39] RTLMI has additional applications, including (1) articulating differences in skill demand within an occupation by employers in their region (as compared with national or more generic profiles) and differences in skill demand within an occupation for industries that have strong clusters in their region; (2) tracking of the top employers by job or skill in their region for the purpose of employer outreach and engagement.

[40] Business–Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.

[41] Business–Higher Education Forum (2013). *The U.S. STEM Undergraduate Model: Applying System Dynamics to Help Meet President Obama's Goals for One Million STEM Graduates and the U.S. Navy's Civilian STEM Workforce Needs*. Washington, DC.

institutions of higher education to work together to develop and promote interventions that can lead to more available STEM workers in a given region. Applied learning opportunities in the form of paid internships and cooperative education programs represent a natural point of shared commitment and partnership. These experiences can provide employers with opportunities to recruit and retain highly skilled STEM students, while helping the students develop the skills and abilities they will need in the STEM workplace. Importantly, internship and cooperative programs have been demonstrated to increase student persistence in STEM[42, 43] and improve job performance once hired,[44] likely because they foster personal identification with STEM careers, in addition to skill development. While all students benefit from richer, more rigorous academic experiences, and from more hands-on authentic learning, the needs of underrepresented minority students and female students must be paramount if we are to close the achievement gaps and participation gaps in STEM majors and careers. The challenges are evidenced by many recent reports on this topic, and need explicit and focused attention as a priority challenge.[45]

In addition to technical skills, internships and other applied learning experiences may also help students develop those workplace competencies that employers often identify as lacking among new hires—employability skills (these skills are also called 21st century skills, among other terms).[46] A recent report from the National Academies of Sciences, Engineering, and Medicine, having performed a review of the available literature, grouped 21st century skills into three broad domains—cognitive, interpersonal, and intrapersonal. Cognitive 21st century skills include critical thinking, creativity, and problem solving (among many others); intrapersonal skills include flexibility, responsibility, and integrity; and interpersonal skills include communication, collaboration, and conflict resolution.[47] Despite an overwhelming (anecdotal) consensus among employers that employability skills are lacking in recent STEM graduates, little research has been performed that has looked systematically at the relationship between these skills and employment outcomes.[48]

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[42] Jaeger, A. J., M. K. Eagan, and L. G. Wirt (2008). Retaining Students in Science, Math, and Engineering Majors: Rediscovering Cooperative Education. *Journal of Cooperative Education and Internships* 42(1):20–31.
[43] Packard, B. W. (2011). Effective Outreach, Recruitment, and Mentoring into STEM Pathways: Strengthening Partnerships with Community Colleges. In National Research Council (2012), *Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit*. Washington, DC: The National Academies Press.
[44] Malsberry, S. (2014). *The Relationship of Skilled Aerospace Manufacturing Workforce Performance to Training*. Ph.D. dissertation. Walden University, Minneapolis, MN.
[45] Among the many reports on this topic, see *Why So Few? Women in Science, Technology, Engineering, and Mathematics* (2010), American Association of University Women, Washington, DC; and *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways* (2016), National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press.
[46] See National Research Council (2014), *Undergraduate Chemistry Education: A Workshop Summary*, Washington, DC: The National Academies Press; American Association of Colleges and Universities (2013), *It Takes More Than a Major: Employer Priorities for Learning and Student Success*, Washington, DC.
[47] National Research Council (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.
[48] Ibid.

A number of colleges and universities are pursuing the development and implementation of interdisciplinary programs that integrate courses and experiences in STEM, the humanities, and liberal arts in an effort to broaden students' skill development and enable them to acquire a broad range of technical skills and employability skills. Given the early and promising results that have emerged from such initiatives,[49] the committee believes there is value in encouraging more of these integrated programs and creating more applied learning experiences for students at the undergraduate level that combine learning experiences in STEM with the development of knowledge and skills in the context of real-world settings (either at a worksite or through simulated work-based experiences on campus). These issues are further explored in Chapters 4 and 5.

It is worth noting that this chapter—and indeed this entire report—focuses on efforts to better align college and university curricula and programs with regional workforce needs. This is not to suggest that the sole purpose of higher education is to serve as a training ground for local, regional, or national business or industry. Nor is it meant to suggest that the vocational aspect of the postsecondary experience is necessarily the primary purpose of pursuing a 2-year, 4-year, or graduate-level college or university degree. Members of the committee subscribe to the belief that a primary purpose of higher education is to develop and strengthen the intellectual, moral, and civic development of young people and of all students of any age. Moreover, higher education provides vital services to our society as a whole through research and social engagement that improve all aspects of our lives. The focus of this report is not intended to minimize the importance of these significant roles of higher education. Rather, this report focuses on two other essential elements of postsecondary education: preparing a deeply knowledgeable and highly skilled workforce, and enhancing the nation's (and a region's) economic development—both of which can enhance the quality of life for all citizens.

A number of broader changes are taking place within higher education that will likely have some effect on regional workforce development ecosystems. As the higher education community responds to calls for increased accountability, it is critical that universities undertake continuous quality improvement efforts to strengthen all aspects of the academic experience—and draw on the quality improvement efforts of local employers to support such efforts. There are many new quality assurance tools that have been developed by coalitions of universities, including the new Degree Qualifications Profile recently supported by the Lumina Foundation.[50] Many industries have also adopted innovative programs and policies to improve quality and productivity, and while the lessons learned from industry are not always a direct fit to higher education, many benefits can be secured. For example, online courses and simulations can enhance ongoing education and training activities in ways that supplement day-to-day instruction. In addition, competency-based models of course delivery, often adopted by industry training

[49] Stewart-Gambino, H and J.S. Rossman. (2015). *Often Asserted, Rarely Measured: The Value of Integrating Humanities, STEM, and Arts in Undergraduate Learning*. Paper presented at National Academies Workshop on Integrating Education in the Arts and Humanities with Education in STEM, December 2, 2015.
[50] Lumina Foundation (2014).The Degree Qualifications Profile: A learning-centered framework for what college graduates should know and be able to do to earn the associate, bachelor's, or master's degree.

programs, and increasingly used by universities, can be offered as either regular courses and as supplements.

Chapter 3
Background on the Selected Regions

INTROUDCTION

In selecting Phoenix, Cleveland, Montgomery, Los Angeles, and Fargo, the committee aimed to capture a broad range of demographic, labor, and educational characteristics. It looked for regions that have a range of types of institutions of higher education (2- and 4-year; public and private); that have active economic development organizations already exploring the science, technology, engineering, and mathematics (STEM) workforce; and that have economies focused on a variety of industries and employer types. The committee prioritized regions that had a mix of research universities and regional comprehensive universities and also paid particular attention to minority-serving institutions. The committee worked to ensure that historically black colleges and universities, Hispanic-serving institutions, and tribal colleges and universities were included as either hosts or participants at several workshops. Desirable regions were those that have received less attention than locales where linkages between higher education and regional workforce have been extensively examined (e.g., the Boston-Cambridge area of Massachusetts or Silicon Valley in California).

The committee's primary objectives in its site selection included having a broad geographical distribution with major urban areas as well as smaller cities in more rural regions. The committee identified regions with distinct demographics, experiencing different labor market dynamics and economic growth, and differing in how successful industry and higher education have been thus far in establishing strong cross-sector partnerships. The committee also worked to ensure that selected regions had a mix of small, medium, and large businesses and firms with both regional and national (and in some cases, international) presences. Practical concerns also came into play. For highly productive regional workshops, a project of this magnitude required a strong core set of college, university, industry, and economic development partners in each locale, as well as people ready and willing to assist the committee in organizing and hosting each of the five events (which all occurred within a 6-month period). Lastly, an important criterion was local participants' eagerness to make progress in their partnerships. Regions were selected in which organizations in both sectors clearly perceived the need for stronger linkages and were moving along the path toward addressing that need.

The data presented below were drawn from a number of sources, including the U.S. Census, the U.S. Bureau of Labor Statistics, and real-time labor market information (RTLMI) analyses commissioned by the committee and performed by the nonprofit organization Jobs for the Future. Data for Los Angeles diverge from those of the other regions because of the modified format of that meeting; it was coorganized by the Los Angeles Area Chamber of Commerce, and due to logistical constraints, we were unable to include RTLMI analyses in that workshop. At that meeting the workforce data were provided by a presenter from Beacon Economics. The descriptions below reflect the order in which the committee visited the locations.

The RTLMI analyses identified the occupations for which each region has a competitive advantage, that is, the occupations that constitute a larger share of the labor market in that region than the average for the United States overall. The areas of competitive advantage may serve as a focal point for higher education, regional employers, and third-party organizations as they consider building or strengthening cross-sector partnerships and developing a regional STEM workforce development ecosystem.

The RTLMI analyses also identified the top industries for STEM-related jobs and the skills most in demand, for both STEM broad and STEM narrow classifications (described in detail in Chapter 2). The analyses showed that every region has many more jobs in STEM broad than in STEM narrow—often by an order of magnitude—demonstrating that higher education's role in training STEM-competent students who thrive in the regional workforce goes beyond the traditional STEM majors and extends to these institutions' conferring a range of STEM competencies. This focus on *skills* is consistent with a theme heard by the committee from employers in the five regions, that is, that STEM skills are often more important than STEM degree fields.

The analyses summarized below capture a moment in time. Clearly, regional needs will change somewhat. The continual evolution of regional economies—and of the macroeconomic environment within which they exist—underscores the need for finer resolution in workforce data and the creation and strengthening of structured partnerships among higher education, government, third-party organizations, and employers in locales nationwide. Table 3-1 presents demographic data for the five regional workshops. Each region is discussed in the order in which the workshops were held.

TABLE 3-1 Demographic Data for the Five Regions Visited

	Phoenix AZ	Cleveland OH	Montgomery AL	Los Angeles CA	Fargo ND
Percentage of people with a high school education or higher, metropolitan area[a]	80.6	77.4	87.5	74.5	94.6
Percentage of people with a high school education or higher, state[a]	85.7	88.5	83.1	81.2	90.9
Percentage of college degree holders, metropolitan area[a]	26.3	14.9	35.7	31.1	39.0
Percentage of college degree holders, state[a]	26.9	25.2	22.6	30.7	27.2
Median household income, metropolitan area[a]	$47,139	$26,217	$43,702	$49,497	$45,458
Median household income, state[a]	$49,774	$48,308	$43,253	$61,094	$53,741
Percentage of residents living below the poverty line, metropolitan area[a]	22.8	35.4	22.6	22.0	16.3
Percentage of residents living below the poverty line, state[a]	17.9	15.8	18.6	15.9	11.9
Percent unemployment rate, metropolitan area[b]	5.7	5.6	6.6	7.5	2.4

[a] U.S. Census Bureau.
[b] U.S. Bureau of Labor Statistics, http://www.bls.gov/eag, accessed July 2015.

PHOENIX, ARIZONA

The Phoenix metropolitan area (4.19 million residents in 2010) is rapidly growing and diverse, and located in a state with a significant Native American population and large Hispanic population. Prior to 2007, the region had one of the most rapidly growing economies in the nation, but it was hit hard by the recession beginning in 2008. Major industries include aerospace, defense, information technology, and biomedicine/health care. In addition to these and other large companies, the region has a sizable number of small- and medium-sized businesses, which were well represented at the workshop. Institutions of higher education include Arizona State University (our host), Grand Canyon University, and the Maricopa County Community College District, a network of 10 community colleges in the Phoenix metropolitan area. Figure 3-1 provides an overview of the need for STEM skills in the Phoenix region.

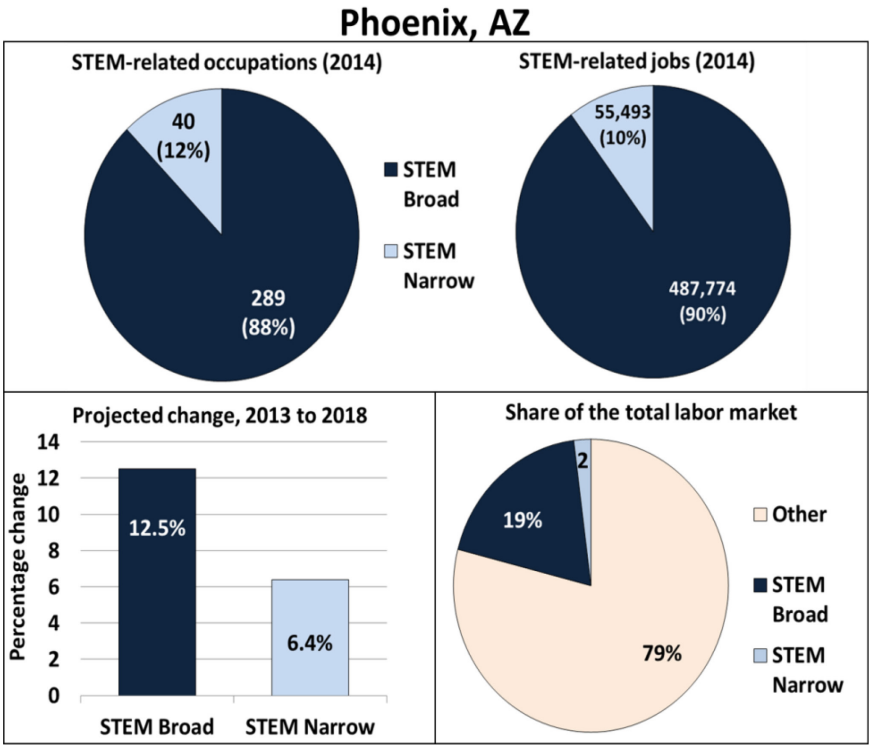

FIGURE 3-1 Overview of the need for STEM skills in the Phoenix region.
Note: The panel in the lower left displays growth or positive change.
Source: Jobs for the Future analysis uses Economic Modeling Specialists International data to assess job numbers.

The Phoenix area has a competitive advantage in a number of occupations, with many more falling into the STEM broad category than into STEM narrow. Table 3-2a lists those occupations for which the Phoenix region has a competitive advantage, organized by educational level. Table 3-2b lists Phoenix's top STEM employers as identified by RTLMI analyses, and Table 3-2c lists the Phoenix workshop participants.

TABLE 3-2a Phoenix Region: Occupations with a Competitive Advantage in 2013

Educational Level	STEM Broad	STEM Narrow
Less than a bachelor's degree	Veterinary technologists and technicians Web developers Computer user support specialists Diagnostic medical sonographers Medical equipment repairers Heating, air conditioning, and refrigeration mechanics and installers	Industrial engineering technicians Electromechanical technicians Aerospace engineering and operations technicians Electrical and electronics engineering technicians Electrical and electronics drafters Engineering technicians other than drafters
Bachelor's degree or higher	Software and applications developers Statistical assistants Computer and information systems managers Financial managers Surveyors Purchasing managers Anesthesiologists	Forensic science technicians Hydrologists Electronics engineers (except computer) Computer hardware engineers Operations research analysts Materials engineer

SOURCE: Analysis by Jobs for the Future using data from Burning Glass Technologies.

TABLE 3-2b Phoenix Region: Top Employers as Identified by RTLMI Analyses

Top STEM Employers—RTLMI Analyses	
Dignity Health	eBay
Best Buy	Mayo Foundation
Banner Health System	Fresenius
United Health Group	American Express
General Motors	Intel Corporation [a]

[a] Attended the regional workshop.

SOURCE: Analysis by Jobs for the Future.

TABLE 3-2c Phoenix Region: Workshop Participants, January 22–23, 2015

Employers/Industry	Higher Education	Third-Party Intermediaries	Policy/ Government	Nonprofit/ Philanthropic
ACESA Corporation	Arizona State University	Greater Phoenix Economic Council	Arizona Commerce Authority	Arizona Technology Council
Arizona Public Service	Maricopa County Community College District	Greater Yuma Economic Development Corporation		Science Foundation Arizona
TJM Electronics	Glendale Community College	Arizona Chamber of Commerce and Industry		Arizona Council of Engineering and Science Associations
Freeport MacMoRan	Estrella Mountain Community College			Association of University Research Parks
Avnet Inc.	Yavapai College			EdLeader21
Intel Arizona	Grand Canyon University			
Google				
Medtronic				
Microchip				
Siemens				
Stratco				

CLEVELAND, OHIO

The Cleveland metropolitan area has a population of 2.1 million (2010) and is located in northern Ohio on the shore of Lake Erie. Historically, its economy has been strong in manufacturing, and key sectors today include manufacturing, health care, and aerospace. Institutions of higher education include Case Western Reserve University, Youngstown State University, Cuyahoga Community College, and Lorain County Community College. The meeting was hosted by the Ohio Aerospace Institute. Figure 3-2 provides an overview of the need for STEM skills in the Cleveland region.

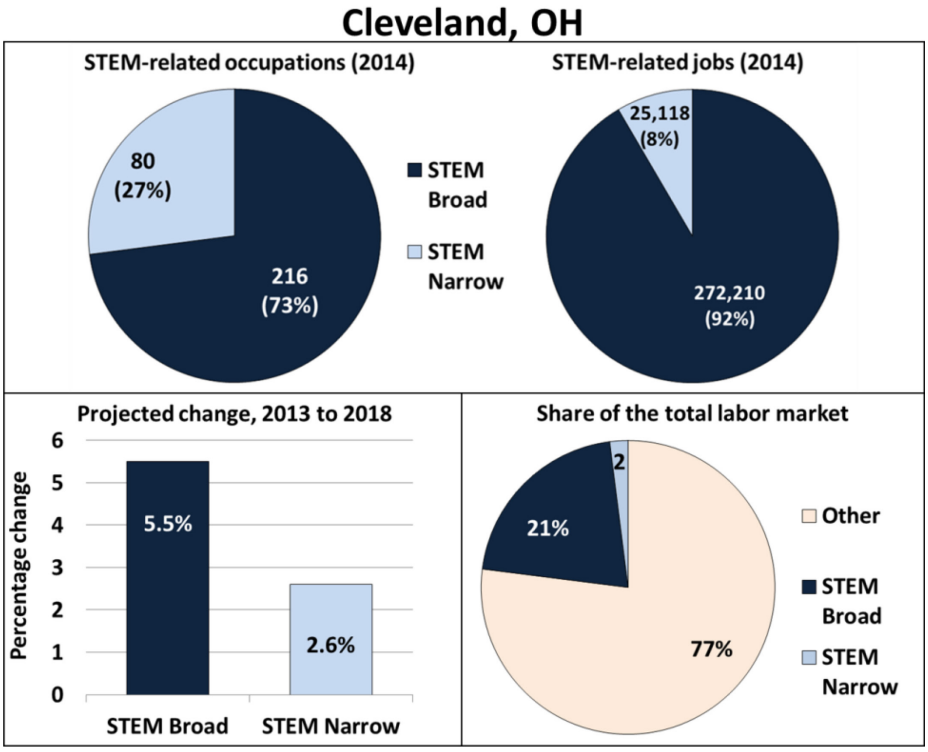

FIGURE 3-2 Overview of the need for STEM skills in the Cleveland region.
Note: The panel in the lower left displays growth or positive change.
Source: Jobs for the Future analysis uses Economic Modeling Specialists International data to assess job numbers.

The Cleveland area has a competitive advantage in a number of occupations, with (as for the other regions visited) many more falling into the STEM broad category than into STEM narrow. Table 3-3a lists those occupations for which the Cleveland region has a competitive advantage, organized by educational level. Table 3-3b lists Cleveland's top STEM employers as identified by RTLMI analyses, and Table 3-3c lists the Cleveland workshop participants.

TABLE 3-3a Cleveland Region: Occupations with a Competitive Advantage in 2013

Educational Level	STEM Broad	STEM Narrow
Less than a bachelor's degree	Foundry mold and core makers Tool and die makers Lathe and turning machine tool setters Operators, credit authorizers Extruding and drawing machine operators Prepress technicians and workers Machinists	Chemical technicians Industrial engineering technicians Mechanical drafters Electromechanical technicians Aerospace engineering and operations technicians Mechanical engineering technicians
Bachelor's degree or higher	Pediatricians Oral and maxillofacial surgeons Sales engineers Psychiatrists Other health care practitioners and technical workers Other physicians and surgeons	Biomedical engineers Materials engineers Actuaries Nuclear engineers Industrial engineers Materials scientists

Source: Analysis by Jobs for the Future using data from Burning Glass Technologies.

TABLE 3-3b Cleveland Region: Top Employers as Identified by RTLMI Analyses

Top STEM Employers—RTLMI Analyses	
Ohio Department of Health	Southwest General Health Center
Ohio Department of Transportation	HCR ManorCare
American Red Cross	Philips Electronics
Sherwin Williams	Lubrizol Corporation [a]
Cleveland Clinic [a]	Alliance Scientific Solutions
University Hospitals	PNC Financial Services
Kindred Healthcare	

[a] Attended the regional workshop.

Source: Analysis by Jobs for the Future.

TABLE 3-3c Cleveland Region: Workshop Participants, April 1, 2015

Employers/Industry	Higher Education	Third-Party Intermediaries	Policy/ Government	Nonprofit/ Philanthropic
The Cleveland Clinic	Cleveland State University	Ohio Aerospace Institute	Cleveland/Cuyahoga County Workforce Investment Board	KeyBank Foundation
TimkenSteel	Youngstown State University	New Growth Group	Ohio Board of Regents	The Nord Family Foundation
PHASTAR Corporation	Lorain County Community College	MAGNET	NASA Glenn Research Center	Cleveland Foundation
COO/ZIN Technologies	Cuyahoga County Community College	Ohio Manufacturing Institute	Ohio Manufacturing Institute	Cleveland Engineering Society
WIRE-Net	Case Western Reserve University			Dayton Regional STEM Center
University Hospitals	Baldwin Wallace University			
ECCL Aerospace Services	Wright State University			
Indus International	University of Cincinnati			
The Lubrizol Corporation				
GE Lighting				

MONTGOMERY, ALABAMA

The Montgomery metropolitan area has 374,000 residents (2010) and is situated in a more rural, southern state. The region has a large African American population, and major industries include defense, aerospace, and the automotive industry. Institutions of higher education include Alabama State University (our host) and Tuskegee University (both historically black universities), Auburn University, and members of the Alabama Community College System. Figure 3-3 provides an overview of the need for STEM skills in the Montgomery region.

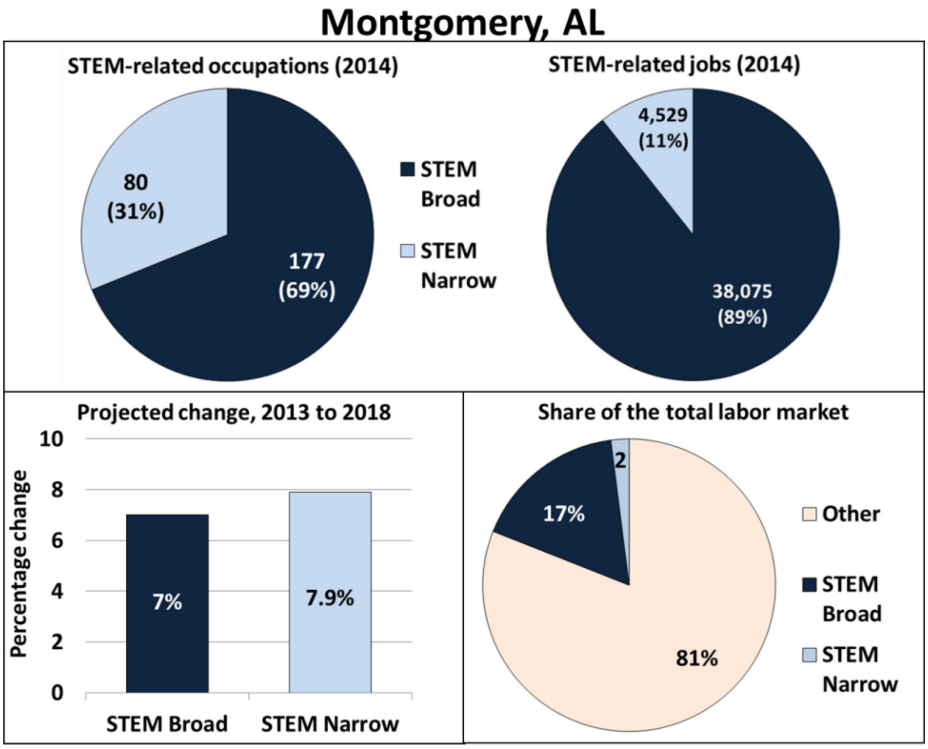

FIGURE 3-3 Overview of the need for STEM skills in the Montgomery region.
Note: The panel in the lower left displays growth or positive change.
Source: Jobs for the Future analysis uses Economic Modeling Specialists International data to assess job numbers.

The Montgomery area has a competitive advantage in a number of occupations, with many more falling into the STEM broad category than into STEM narrow. Table 3-4a lists those occupations for which the Montgomery region has a competitive advantage, organized by educational level. Table 3-4b lists Montgomery's top STEM employers as identified by RTLMI analyses, and Table 3-4c lists the Montgomery workshop participants.

TABLE 3-4a Montgomery Region: Occupations with a Competitive Advantage in 2013

Educational Level	STEM Broad	STEM Narrow
Less than a bachelor's degree	Power plant operators Broadcast technicians Veterinary assistants Computer, automated teller, and office machine repairers Welders	Environmental engineering technicians Environmental science and protection technicians Surveyors Mechanical engineering technicians
Bachelor's degree or higher	Database administrators Forensic science technicians Other computer occupations Computer programmers Instructional coordinators Budget analysts	Foresters Urban and regional planners Environmental engineers Forensic science technicians Statisticians Environmental scientists

SOURCE: Analysis by Jobs for the Future using data from Burning Glass Technologies.

TABLE 3-4b Montgomery Region: Top Employers as Identified by RTLMI Analyses

Top STEM Employers—RTLMI Analyses	
Sherlock Smith and Adams	Bridgestone/Firestone
City of Montgomery	Department of Veterans Affairs
GKN Aerospace	IBM
Ricoh Electronics	Alcatel-Lucent
Hargrove Engineers + Constructors	Rheem Manufacturing
Jackson Hospital	American Express
Baptist Medical Center	General Dynamics

Source: Analysis by Jobs for the Future.

TABLE 3-4c Montgomery Region: Workshop Participants, May 11, 2015

Employers/Industry	Higher Education	Third-Party Intermediaries	Policy/ Government	Nonprofit/ Philanthropic
Lockheed Martin Conference America	Alabama State University Tuskegee University Auburn University Alabama Community College System H. Councill Trenholm State Community College	Montgomery Area Chamber of Commerce Economic Development Association of Alabama	Alabama Department of Commerce Alabama Commission on Higher Education	Alabama Science in Motion

LOS ANGELES, CALIFORNIA

The committee's Los Angeles meeting took a somewhat different shape, as the opportunity arose to collaborate with the Los Angeles Area Chamber of Commerce in an event already in the planning stages that would reach a substantial number of STEM employers in the region. This meeting thus drew a relatively larger number of representatives of the regional workforce. In addition, the workforce data presented were provided by a local economic research organization, Beacon Economics, rather than by Jobs for the Future, as was done in the other four meetings.

Los Angeles is the second-largest metropolitan area in the United States with a population in 2010 of 12.8 million. It is highly diverse ethnically and socioeconomically, including a large Hispanic population. Whereas other areas of California have historically received more attention from efforts to develop and sustain university-industry partnerships—notably, Silicon Valley and the San Francisco Bay Area—the Los Angeles basin may have less robust partnerships, but at the same time, a broader range of industries with which higher education is or can be connected. The region has a large network of 2- and 4-year institutions of higher education, including the California State Universities at Dominguez Hills, Fullerton, Long Beach, Los Angeles, and Northridge; California State Polytechnic University, Pomona; the University of California, Los Angeles; the University of California, Irvine; the California Institute of Technology; the University of Southern California, the Los Angeles Community College District, Santa Monica Community College, Glendale Community College (among others); and a number of private colleges and universities.

In Los Angeles County, top STEM occupations include health care, professional/business, manufacturing, financial activities, education, government, retail trade, information, transport/utilities, leisure and hospitality, and wholesale trade. Between 2000 and 2013, negative growth was seen in manufacturing and information (Figure 3-4), while considerable growth was seen in health care, professional/business, education, and government. Dramatic growth was seen in the category of leisure and hospitality, which, while small, grew by 125.2 percent over that period (to 6,003 jobs). Health care showed the greatest increase in share of the labor market with 4.3 percent. Figure 3-4 provides an overview of the STEM workforce in Los Angeles, and Table 3-5 lists the Los Angles workshop participants.

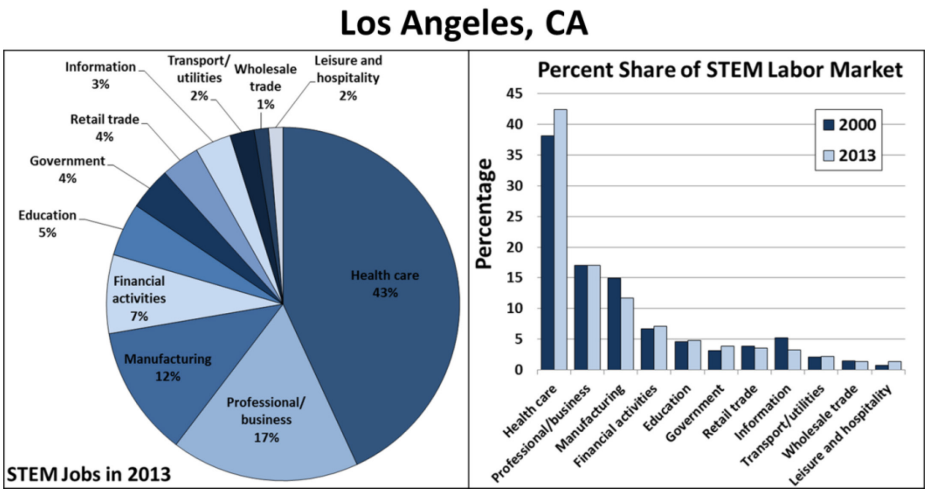

FIGURE 3-4 Overview of the STEM workforce landscape in Los Angeles.
Note: Workforce and occupation data for the Los Angeles workshop was analyzed and presented by the consulting firm Beacon Economics and not Jobs for the Future as in the other regions.
Sources: Adapted from Beacon Economics; U.S. Census 2000; U.S. Census ACS 2013.

The top 4-year degrees leading to STEM jobs in the region were engineering (57,730, or 18.6 percent of workers), nursing (36,798, or 11.8 percent of workers), biology (20,131, or 6.5 percent of workers), computer science (14,746, or 4.7 percent of workers), psychology or business management/administration (12,190, or 3.9 percent of workers), general business (9,366, or 3.0 percent of workers), architecture (6,902, or 2.2 percent of workers), and economics (6,458, or 2.1 percent of workers).

TABLE 3-5 Los Angeles Region Workshop Participants, May 27, 2015

Employers/Industry	Higher Education	Third-Party Intermediaries	Policy/ Government	Nonprofit/ Philanthropic
AAA T.L.C. Health Care Inc.	California State University, Los Angeles	Los Angeles Area Chamber of Commerce	Los Angeles County Metropolitan Transportation Authority	Nonprofit/ Philanthropic
AECOM	California State University, Dominguez Hills	Bixel Exchange	Los Angeles County Office of Education	American Cancer Society
AltaSea, Port of Los Angeles	California State University, Northridge	Los Angeles County Economic Development Corporation	Los Angeles County Workforce Investment Board	Big Brothers Big Sisters of Greater Los Angeles
AP Group	California Institute of Technology	Managed Career Solutions	Los Angeles Jobs Corps Center (U.S. Department of Labor)	Boy Scouts of America
Avery James Inc.	Citrus College	San Gabriel Valley Economic Partnership		California Community Foundation
Beacon Management Group	DeVry University	South Bay Workforce Investment Board		College-Bridge
Cedars-Sinai Health System	East Los Angeles College			Common Sense Education
City of Los Angeles	El Camino College			EnCorps STEM Teachers
Cumming Construction Management Inc.	Los Angeles Community College District			Friends of Hollywood Central Park
Deloitte LLP	Los Angeles Harbor College			Great Minds in STEM
Farmers Insurance Group of Companies	Los Angeles Southwest Community College			I Have A Dream
Hitachi Ltd. Los Angeles Office	Loyola Marymount University			Mentors International
HMC Architects	Mt. San Antonio College			Society of Hispanic Professional Engineers
JPMorgan Chase Bank	Pasadena City College			Specialty Family Foundation
Los Angeles Unified School District	University of California, Los Angeles			Teach for America
Northrup Grumman Corporation	University of Southern California			The Carol and James Collins Foundation
Pearson Education	Woodbury University			The Durfee Foundation
Port of Los Angeles				Tiger Woods Foundation
Raytheon				William C. Bannerman Foundation
Roll Global				YMCA of Metropolitan Los Angeles
Sims Recycling Solutions				
Texas Instruments				

FARGO, NORTH DAKOTA

Fargo is a city of 209,000 inhabitants (2010) located in eastern North Dakota. For the past 5 years it has experienced an economic boom as a result of a surge of oil and gas production in the western part of the state. The state is rural and has a significant Native American population. Major industries include oil and gas extraction, agriculture, transportation, and equipment manufacturing. Institutions of higher education in the region include North Dakota State University (our host), North Dakota State College of Science, University of North Dakota, and Valley City State University; the meeting also had representation from the North Dakota Association of Tribal Colleges. Figure 3-5 provides an overview of the need for STEM skills in the Fargo region.

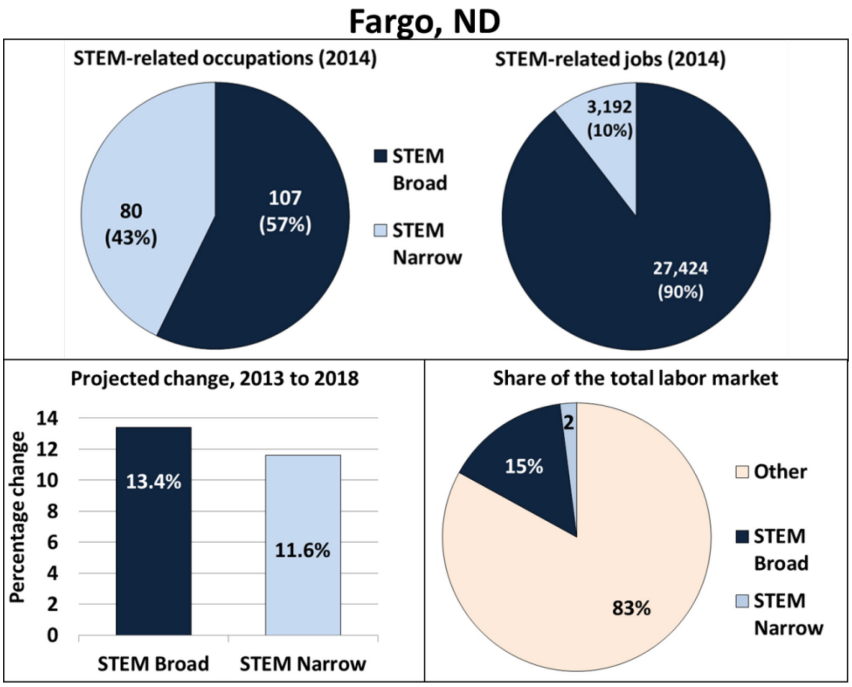

FIGURE 3-5 Overview of the need for STEM skills in the Fargo region.
Note: The panel in the lower left displays job growth or positive change.
Source: Jobs for the Future analysis uses Economic Modeling Specialists International data to assess job numbers.

The Fargo area has a competitive advantage in a number of occupations, and the STEM broad category includes significantly more job types than does STEM narrow. Table 3-6a lists those occupations for which the Fargo region has a competitive advantage, organized by educational level. Table 3-6b lists Fargo's top STEM employers as identified by RTLMI analyses, and Table 3-6c lists the Fargo workshop participants.

TABLE 3-6a Fargo Region: Occupations with a Competitive Advantage in 2013

Educational Level	STEM Broad	STEM Narrow
Less than a bachelor's degree	Precision instrument repairers Cement masons and concrete finishers Installers and repairers of electronic home entertainment equipment Structural iron and steel workers Mobile heavy equipment mechanics Mechanical drafters	Agricultural and food science technicians Civil engineering technicians Mechanical drafters Mechanical engineering technicians Industrial engineering technicians
Bachelor's degree or higher	Surgeons Optometrists Occupational therapists Chiropractors Financial specialists Secondary school career/technical education teachers	Soil and plant scientists Food scientists and technologists Life scientists Biological scientists Foresters Atmospheric and space scientists

SOURCE: Analysis by Jobs for the Future using data from Burning Glass Technologies.

TABLE 3-6b Fargo Region: Top Employers as Identified by RTLMI Analyses

Top STEM Employers—RTLMI Analyses	
North Dakota State University [a]	Department of Veterans Affairs
KJL Engineering [a]	RDO Equipment [a]
Kar Auction Services	Deere and Company
Automotive Finance Corporation	Appareo [a]
Ulteig Engineers	Doosan Bobcat Company [a]
Essentia Health	Blue Cross Blue Shield of North Dakota
Sanford Health	

[a] Attended the regional workshop.

Source: Analysis by Jobs for the Future.

TABLE 3-6c Fargo Region: Workshop Participants, June 30, 2015

Employers/Industry	Higher Education	Third-Party Intermediaries	Policy/ Government	Nonprofit/ Philanthropic
Microsoft Fargo	North Dakota State University	Greater Fargo Moorhead Economic Development Corporation	North Dakota Department of Commerce	Gateway to Science
Doosan Bobcat Company	North Dakota State College of Science	North Dakota STEM Network	Job Service North Dakota	Emerging Prairie – Speaker's Bureau
Trail King Industries	University of North Dakota	Jamestown/Stutsman Development Corporation	North Dakota Department of Career and Technical Education	
Sanford Health	Valley City State University			
Appareo	North Dakota Association of Tribal Colleges			
Minn-Dak Farmers Cooperative	Bismarck State College			
Tecton Products LLC	Lake Region State College			
Caterpillar Reman	Mayville State University			
KJL Engineering				
General Equipment and Supplies				
F-M Ambulance Service				
Marvin Windows and Doors—Integrity and Tecton Products				
Partner				
RDO Equipment Company				
Laney's Inc.				

Chapter 4
Lessons Learned and Analysis

The five regional meetings in Phoenix, Cleveland, Montgomery, Los Angeles, and Fargo generated productive discussions among the wide range of stakeholders convened at each event, which included leadership and employees of local and regional businesses; administrators, faculty, students, and staff from 2- and 4-year institutions of higher education; representatives of nonprofit organizations; local and state policy makers; and representatives of local and regional economic development organizations. Participants spoke openly about the barriers they perceived that hinder the development of a strong science, technology, engineering, and mathematics–related (STEM-related) workforce and that impede effective communication and productive, sustainable partnerships between higher education and businesses in their regional economies. They also shared their successes and the many lessons they have learned working together to initiate, develop, and sustain effective workforce development partnerships that meet their region's STEM workforce needs.

This chapter first outlines the major workforce requirements—including skills and better connectivity between educators and employers—as articulated by employers present at the five regional events. Second, it summarizes the barriers that participants described as standing in the way of both a strong STEM economy and effective and sustained workforce development partnerships. Third, it presents a set of promising practices that workshop participants identified as key to building and sustaining these effective partnerships.

WORKFORCE NEEDS AS ARTICULATED BY EMPLOYERS

Employers and economic development professionals across the five regions described a similar set of criteria for building a strong STEM workforce. Participants reported that, in many cases, the pool of potential employees is too small. Too often, companies requiring a STEM-competent workforce lack a sufficient quantity of people possessing the basic requirements for success in a given industry.[1] A participant in Fargo, for example,

[1] There has been much debate among employers, educators, and policy makers (and in the academic literature and popular press) about whether the United States faces a shortage or surplus of STEM workers. See Carnavale et al. (2011), *STEM: Science, Technology, Engineering, Mathematics,* Washington, DC: Georgetown University Center on Education and the Workforce; Rothwell (2013), *The Hidden STEM Economy,* Washington, DC: The Brookings Institute; Salzman (2013), "What Shortages? The Real Evidence about the STEM Workforce," *Issues in Science and Technology*, XXIX(4); National Science Board (February 2015), *Revisiting the STEM Workforce*. See also Box 2-2 in this report.

observing that economies are becoming less dependent on financial capital and more dependent on human capital for a wide range of companies in software, pharmaceuticals, and applied materials, described how talent of every type is in short supply in that region, especially in the managerial and technical ranks. In Montgomery, a participant spoke to the undersupply of people trained in more highly skilled STEM areas and the need for STEM education to be a priority for policy makers in Alabama.

An overarching theme across all five regional workshops was the need for more systematic connectivity among institutions of higher education and local and regional employers. They noted that "one-off," small, or ad hoc connections between the two sectors are valuable, but much more needs to be done at multiple levels within businesses and higher education to ensure tighter linkages. Third-party intermediaries play a critical role in fostering and maintaining cross-sector collaboration and connectivity. Without the planning, convening, brokering, and evaluating functions that a trusted intermediary provides, it will be difficult to develop and sustain business-education collaborations beyond one-off connections. In addition, participants representing local companies as well as national firms identified specific skills and attributes critical for workplace success that new employees often lack. These include specific, highly technical skills narrowly focused on certain job types; more general technical skills used in a broad array of STEM-related jobs; and employability skills—variously termed professional, workplace-ready, essential, soft, noncognitive, or 21st century skills, or referred to as the 4 Cs (creativity, communication, collaboration, and critical thinking).[2]

More Systematic Connectivity between Higher Education and Employers

Representatives from small, medium, and large companies all stated that they desired more systematic connectivity between their firms and colleges and universities.[3] Participants in Fargo and Phoenix discussed how successful academic-industry relationships need to be clearly defined and how *outcomes need to be clearly identified*. They described how higher education and industry, working together, need to define the specific, local problems they are trying to solve—for example, the type of engineers needed now and projected to be needed 5 and 10 years in the future, their required skill sets currently and looking ahead, and the total numbers of such employees projected to be needed. Many employers and representatives of higher education and economic development organizations called for partnerships between companies and higher education that go beyond ad hoc efforts and traditional advisory boards to include more substantive industry involvement.

Participants including those in breakout groups in Fargo, Phoenix, and Cleveland discussed how tighter and more effective *feedback loops* between higher education and employers are needed to ensure that faculty and the leadership of regional colleges and universities have

[2] For the purposes of this report, the committee will use the term *employability skills* to capture the range of nontechnical skills needed to be successful in the 21st century workplace.

[3] These observations are consistent with a number of prior efforts that have assessed STEM workforce development partnerships. See National Research Council (2014), *Undergraduate Chemistry Education: A Workshop Summary*, Washington, DC: The National Academies Press; and American Association of Colleges and Universities (2013), *It Takes More Than a Major: Employer Priorities for Learning and Student Success*, Washington, DC.

solid knowledge of the skills and competencies their graduates will need in the workforce. Feedback loops provide higher education and industry partners with communication channels that allow both to adapt in real time as new occupations requiring new (or modified) skills and competencies emerge. Continuous feedback and open communication also provide connectivity that allows partners to confront other obstacles that may arise, including personnel changes, funding issues, and intellectual property concerns.

Another consistent theme emerging from the regional workshops was that of employers calling for easier *access to institutions of higher education*. Local and regional employers reported having difficulty navigating within higher education—both the physical campuses and the administrative structure. When employers wish to connect with higher education, they often have difficulty identifying an initial point of contact at the college or university—an issue emphasized by Jim Searcy, executive director of the Economic Development Association of Alabama; Stacey Breuer, director of human resources at Dooson Bobcat in Fargo; and senior officials at Arizona State University. Beyond the need for this initial point of contact, a number of workshop participants stressed the importance of dedicating one staff person to cross-sector partnerships and immediately replacing that person if he or she moves out of that role. The committee heard this message in discussion groups in Phoenix, from Francisco Rodriguez, the chancellor of the Los Angeles Community College District, and Terri Sandu, the executive director of workforce development and director of the Entrepreneurship Innovation Institute at the Lorain County Community College in Cleveland. Third-party intermediaries can also facilitate and support access and continuity by attending to staffing turnover among partners, encouraging timely redesignation of key contacts, and quickly integrating new key contacts for the cross-sector partnership.

Meeting participants also noted how systematic connectivity needs to include more structured *industry participation in students' educational experiences*. In the classroom, there is a need for the use of project-based learning modules drawn from real-world challenges, as emphasized, for example, by Paul Johnson, dean of the School of Engineering at Arizona State University and widely cited as a critical component of effective partnerships by participants during small-group breakout sessions in every regional meeting.

A number of participants in all five regional meetings, including Bud Baeslack, provost of Case Western Reserve University, and Harvey Link, vice president of academic and student affairs at North Dakota State College of Science, spoke of the need for greater opportunity for *student internships and apprenticeships* throughout the STEM-related workforce. Participants, including leaders in two different communities—Chris Rico, director of innovation in the Los Angeles County Economic Development Corporation, and Michael Mobley, executive director of the Center for Integrated Science, Engineering, and Technology at Grand Canyon University—called for industry participation in the redesign of curricula and labs on campuses.

Technical Skills

Businesses hiring STEM-competent students also seek a great diversity of technical skills, and higher education has a fundamental role to play in developing these skills and

competencies. In all five regional meetings, employers described the need for workers who have the necessary technical skills, are capable of transferring these skills to new technical areas, and understand how to apply them in ways that contribute to a company's mission and goals. These technical skills include more general skills and knowledge (e.g., basic knowledge of biology, chemistry, physics, engineering, statistics, or quantitative reasoning) that are transferable across STEM fields or careers, as well as skills specific to the industry or a particular company (e.g., the ability to use specific instruments and/or perform specific experimental procedures). In this regard, the committee perceived two possible trends. One was a trend in employer expectations for new graduates, shifting from employers' willingness to spend considerable time—perhaps a few months—doing *onboarding* for new hires, to the expectation that new hires will be up to speed in a number of highly technical areas in a matter of weeks. A second possible trend was the preference that some employers at the regional meetings had for skills and shorter-term credentials (such as certificates), over (or in addition to) to STEM majors pursued in 4-year degrees.

Participants at all five regional meetings noted the importance of general technical competencies as a set of abilities that prepare new hires for learning at the workplace and being able to adapt formal knowledge to job-specific objectives. Employers and economic development professionals noted that when companies are hiring, they often seek students with general technical competencies more than those with specific technical skills. For example, a biotechnology company may look for new hires that have basic biology and chemistry knowledge, laboratory and instrumentation skills, knowledge of data analytics, and quantitative reasoning skills.

Jim Searcy, executive director of the Economic Development Association of Alabama, relayed a preference he had heard from employers in his state for students to arrive at the workplace with a basic understanding of the field and the ability to learn—leaving it to the companies to then teach new hires about their culture and their ways of doing particular tasks. A representative of an aerospace company in Cleveland said that even if students are trained in specific technologies on campus, the technologies used in the workplace are often different, and new hires need to be retrained—thus it is critical that employees come to the firm with the ability to learn on the job.

General technical competencies also confer flexibility on new graduates that can be valuable for a company over time. While companies must make hiring decisions according to current needs, the rapid technological change in many fields means that its needs in 2, 5, and 10 years will likely have changed. If its employees have a solid education in basic technical and scientific areas, they are more likely to be successful and an asset to the company over the long term.

Several workshop participants observed that in many cases, coursework (including laboratory courses) can be an effective way to train students with general technical skills, while collaboration between employers and higher education (on or off campus) can be a more effective way to achieve more specific technical training, in part because colleges and universities have limited time and resources (including equipment) with which to cover multiple industries' specific training needs. See Box 4-1 for a list of selected skills being sought by employers in Phoenix, Cleveland, Montgomery, and Fargo.

BOX 4-1 Selected Technical Skills In Demand by Regional Employers [a]

	Phoenix, AZ	Cleveland, OH	Montgomery, AL	Fargo, ND
Job Function	• Patient care • Patient evaluation • Care planning • Business process • Software engineering • Software development • Data analysis • Technical support	• Patient care • Treatment planning • Accounting • Business process • Manufacturing process • Product development • Technical support	• Patient care • Treatment planning • Technical support • System administration • Technical writing and editing • Data analysis • Data management • Business process • Process engineering • Heating, ventilation, and air conditioning • Manufacturing engineering	• Patient care • Software engineering • Manufacturing engineering • Technical support • Data analysis • Technical support
Discipline	• Electrical engineering • Software engineering	• Chemistry • Mathematics • Mechanical engineering • Electrical engineering	• Mathematics • Electrical engineering	• Civil engineering • Electrical engineering • Mechanical engineering • Mathematics • Chemistry • Agronomy
Computer Skills	• UNIX[b] • SQL[b] • Java[b] • Linux[b] • Oracle[b]	• AutoCAD[b] • Java[b] • SQL[b]	• UNIX[b] • Java[b]	• AutoCAD • SQL[b] • Java[b]

[a] The skills listed here (some of which are job functions or employment areas) were generated by a series of real-time labor market analyses commissioned by the committee and performed by Jobs for the Future. These skills were all identified in job postings that also listed a bachelor's degree as a minimum requirement. Due to logistical and practical constraints, the committee was unable to perform a labor market analysis for Los Angeles.

[b] SQL and Java are programming languages, Oracle is a database management system, and Linux and UNIX are operating systems. AutoCAD is design software.

Employability and Workforce-Ready Skills

Compared to general or specific technical skills, participants in the five regional meetings spent relatively more time focused on the need for graduates to have much stronger skills in nontechnical areas. This may be due to the difficulty employers have in articulating their needs for certain technical skills, or it may be because STEM graduates tend to be

lacking in some of these nontechnical skills.[4] These employability skills, or 21st century skills, are conceptualized by employers as attitudes, behaviors, motivational states, and skills that they deem as critical for workplace success.[5] A recent report from the National Academies of Sciences, Engineering, and Medicine, having performed a review of the available literature, grouped 21st century skills into three broad domains—cognitive, interpersonal, and intrapersonal. Cognitive 21st century skills include critical thinking, creativity, and problem solving (among many others); intrapersonal skills include flexibility, responsibility, and integrity; and interpersonal skills include teamwork, collaboration, and leadership skills[6]—types of skills grouped by many workshop participants into the category of employability skills. While this report was comprehensive, there are many other lists of employability skills (and different names for this grouping of skills) that have been developed by different advocacy and employer organizations (see Box 4-2 for additional discussion of these various lists and categorizations).

BOX 4-2 Describing and Classifying Employability Skills

Business leaders and policy makers are increasingly asking colleges and universities to ensure that graduates possess skills like problem solving, critical thinking, communication, teamwork, conscientiousness, and professionalism. Although there is disagreement on how to describe and classify these skills, numerous employer and advocacy organizations have developed and circulated different lists of skills. It would be impossible to catalog all such lists, so here we offer three lists that seem to resonate most with workshop participants and the committee.

21st Century Skills—from *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, a 2012 report by the National Research Council[a]

Based on an extensive literature review, this report classified skills into three competency domains: cognitive, intrapersonal, and interpersonal.

Cognitive: critical thinking; problem solving; analysis; reasoning/argumentation; interpretation; decision making; adaptive learning; executive function; information and communications technology literacy; oral and written communication; active listening; creativity; innovation.

Interpersonal: communication; collaboration; teamwork; cooperation; coordination; empathy; trust; service orientation; conflict resolution; negotiation; leadership, responsibility, assertive communication, self-presentation, social influence with others.

Intrapersonal: flexibility; adaptability; artistic and cultural appreciation; responsibility; continuous learning; curiosity; ability to take initiative; self-direction; responsibility; perseverance; productivity; grit; metacognitive skills; professionalism; ethics; integrity; citizenship; career orientation; self-monitoring, self-evaluation, and self-reinforcement; physical and psychological health.

[4] Hurtado, S., K. Eagan, and B. Hughes (2012). *Priming the Pump or the Sieve: Institutional Contexts and URM STEM Degree Attainments*. Association for Institutional Research Annual Forum, New Orleans, LA.
[5] Miller, R. K. (2015). *Why the Hard Science of Engineering is No Longer Enough to Meet the 21st Century Challenges*. Olin College of Engineering.
[6] National Research Council (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.

BOX 4-2 Continued

Common Employability Skills—National Network of Business and Industry Associations[b]

The National Network represents major business sectors and is funded through a collaborative partnership of Business Roundtable, ACT Foundation, the Bill and Melinda Gates Foundation, Joyce Foundation, and Lumina Foundation. Member companies represent the source of almost 75 percent of projected job growth through 2020. Based on a survey of its member organizations, the National Network's skill list classifies skills into four categories.

Personal Skills: integrity; initiative; dependability and reliability; adaptability; professionalism.
People Skills: teamwork; communication; respect.
Applied Knowledge: reading, writing, mathematics, science, technology, critical thinking.
Workplace Skills: planning and organization; problem solving; decision making; business fundamentals; customer focus; working with tools and technology.

Professional Skills—Richard Miller, President, Olin College of Engineering[c]

A summary of skills from a variety of industry and academy reports includes the following: ethical behavior and trustworthiness; self-confidence, a positive outlook, sincerity, civility, and accepting responsibility; perseverance and "grit"; effective communication, including advocacy and persuasion; effective collaboration, including leadership, teamwork, and consensus building; entrepreneurial mindset and associated business acumen; interdisciplinary and multidisciplinary thinking; creativity, curiosity, and design; empathy and social responsibility; global awareness and perspective.

[a] National Research Council (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.
[b] The National Network (2014). *Common Employability Skills, A Foundation for Success in the Workplace: The Skills that All Employees Need, No Matter Where They Work*.
[c] Miller, R. K. (2015). *Why the Hard Science of Engineering is No Longer Enough to Meet the 21st Century Challenges*. Olin College of Engineering.

Meeting participants' views concurred with a number of research studies that have shown that students who earn STEM degrees and students who earn non-STEM degrees differ from one another in marked ways.[7] Students who earn STEM degrees tend to leave college much more confident in their academic abilities and math abilities and are much more likely to exhibit habits of mind for life-long learning. However, they are also (on average) less confident in skills related to creativity, leadership ability, and public speaking ability, and they are less able to work effectively with people from other races and ethnicities, understand different cultures, and have their own views challenged.[8] Participants in the regional meetings were not asked to compare STEM graduates and non-STEM graduates, but employers often stated that STEM graduates frequently lacked experience and confidence with respect to the above characteristics. For example, Tifanie Gelinske, vice president of workforce development for the Greater Fargo Moorhead Economic Development Corporation, said that the companies with which they work are consistently

[7] Hurtado, S., K. Eagan, and B. Hughes (2012). *Priming the Pump or the Sieve: Institutional Contexts and URM STEM Degree Attainments*. Association for Institutional Research Annual Forum, New Orleans, LA.
[8] Ibid.

looking for people who are creative, who can collaborate, and who are critical thinkers and good communicators. This major theme in each region—the desire of employers for STEM graduates who enter the workplace with at least some employability skills—reflects the findings of prior efforts to capture employers' views on employability skills.[9]

One particular area in which participants noted deficiencies of some new graduates upon their arrival in the workplace was *effective work habits***,** such as time management and organizational skills. New hires may not arrive on time, may not communicate with supervisors if they will be late or absent, or may fail to respond to coworkers' or supervisors' communication in a timely manner**.** Heather Weber, dean of occupational education at Estrella Mountain Community College, described hearing employers ask for students to come equipped with professional skills including being good communicators and arriving to work on time. In response to timeliness issues with new employees, Trail King Industries in North Dakota has installed time clocks in their laboratories.

More broadly, many STEM-competent graduates lack *business acumen*, an understanding of the constraints and requirements surrounding their efforts at work, including market pressures felt by their employers. In the words of Rosalyn Boxer, vice president for workforce at the Arizona Commerce Authority, students "don't understand when they come to work what the responsibilities are of being an employee and what the philosophy is of industry that they are going into. They have a very good understanding of the technical aspects of it, but they don't have the pragmatic side: budgets, time constraints, and how to interact with other departments, other businesses, and suppliers." Stacey Breuer, director of human resources at Doosan Bobcat in North Dakota, noted that it is not enough for a product to be engineered beautifully, but it must also be satisfying for a customer to interact with and be cost-effective for the company to produce. Paraphrasing Steve Jobs, the late chief executive officer (CEO) of Apple, she said that "engineers can make stuff work, but they can't necessarily make it beautiful. They can't necessarily make the product something that you want to own, you want to touch, you want to buy." Le-Quita Booth, dean of the College of Business Administration at Alabama State University, consistently hears a call from industry partners for "essential skills." She noted that "if an innovation does not get out of the lab, then it is simply a report;" the challenge is moving an innovation from the laboratory into the industry where it is bought, sold, or traded for a good or service. Case Western Reserve University's School of Engineering engaged 30 companies in prioritizing the American Society of Civil Engineers' list of professional skills,[10] gave the prioritized list to the engineering faculty, and requested that faculty integrate those areas into coursework and experiential learning. In Fargo, staff from the regional economic development organization are teaching a course on life skills.

Companies have a strong interest in *critical thinking skills*. Jim Searcy, executive director of the Economic Development Association of Alabama, discussed the importance of employees' abilities to work together and to take abstract issues and apply their education

[9] See National Research Council (2014), *Undergraduate Chemistry Education: A Workshop Summary*, Washington, DC: The National Academies Press; and American Association of Colleges & Universities (2013), *It Takes More Than a Major: Employer Priorities for Learning and Student Success*, Washington, DC.
[10] Available at http://www.asce.org/civil_engineering_body_of_knowledge/. Accessed November 2, 2015.

to solve problems. In many STEM courses, students become accustomed to pursuing a right answer, whereas in the high-tech, multifaceted workplace, there often is no single correct answer. Employers need graduates who are able to consider all relevant variables for a particular task, begin moving toward a solution, and know what actions to take if they encounter barriers or difficulties (skills that some faculty may desire assistance in learning to teach). An employee of Doosan Bobcat in North Dakota described how students, as new employees at the company, are often unable to anticipate what is next; they do exactly as they are told, as they are accustomed to doing in their coursework. But, she noted, "in industry there is no one right answer in the back of the book and many variables go into decisions."

The committee also heard from companies that are looking for graduates who can *teach themselves new skills quickly*—and who can think innovatively and "outside the box." One of the four characteristics sought by Google, according to Google education evangelist Jaime Casap, is the ability to relearn, for example, new coding languages or new Internet technology (IT) platforms. Because the IT and other STEM industries are changing so rapidly, this ability to relearn on the job, and on one's own, is a vital characteristic valued by many employers.

Meeting participants called for STEM graduates who have stronger *interpersonal skills, including communication skills and the ability to work in multidisciplinary teams*. This need was heard widely, from people in higher education (e.g., Michael Mobley, executive director of the Center for Integrated Science, Engineering, and Technology at Grand Canyon University; Bud Baeslack, provost of Case Western Reserve University) and in industry (Stacey Breuer, human resources manager at Doosan Bobcat, and Sherm Syverson, an employee at F-M Ambulance in Fargo). Written and oral communication skills are often poor among companies' new STEM hires; Greg Lardy, associate vice president for agricultural affairs at North Dakota State University, noted that any instruction that students may have received (perhaps a speech communication course as a freshman or technical writing as a sophomore) is often not sufficient to equip them to communicate efficiently in the workplace. Communication skills were also cited as a key part of the mismatch between expectations in the workplace and the skills brought by recent graduates that was described by Terri Sandu, director of the Entrepreneurship Innovation Institute at Lorrain County Community College in Ohio. Perry Lubbers, vice president of manufacturing at Trail King Industries (Fargo) also noted that a major problem with recent engineering graduates is their inability to communicate effectively with their coworkers, even in daily one-on-one and small group interactions. He described the importance for the company that their new hires spend time on the production floor discussing the day-to-day issues of other employees who assemble the product.

Lastly, given that the experience of many STEM-competent graduates during their undergraduate years is largely confined to interactions with faculty and other students in their majors, meeting participants spoke to the need for graduates to have a stronger *ability to interact with people in other disciplines*. The workplace often requires that graduates interact effectively with people in different technical fields and with people in nontechnical fields such as finance, marketing, and design. Participants in a breakout

session in Phoenix spoke to this need at colleges' and universities' departmental level, suggesting that higher education organize curricula around real-world problems rather than around academic disciplines. In Cleveland, Bud Baeslack, provost and executive vice president of Case Western Reserve University, described the need more generally to train engineering students to work with people in different disciplines, from students majoring in various scientific disciplines to business majors.

BARRIERS TO EFFECTIVE INTERACTIONS BETWEEN EMPLOYERS AND HIGHER EDUCATION

Participants at each workshop were encouraged to identify barriers to a strong STEM workforce overall as well as barriers that hinder the development of effective, sustainable workforce development partnerships. Participants in the five regional workshops expressed enthusiasm for stronger relationships between employers and higher education: both sectors see a need for more systematic, region-wide interactions that produce more competent employees who bring greater innovation to companies, contributing in turn to more vibrant regional economies. The following section outlines the structural and cultural barriers workshop participants identified that may weaken a region's STEM workforce and hinder cross-sector partnerships, respectively.

Barriers to a Strong Regional STEM Workforce Development Ecosystem

Participants in all five regional meetings spoke of the *lack of signaling* between higher education and regional employers as a major structural barrier hindering the development of regional STEM-related workforces. Faculty, staff, and administrators in higher education lack effective channels by which to understand the needs of regional employers, and in some instances, employers make unrealistic demands of their new hires. Cross-sector partnerships, whose components are discussed below, help to fill this need. Partners looking to increase the alignment between educational resources and the business community will see better results if they start their analysis with an asset map that identifies their regions' resources, including population, industries, educational institutions, community-based organizations, government, local policies, and other environmental factors.[11] A critical feature of this asset map is real-time labor market information (RTLMI). When this inventory is compared to regional economic development goals, the region's strengths and gaps are more easily identifiable. Areas of competitive advantage can serve as a focal organizing point for partners, and by intentionally organizing their efforts around these occupations and skill sets, organizers can maximize their success,[12] although users of RTLMI must be aware of potential market distortions (see Box 4-3).

[11] Jobs for the Future and Achieving the Dream (2014). *STEM Regional Collaboratives: The Opportunity*.
[12] Rosenblum, I., and C. Spence (2015). *Success in Real-Time: Using Real-Time Labor Market Information to Build Better Middle-Skill STEM Pathways*. Jobs for the Future.

BOX 4-3 Labor Market Dynamics and Market Distortions

The Business-Higher Education Forum (BHEF), a membership organization of business of CEOs and university presidents, supports workforce projects in cybersecurity and other emerging STEM fields. Their work in initiating these projects includes intensive labor market analyses across several regions. These analyses have uncovered two distinct types of market distortions: the first derives from the available talent model, and the second from the dominance of government in certain industry sectors. BHEF has developed an understanding of regional cyber talent hiring models by researching its business members' own talent models and commissioned work from Burning Glass Technologies. These two sources of data suggest that the talent market is skewed toward incumbent workers due to the absence in these regions of a robust talent ecosystem producing new-hire talent. As a result, job postings reflect relatively high levels of experience.

The second dynamic derives from the dominant role of government, and in particular, requirements that government places on aerospace and defense companies that receive government cybersecurity contracts. The National Security Agency requires employees working on government contracts to possess certifications that require a baccalaureate degree and 5 years of relevant experience, thereby excluding recent graduates from the pool of eligible workers.

A second structural barrier or obstacle to a robust STEM workforce is the *high level of attrition*, especially of women and underrepresented groups, among students in STEM majors. Although interest in STEM credentials continues to grow among high school graduates who plan to attend a college or university,[13] 6-year degree completion rates remain low—around 40 percent.[14] One tool that can help university leaders and faculty understand student movement into and out of STEM majors is a "student migration analysis."[15] This analysis can identify those courses that lead to students leaving a STEM major and can help pinpoint which courses may need to be redesigned or restructured to provide more applied learning activities or other interventions known to boost student persistence. A report in 2012 by the President's Council of Advisors on Science and Technology identified the first 2 years of undergraduate education as a critical inflection point in a student's pathway from interest in STEM fields to completing a STEM degree and eventually joining the STEM workforce. The report also identified a number of evidence-based interventions that can improve retention and expand the STEM workforce pathway. These include authentic, experiential learning and research activities; curriculum redesign; and wrap-around support services.[16] Many of these interventions were also identified by workshop participants and are discussed below. Such interventions represent a critical leverage point for industry engagement in STEM education and workforce development[17]

[13] National Science Board (2014); U.S. Department of Education (2013).
[14] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in STEM*. Washington, DC: Executive Office of the President.
[15] Koff, R., L. Molter, and K. A. Renninger (2009). *Why Students Leave STEM Fields: Development of a Common Data Template and Survey Tool*. New York: Alfred P. Sloan Foundation.
[16] Ibid.
[17] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in STEM*. Washington, DC: Executive Office of the President.

and are especially valuable ways to broaden participation in STEM and increase the persistence of underrepresented groups in STEM majors.[18]

A third structural barrier, which lies largely outside of the scope of this study, is the quality of STEM instruction that students receive in the *K-12 system*.[19] In many cities and regions throughout the United States, the STEM education received by students in primary and secondary school grades does not adequately prepare them to pursue STEM-related advanced degrees or careers successfully.

We heard concerns about K-12 STEM instruction in multiple locations around the country. Bob Pawloski, the STEM field coordinator at the University of North Dakota, spoke about K-12 teachers who need to improve or refine their skills in STEM subjects, noting that two-thirds of high-school math students and one-third of students in physical science have teachers who did not major in college in the subject they are certified to teach.[20] Participants in a breakout session in Montgomery described the need for more local initiatives to train teachers in STEM and in the scientific method, and a participant in Phoenix called for education that will make K-12 teachers "STEM savvy." Participants in Montgomery and Cleveland expressed the view that, given the high numbers of high school graduates needing remedial instruction once they reach higher education, the K-12 educational system needs to be reassessed, particularly STEM subjects. Although estimates vary widely across studies,[21, 22] the most recent data available from the National Center for Education Statistics indicates that nearly 55 percent of first- and second-year undergraduate students report taking a remedial course after high school graduation.[23] These deficits hinder efforts by institutions of higher education and employers to train and develop a strong local workforce.

The workshops pointed to six key endeavors that can foster greater K-12 student interest, achievement, and persistence in STEM:

- More hands-on, project-based learning activities for students.
- Professional development for teachers in project-based learning instruction.
- More opportunities for students, teachers, and parents to interact with STEM professionals and learn about employers and career opportunities.

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[18] National Academies of Science, Engineering, and Medicine. (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways*. Washington, DC: The National Academies Press.

[19] The quality of K-12 education and the level of preparedness (or lack thereof) of high school graduates is also a major obstacle to students enrolling in and completing majors in STEM fields. See also *Engage to Excel*, President's Council of Advisors on Science and Technology, 2012.

[20] National Research Council (2010). *Preparing Teachers: Building Evidence for Sound Policy*. Washington, DC: The National Academies Press.

[21] Bettinger, E., et al. (2013). Student Supports: Developmental Education and Other Academic Programs. *The Future of Children* 23(1), Princeton University.

[22] Scott-Clayton et al. (2014). Improving the Targeting of Treatment: Evidence from College Remediation. *Educational Evaluation and Policy Analysis* 36(3):371–393.

[23] National Center for Education Statistics (2014). *Profile of Undergraduate Students: 2011-12, Web Tables*. U.S. Department of Education.

- Outreach to females and underrepresented minorities that includes opportunities to meet role models and mentors who look like the students.
- Mechanisms to facilitate connections between teachers and STEM professionals who wish to function as volunteer speakers and/or mentors.
- Dual enrollment and other programs that provide support to students as they cross the bridge from high school to postsecondary institutions, so that they persist in education and STEM fields.

For more specific information on these practices, please see Appendix D.

Barriers to Effective Partnerships between Higher Education and Regional Employers

Initiating, developing, and sustaining partnerships between industry and higher education can be particularly difficult, given different missions, levels of resources, lack of common terminology, and other factors, even if both partners share a commitment to a stronger workforce.[24] These cultural barriers between higher education and regional employers impede effective cross-sector partnerships. One impediment is that individuals and organizations in the two sectors often have different *expectations of outcomes and definitions of success*. While employers are focused on the size and quality of their "talent pipelines"—the pool of people who are prepared or are in the process of being trained to step into important roles in a company—colleges and universities often inadequately recognize their role in training those people, nor are these activities given high priority in faculty tenure evaluations or in annual performance reviews.

Second, some companies are more comfortable *taking risks*—or at the very least are accustomed to innovation as a way of life—as they endeavor to satisfy shareholders. In contrast, nonprofit institutions of higher education can be tradition bound and risk averse. An education manager at Intel described how the company values academic departments that have the ability to think big and the willingness to take on a project, not knowing where it will lead. One way that higher education can instill a more innovative mindset in its faculty and students is to encourage experimentation at the interface of research and product development. At the Los Angeles meeting, breakout session participants suggested that higher education should foster an environment in which failure is embraced as a learning opportunity. Participants in a breakout session in Cleveland also advocated that higher education "should allow itself—students and institutions—to fail. Pilot early, then modify and repeat." Unfortunately, evaluations of faculty performance rarely accept failure with equanimity.

Third, following directly from these differences, businesses and higher education have distinct *reward structures*. Partnerships between the two can be inhibited when the individuals involved are asked to undertake activities that fall outside of those for which they are traditionally rewarded. Concerning higher education, a participant in Montgomery

[24] Klawe, M. (2004). *Getting the University-Industry Partnership Right . . . or Not*. Washington, DC: The Futures Forum.

advocated for college and university leadership to free up faculty time in a targeted manner, specifically to allow them to explore and sustain relationships with industry. Participants in a breakout session in Cleveland suggested that sabbatical opportunities be reinstituted and expanded, so that STEM faculty can spend more time working in industry. Such flexibility in time commitments and the reward structure on campuses and in the workforce is rare, however; and efforts to build relationships between university faculty and business employees are often stymied by inflexible university policies and lack of recognition in the workplace. A participant in Fargo noted how he had withdrawn from his position as a business liaison to North Dakota State University because his supervisors did not recognize the value of that work.

Fortunately, there may be opportunities to change rules and procedures in ways that encourage such collaboration. Martin Abraham, the interim provost at Youngstown State University, commented that changes to the tenure and promotion process may need to come "one enlightened administrator at a time." On the employer side, Don Morton, site leader at Microsoft Fargo, noted that "what you incentivize people about is what they do," and described shifts in the company's reward structure that place a high priority on collaboration by rewarding an employee for his or her *coworkers'* success. The committee heard from a number of companies and institutions of higher education that appeared to be successfully shaping their reward structures to embrace cross-sector partnerships. More systematic study of these organizations' practices would likely yield valuable additional insights.

Fourth, companies and higher education operate on relatively short and relatively longer *time lines*, respectively. Companies experience pressure to innovate increasingly rapidly, while higher education's time line to create new courses or programs is often many months or years. This discrepancy creates a real obstacle for higher education institutions endeavoring to be responsive to local and regional STEM workforce needs. Participants in a breakout session in Fargo noted how the education sector has difficulty responding and adapting as quickly as industry needs it to in order to meet workforce demands. One participant in Phoenix contrasted "faculty cultures of tradition and intransigence" with rapidly changing industry schedules and challenges. As a participant in Montgomery said, "When a business reaches out to a university and asks for assistance, it is looking at its watch. When the university responds, it is looking at a calendar."

Fifth, concerning *intellectual property (IP)*, the barrier to effective partnerships stems from companies' and higher education's needs being, in this case, similar. Researchers and product developers in both sectors aim to retain the intellectual property resulting from their work. In addition, the academic reward structure pressures researchers to publish their results, which can be in conflict with industry's goal of securing intellectual property rights and protecting proprietary information. Melvin Greer, senior fellow and chief strategist with Lockheed Martin, described the company's definition of a successful relationship with a faculty member in terms of value measured as return on sales or return on investment, with a focus on the generation of intellectual property. He stated that "if you are not creating intellectual property [for the company], the relationship is not going to work." The organizer of students' capstone projects in computer science at North Dakota

State University described how intellectual property issues make collaborations very challenging in their industry-university consortium. He related how several companies had told them, "we would love to work with you, but we need complete ownership of the IP," which creates a barrier to the university working with industry at the faculty level.

Participants in a breakout session in Phoenix acknowledged the significant amount of time that is often required for industry and higher education to agree on how intellectual property will be treated. The executive director of entrepreneurship and innovative initiatives at Arizona State University spoke to how universities need to encourage entrepreneurship and learn how to handle intellectual property issues.[25] On the workforce side, an employer at an aerospace company in Cleveland suggested that "businesses have to be more willing to say 'I don't care if you publish' and be willing to give up some of that intellectual property," in order not to place limitations on academic researchers' ability to publish. In sum, as participants in a breakout session in Phoenix discussed, intellectual property protocols need to be developed that both parties consider fair.

PROMISING PRACTICES: CREATING SUCCESSFUL PARTNERSHIPS BETWEEN EMPLOYERS AND HIGHER EDUCATION

Workshop participants offered a wealth of ideas for creating and sustaining effective partnerships that can increase the number of STEM-competent graduates who are both well trained relative to companies' current needs and have the necessary flexibility of mindset and skills to function well in the regional workforce in the coming years. These promising practices are the topic of this section. Over the course of the committee's five regional workshops, it learned that partnerships often start small and rely, in their early months or years, on connections between particularly passionate individuals. A workforce representative in Phoenix said, "It starts with relationships, it ends with relationships…. It's about trusting relationships that are win-win, where we [all] get to act in our best self-interest." The committee concluded that there would be value in a "self-assessment" tool that universities and employers—both individually and in collaboration with one another—might use to evaluate their current status in building a partnership, and in monitoring progress toward an effective, long-term relationship. This is discussed in more detail in Chapter 5.

[25] The challenges associated with IP management in the context of university-industry partnerships have been well characterized, and several prior reports have called on universities to improve their management of IP. These include calls for universities to improve their capabilities in technology transfer, in part by involving more stakeholders (including representatives of the relevant business, investment, and economic development communities) in the development of policies and practices for technology transfer and IP management. Other groups, including the University-Industry Demonstration Partnership have developed guidelines and best practices for universities seeking to improve and/or expand their IP management and technology transfer capabilities. For more information, see National Research Council (2011), *Managing University Intellectual Property in the Public Interest*, Washington, DC: The National Academies Press; and National Research Council (2012), *Research Universities and the Future of America*, Washington, DC: The National Academies Press.

The following section first describes the elements workshop participants identified as critical for the development of a rich and effective STEM workforce development ecosystem, including commitment from leaders, the role of third-party intermediary organizations, and industry consortia. It then offers specific strategies for building a strong STEM workforce development ecosystem, including the importance of achieving small, early successes; assigning a single point of contact for employers seeking to engage universities; engaging in specific collaborative activities; and offering applied learning opportunities such as internships and cooperative education programs. These strategies are discussed chronologically from the perspective of a university or company seeking to build a partnership. As noted below, there is a larger base of evidence for strategies described toward the end of this section—collaborative activities and applied learning opportunities.

Creation of a Rich Regional STEM Workforce Development Ecosystem

Data and information needs. A major theme emerging from the five regional meetings was the need for both higher education and employers to recognize that they are constituent members of a regional STEM workforce development ecosystem. The committee heard participants explain how partnerships need to be structured (and not ad hoc), data based, and oriented toward a region's specific challenges. A first step can be a joint conversation among the business community, government, and higher education about current workforce needs and how the regional economy might be reenergized. A well-positioned and trusted third-party intermediary could convene this joint conversation as a first step toward developing alignments, an agenda, and a data-gathering plan for the collaborative effort. For many regions, more real-time jobs data will be required for a reliable assessment of workforce needs. Often, faculty and administrators in higher education lack a clear understanding of workforce demand and the skills students should possess to thrive in the workforce. Jobs and skills data will also benefit students, who often are unaware of the career opportunities in a region.

Participants in a breakout session in Cleveland discussed how metrics for success need to be developed and data on outcomes need to be collected. One participant in Fargo called for stronger data on workforce supply and demand. In that region, higher education's understanding of the jobs available in the state is derived from the website of Job Service North Dakota, but those numbers are widely believed to be underestimates. The state longitudinal data system is currently being updated to make stronger supply-and-demand data available to employers, legislators, and institutions of higher education. Such data will quantitatively demonstrate a region's competitive advantage around which effective partnerships can be designed, as illustrated, for example, by the National Science Foundation's engineering research centers.[26]

A second step in strengthening a regional STEM workforce development ecosystem might be a joint discussion among sectors about how technology and innovation are drivers for change and growth. These first two steps can lead to the third: an exploration of how leaders in higher education, government, and business can collaborate to develop the

[26] See http://erc-assoc.org/.

human resources needed for the regional economy to grow.[27] Third-party organizations can play a valuable role in this process, as they may be able to provide data and models and other resources and services. For example, the Arizona Commerce Authority's workforce program uses a data-driven model of sector partnerships to ensure that it trains enough workers with the appropriate skills to meet regional workforce needs.

Partnerships need to be initiated before all of the optimal data have been gathered. As noted by Ed Castile, director of Alabama Industrial Development Training in the Alabama Department of Commerce, "Don't be data rich and action poor. If you have data, act on it."

Commitment from leadership. At all five regional workshops, multiple participants spoke of the need for leaders in both sectors to demonstrate commitment. Presidents, provosts, and deans in higher education and CEOs in the regional businesses need to make visible, substantive commitments to industry–higher education partnerships. These leaders provide resources (including building time for partnership work into employees' schedules) and incentivize collaborative and mentorship activities. A key lesson learned from the five regional workshops was that individual entrepreneurship at the faculty, department, or school level often triggers the launch of new programs, policies, and strategies for employer engagement at colleges and universities, but those initiatives are unlikely to thrive and be sustained without strong and visible leadership from the top. Individuals in both sectors called for institutions of higher education as well as employers to create a position in their organization dedicated to supporting partnership activities. Many participants felt that this was one of the most critical features that can ensure effective and sustainable partnerships. It will be critical to use data and metrics to demonstrate to boards of directors and trustees that any financial resources devoted to creating and sustaining such positions are associated with a return on investment. See Box 4-4 for additional details on corporate approaches to workforce development.

Participants in a breakout session in Fargo noted the value of a memorandum of understanding that was developed by and circulated on campus that outlines mutual understanding of higher education and industry's needs to support transparency in the partnership. This memorandum is regularly updated and specifically outlines feedback loops and communication channels that partners can use. The provost of North Dakota State University suggested that the administration can provide seed grants and can ask faculty and staff to create innovative programs, but she considered it her responsibility to make sure that those programs also create assessment and scalability plans so that three or four strong programs—and not dozens of one-off programs—are embedded and supported and become part of the culture of the institution. Consistent with prior studies of regional efforts to align educational and employer partners,[28, 29, 30] the bulk of participant comments

[27] See Moretti, E. (2013), *The New Geography of Jobs*, Boston, New York: Mariner Books, Houghton Mifflin Harcourt.. See also Milken Institute (2013), *A Matter of Degrees: The Effect of Educational Attainment on Regional Economic Prosperity;* and Abel, J. R., and R. Deitz (2011), The Role of Colleges and Universities in Building Local Human Capital, Federal Reserve Bank of New York, *Current Issues in Economics and Finance* 17, no 6.

[28] Business-Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.

[29] Couturier, L. K. (2014). *STEM Regional Collaboratives: The Opportunity*. Jobs for the Future.

suggested that it is incumbent on leaders within both sectors to foster a culture of collaboration and partnership organized around shared goals of building a strong STEM ecosystem, centered on a workforce well equipped with the knowledge, skills, and abilities that contribute to a region's economic competitiveness.

Third-party organizations. Many contributions were made at the five regional meetings by representatives of third-party organizations and by employers and people in higher education who have benefited from the work of such organizations. These organizations include economic development authorities, workforce development organizations, and nonprofit entities dedicated to strengthening the workforce and the ability of higher education to produce strong graduates. Consistent with prior studies examining regional STEM workforce needs,[31, 32] workshop participants affirmed the critical importance of third-party intermediary organizations in facilitating regional workforce development ecosystems. Participants discussed the valuable work of the Greater Phoenix Economic Council and Science Foundation Arizona; the Ohio Board of Regents and the Cleveland/Cuyahoga County Workforce Investment Board; the LA Regional STEM Hub and LA HI-TECH (a partnership between the chamber of commerce, community colleges, and high schools); Alabama Industrial Development and Training and the Economic Development Association of Alabama; and the North Dakota STEM Network, North Dakota Department of Commerce, and the Greater Fargo Moorhead Economic Development Corporation in Fargo. These organizations play at least two essential roles in the STEM workforce development ecosystem.[33] They can assist partners in overcoming some of the cultural barriers described above, and perhaps most importantly, they can often bring to scale small, but promising, collaborative activities and other promising strategies for strengthening connections between employers and universities. These organizations can also play a central role in encouraging employer and university partners to organize their efforts around real-time labor market information and their region's occupational competitive advantage(s).[34, 35, 36, 37]

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[30] DeRenzis, B., and B. Wilson (2015). *Skills in the States: Sector Partnership Policy*. National Skills Coalition.
[31] Lee, J. A., et al. (2014). *Cracking the Code on STEM: A People Strategy for the State of Nevada*. Washington, DC: The Brookings Metropolitan Policy Program.
[32] TIP Strategies (2015). *Regional Workforce Study: Greater Fargo/Moorhead Region*.
[33] Consistent with the critical role that third-party intermediary organizations play in building and sustaining effective university-employer partnerships, at least one National Science Foundation grant program, the Experimental Program to Stimulate Competitive Research, has award criteria that emphasize the presence of third-party partner(s) in regionally focused university-employer research partnerships.
[34] Couturier, L. K. (2014). *STEM Regional Collaboratives: The Opportunity*. Jobs for the Future.
[35] Rosenblum, I., and C. Spence. (2015). *Success in Real-Time: Using Labor Market Information to Build Better Middle-Skill STEM Pathways*. Jobs for the Future.
[36] Business-Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.
[37] DeRenzis, B., and B. Wilson (2015). *Skills in the States: Sector Partnership Policy*. National Skills Coalition.

BOX 4-4 Corporate Approaches to Workforce Development

Institutions of higher education seeking to engage with businesses to form workforce development partnerships often face challenges in identifying and securing the opportunity to work with the right department or organization within the company. Historically, corporations have provided funding for and interacted with colleges and universities for a variety of objectives, ranging from pure philanthropy to research and development (R&D) to workforce recruitment. Funding to support each of these purposes comes from different organizations and budgets within the corporation, and which one dominates varies somewhat from company to company.

In the current era, when corporations are experiencing profound need to develop the future workforce—often with no additional funds available for that purpose, many are targeting corporate giving and different investment funds to support workforce development. Which account the money comes from determines the lens through which choices are made and projects are aligned. A grant received through a corporate responsibility office is likely to have a different focus—for example, emphasis on diversity and inclusion—than funding received from an R&D department—which is likely driving toward a more innovative and agile workforce. And, funding from a local business unit can be expected to have more immediate workforce hiring and/or community relations objectives than do investments determined by corporate strategic priorities.

Consciousness is growing that future workforce development is not the responsibility of human resources departments but rather a fundamental element of business strategy and operations which must be addressed and driven in the "C-suite." Institutions of higher education need to be aware that while several entities within any large company have some role to play in these endeavors, it is critical to ascertain from the CEO who in the organization has cognizance of and the authority to make decisions on and provide funding for long-term workforce development as a matter of corporate business strategy.

Third-party intermediaries serve as neutral, anchor organizations to facilitate effective collaboration and progress among regional partners. A successful third-party intermediary will often adopt a servant leadership[38] role and work quietly behind the scenes to support and lift up the work of the partners. A trusted, well-positioned, and effective intermediary will have the clout to bring the appropriate leaders to the table and the skills to provide cohesion, guidance, and facilitation for the collaborative. This role is essential in helping to promote and sustain comprehensive systems change. The functions of a strategic intermediary typically include convening leaders; connecting, brokering, or providing services to partner organizations; measuring effectiveness and ensuring quality and impact of efforts; and sustaining effective practices through advocacy and progressive policies. An intermediary that effectively performs these functions would strongly support the development of a STEM workforce development ecosystem.

The Ohio Aerospace Institute (OAI), the host of the Cleveland workshop, provides a good example of the role that third-party organizations can play in regional STEM workforce development. OAI positions itself as a broker among Ohio's two aerospace-related federal research laboratories (NASA Glenn Research Center and the Air Force Research

[38] *Servant leadership*, a term coined by Robert Greenleaf in his 1970 essay "The Servant as Leader" is conceptualized as a leader who shares power, putting the needs of others first and helping others develop and achieve performance goals.

Laboratory), numerous aerospace and related companies with significant operational footprints in northeast Ohio (e.g., Parker Hannifin, Lockheed Martin, TimkenSteel, GE Aviation), and regional universities and community colleges (Case Western Reserve University, Cleveland State University, Kent State University, the Ohio State University, the University of Akron, University of Cincinnati, University of Dayton, Youngstown State University, Cuyahoga Community College, and Lorain County Community College). By helping to connect industry, government, and institutions of higher education in the region, the OAI aims to leverage northeast Ohio's competitive advantage in aerospace and help build and sustain effective workforce development partnerships. See Box 4-5 for an additional example of the key role intermediary organizations play in organizing and focusing regional STEM workforce development efforts.

BOX 4-5 Role of Intermediary Organizations in STEM Workforce Development Ecosystems: Addressing Data Needs [a]

The Business Leaders for Education (BLE), a task force of Greater Louisville, Inc., the region's Chamber of Commerce, led a multiyear assessment of educational outcomes and promoted adoption of a bold aspiration goal of adding 55,000 additional degrees—40,000 baccalaureate degrees and 15,000 master's degrees—to the region's workforce in order to move them into the top tier of regions with their aspirational peers. The community united around the Greater Louisville Education Commitment, signed by 25 leaders, and created a new nonprofit, 55,000 Degrees, to serve as steward of this commitment. BLE identified areas of comparative advantage and the major firms in the sectors, including value-add logistics (UPS), food and beverage science (regional distillers and YUM), advanced manufacturing (GE appliances) and health and wellness (numerous research hospitals and a major health insurer). 55,000 Degrees focused on students in middle school and high school with the goal of increasing college enrollment and success, and Greater Louisville, Inc., with a grant from the Lumina Foundation, focused on adult learners—those with some college but no degree—to contribute to this goal and align workforce development with the needs of sectors to the region's growth.

[a] Business-Higher Education Forum (2012). *National & Regional Workforce Solutions: New Industry–Higher Education Projects for the NexGen U.S. Workforce*.

Industry consortia. Participants at all five workshops discussed the value of companies' coming together to form industry consortia. When employers shift from seeing themselves as *competitors* for a limited supply of labor to *collaborators* in building a workforce or talent pipeline, they can better identify the skills they need and pool their resources to obtain employees having these skills. Consortia can also help to ensure that small businesses' needs are addressed, as small businesses are often less able to devote the time needed to initiate partnerships with higher education and less able to fund such initiatives. Furthermore, like third-party intermediary organizations, industry consortia can also enable the process of taking promising partnership efforts or activities to scale.

Energy utilities in Arizona have created one such consortium and are working as a group with higher education to train their future workforce (see Box 4-6). In North Dakota, a number of diesel companies were represented at the regional meeting, and these

employees also spoke to the value of collaboration within an industry. They described how Butler Machinery, RDO, and General Equipment have partnered with local high schools and the North Dakota State College of Science to raise students' awareness of career paths for diesel technicians, a position for which there is great demand. Other participants also strongly encouraged companies to form consortia, including the senior vice president of the Office of Knowledge Enterprise Development at Arizona State University, the education manager at Intel Arizona, and the executive vice president of the Workforce and Economic Development Division at Cuyahoga Community College in Ohio. Box 4-7 provides an additional example of a sector-based approach to STEM workforce development.

BOX 4-6 Industry Consortia Approaches to Workforce Development: Arizona's Get Into Energy Program

Workforce development needs have recently emerged as an important topic for the utility industry in Arizona, which is facing an imminent wave of retirements and attrition over the next few years. To address this issue, all Arizona utilities and Estrella Mountain, Chandler-Gilbert, Pima, Yavapai, and Northland Pioneer community colleges formed a partnership with the intent of identifying the industry's future workforce needs and establishing programs to train new employees with the skills to fill gaps. Using workforce analytics, the collaborators identified a range of current industry skill requirements to be continually refined as the industry evolves in the coming years.

To meet the industry's training needs, the consortium colleges adapted the Center for Energy Workforce Development's Get Into Energy Program. As a result, each of the five colleges established associate degree and certificate pathways focused on specific career outcomes in Arizona's energy industry. Program and curriculum development was offset by federal grant funding. The strength of the Get Into Energy project is committed employer engagement, in which partners are connected to students throughout the entire 1- or 2-year training programs. Employers vet and endorse the community college curriculum, which includes stackable credentials and competencies. The National Career Readiness Certificate is embedded into the model to ensure that graduates not only have sharp technical skills, but strong employability skills as well.

The Get Into Energy partnership is beneficial to the employer, college, and student. It bolsters industry confidence in the skills of their prospective employees and provides students with access to information about the energy industry, mentorship, and clear career pathways within their chosen program.

BOX 4-7 Aerospace and Defense Industries:
A Sector-Wide Approach to STEM Education and Workforce Development

For nearly a decade, the aerospace and defense (A&D) industry has exerted leadership in fostering communication and collaboration among stakeholders in STEM education and workforce development. The National Academies' publication of the *Rising Above the Gathering Storm* report focused attention on the central importance of endeavors to improve student interest and achievement in math and science. Aerospace and defense executives know that their industries are uniquely affected by inadequate performance and engagement of U.S. students in STEM subjects. Because many of their most important jobs require security clearances, these firms must be able to hire qualified Americans; they cannot fill those positions with foreign nationals or move the jobs overseas. Beyond their direct business interest to remain competitive globally, A&D leaders are motivated to address the formidable threat posed to the national security and economic well-being of the United States.

Noting their preeminent interest in the U.S. future STEM workforce, and recognizing that they cannot solve the A&D workforce challenge alone, aerospace and defense leaders declared their interest and intention to collaborate with all other concerned stakeholders—at the national, state, and local levels—to meet the challenge as stated by the *Rising Above the Gathering Storm* report.

To pursue these objectives, the CEOs constituting the Executive Committee of the Aerospace Industries Association (AIA) charged that organization with addressing the future workforce challenge. An ad hoc committee was established in 2006 to explore the issues, identify best practices, and provide recommendations on how to proceed. The following year a sister industry group, the National Defense Industrial Association (NDIA), formed a STEM Workforce Division. The AIA and NDIA committees have worked jointly since 2007 to drive communication, collaboration, and the formation of coalitions and public-private partnerships to develop the future STEM workforce.

Much of AIA and NDIA's work has focused on convening stakeholders at the state and local levels. Originally planned as fact-finding sessions to learn more about what their member companies were doing in partnership with local groups, for the past 5 years these joint AIA/NDIA STEM forums have explicitly been designed to foster closer collaboration and the establishment or expansion of formal public-private partnerships to include state STEM networks.

Each STEM forum is planned and conducted by AIA and NDIA in partnership with one or more local organizations, such as a local NDIA chapter or other business group. The Ohio Aerospace Institute in Cleveland was the local organizer and host of an Ohio STEM Forum in 2014. Similarly, the Los Angeles Chamber of Commerce partnered with AIA/NDIA to convene a forum in 2013 at which they launched the Los Angeles Hub of the California STEM Learning Network.

Whereas AIA and NDIA's workforce efforts at the outset focused heavily on K-12 classroom and afterschool programs, over time they expanded to include attention to higher education programs and, more recently, the skills gap in manufacturing and other technical workforces.

All of this work is based on collaboration with other key stakeholders. For instance, AIA and NDIA have worked in tandem with the Business-Higher Education Forum to advance regional workforce projects at the postsecondary level; with the Manufacturing Institute and other associations on the skills gap challenge; and with Battelle and STEMx to foster and grow state STEM networks in K-12 education.

AIA and NDIA's experience has consistently demonstrated the power and value of bringing together all motivated stakeholders to scope the regional STEM education and workforce challenge, identify key next steps, and take responsibility for and commit to action.

Specific Strategies for Building a Strong STEM Workforce Development Ecosystem

Participants in the five regional meetings offered a wealth of promising strategies that form a part of—or can lead to the formation of—structured, effective regional partnerships between industry and higher education. The strategies listed below are presented in a roughly chronological fashion, beginning with activities typically undertaken early in the formation of a partnership. Where the discussion moves into descriptions of a range of collaborative activities, these can be productively used in whatever order and combination is optimal for a given location. Applied and experiential learning opportunities, because of their prominence in discussions at the five regional meetings, are highlighted separately at the end, along with research supporting their effectiveness.

Small, early successes with broad potential for adoption. For incipient cross-sector partnerships, participants encouraged both universities and employers to seek early successes to create momentum and draw the attention of people in different roles in an organization.[39] In Cleveland, Martin Abraham, interim provost of Youngstown State University, discussed a "partnership continuum," key steps in a process of building industry–higher education relationships, in which individual-by-individual interactions form the basis of a growing, trusting relationship. Participants in a breakout session in Fargo cited the value of a grassroots champion who can spur the establishment of a partnership and help to create a culture of collaboration. And in Phoenix, a board member of the Science Foundation of Arizona discussed the value of a small group of people in a company who can work as ambassadors to a college or university to show some early successes. In encouraging academics to begin partnering in ways that are small and simple, she said, "You have to recognize that your industry partners don't know how to do this." While pilot programs and one-off initiatives cannot themselves constitute the basis of an effective, structured partnership, they play a valuable role in beginning the development of a region-wide effort.

Single point of contact. Employers reported having difficulty navigating within higher education—both the physical campuses and the administrative structure. When they wish to connect with higher education, employers often have difficulty identifying an initial point of contact at the college or university—an issue emphasized by Jim Searcy, executive director of the Economic Development Association of Alabama; Stacey Breuer, director of human resources at Doosan Bobcat in Fargo; and senior officials at Arizona State University. Beyond the need for this initial contact, a number of workshop participants stressed (as mentioned above) the importance of an organization having one staff person dedicated to cross-sector partnerships and immediately replacing that person if he or she moves out of that role. The committee heard this message in discussion groups in Phoenix, from Francisco Rodriguez, chancellor of the Los Angeles Community College District, and from Terri Sandu, executive director of workforce development and director of the Entrepreneurship Innovation Institute at the Lorain County Community College in Cleveland.

[39] Ideally, these small, early successes can be taken to scale via the efforts of third-party intermediary organizations and/or industry consortia, as described in the preceding section.

Institutions of higher education can designate and publicize a single point of contact from which companies' inquiries can be directed to the appropriate divisions or departments in the college or university, as has been done at Arizona State University (see Box 4-8). Participants in breakout sessions in Phoenix cited the value for employers of this point of contact, and Jim Searcy, executive director of the Economic Development Association of Alabama, noted that this role could be played by administrators such as provosts and associate deans for research who have been charged with economic development. Within an academic department, the point of contact can be a career center staff member charged with connecting employers with students, as described by Paul Johnson, dean of the School of Engineering at Arizona State University.

BOX 4-8 Economic Development Strategies at Arizona State University

In an effort to further become socially embedded in the communities it serves, Arizona State University (ASU) developed SkySong, the ASU Scottsdale Innovation Center to drive economic development and corporate engagement. The center's economic development team works to provide a point of contact to assist employers and industry representatives in navigating—both physically and administratively—around the university. The economic development team is charged with engaging regional and state economic development organizations, keeping up to date on the types of research being conducted at the university, and engaging with corporate partners to facilitate their relationship with the university. ASU also maintains a corporate engagement council that brings senior staff from various academic and administrative departments together on a quarterly basis to discuss emerging research areas that may garner corporate attention.

According to the Greater Phoenix Economic Council, "ASU's sterling reputation when it comes to university-industry collaboration is a major attraction point for companies considering a move to or expansion in Arizona. ASU's partnerships with the business community have fostered innovation, economic growth and the creation of high-quality jobs."

Similarly, businesses can dedicate part or all of a position to collaborations with higher education. Chris Rico, director of innovation at the Los Angeles County Economic Development Corporation, suggested that large companies in the region, such as Hyperloop, SpaceX, Boeing, the Jet Propulsion Laboratory, and Disney, should have at least one employee dedicated to working collaboratively with higher education on the design and adoption of curricula. In North Dakota, Doosan Bobcat has a full-time employee whose job it is to build relationships with universities in the upper Midwest. This person's responsibilities include serving as the company's point of contact for academic institutions and working with company colleagues to develop internship and mentoring opportunities. For this position to contribute most effectively to structured, region-wide partnerships, it is valuable for it to be established within the CEO's office as a business development function, not in a company's human resources division (as might seem logical).

Collaborative activities that contribute to successful partnerships. Participants at the five regional meetings spoke to the value of a range of initiatives inside and outside the classroom that can form the core of successful partnerships. These initiatives and activities offer valuable training for students as well as channels for regular, substantive

communication between the sectors about workforce needs. This section describes the role of industry advisory boards; the value of larger convening activities; industry sponsorship of capstone projects; ways in which employees of local firms can be involved in courses and laboratory work; and physical spaces on campuses or in communities where students, faculty, and employers can engage in collaborative projects based on real-world problems.

Many academic schools and departments already have *industry advisory boards*, and these can play an important role in the regional STEM workforce development ecosystem if they are structured appropriately. The committee heard repeatedly that advisory boards usually need to be restructured if they are to function effectively as a collaborative space for the development and maintenance of partnerships (see Box 4-9).

BOX 4-9 Revamped Advisory Boards

Industry advisory boards in higher education need to offer frequent opportunities of different types for companies to articulate their needs and to provide higher education with feedback about students' skills and abilities. Advisory meetings also need to be a place where companies discuss, to the degree they are able, their future workforce needs. As noted by the vice president of academic and student affairs at North Dakota State College of Science, "Where do [companies] need to be? Not next year, but in 5 or 10 years?" The dean of technology and services at the North Dakota State College of Science advocated broadening this advisory function by bringing an entire industry sector into one room to discuss industry-wide needs.

Advisory boards can be a vehicle by which employers' involvement in higher education can begin to be expanded. Participants in a breakout session in Los Angeles asserted that higher education does not ask enough of industry and advocated strengthening the boards by making them bidirectional and by engaging employers more directly in the design of programs and curricula. In the Alabama Community College System, when an academic program requests additional funding—for example, for updated equipment—it is required to have the endorsement of the relevant industry.

It is important that advisory boards include people in different roles in industry—participants in Fargo spoke to the need for some representatives to have decision-making power and for others to be recent graduates and midcareer employees.

Finally, participants urged continuity. The vice president for workforce development at the Greater Fargo Moorhead Economic Development Corporation noted that if an industry representative is unable to attend meetings regularly, he or she needs to designate a replacement; while participants in a breakout session in Fargo suggested that if a representative leaves his or her position or the company, a successor should be named as quickly as possible. These practices help to ensure the ongoing participation of regional employers in those activities in higher education designed to support the local economy.

Higher education can also sponsor *larger-scale convening events* that bring together broad swaths of a regional industry for intensive discussions about their workforce needs. One participant from North Dakota State College of Science suggested, as a way to raise the level of discussion between business and industry, that administrators bring an entire industry sector into one room to discuss their current and projected workforce needs. She worked to convene the college's heating, ventilation, and air conditioning program and industry leaders across North Dakota, and the result was a full meeting room with influential people

discussing issues affecting the industry throughout the state. Effective advisory boards and larger, industry-wide events can help define regional workforce needs and determine the shape of the region-wide STEM ecosystem.

Workshop participants described a number of ways, once employers' needs are well defined, that employers and faculty or entire academic departments can work together to improve higher education's ability to train graduates with the greatest likelihood of success in the regional workforce.

To help teach students the skills they will need in the workplace, companies can *sponsor capstone or other student projects* that focus on solving real-world problems facing society. Arizona State University's Innovation Challenge Program is one such program that brings together students from diverse disciplines to work together to solve a challenge, pressing them to think beyond the most immediate solution. Each year a company poses a major challenge—in 2015, Verizon created the Smart Cities Challenge—and any team of students from any majors can attempt to solve it. The executive director of entrepreneurship and innovative initiatives at Arizona State University also described the university's iProjects, a program that pairs student teams and faculty mentors with industry partners to work on real-world challenges faced by the company. Some recent projects attempted to make packaging more sustainable, enable pet groomers to use less water, and create a device to improve the running ability of soldiers. The program allows students to apply knowledge gained in the classroom on a practical problem, while familiarizing them with the company's operation and culture and allows industry partners to evaluate the students as potential employees. The iProjects experience can be replicated anywhere there are willing faculty and industry mentors and partners.

Employees at regional companies can also be involved in classrooms and labs, serving as adjunct faculty or giving individual class lectures where appropriate, or companies can donate state-of-the-art equipment to enhance student learning. Don Morton, site leader at Microsoft Fargo, described how engineers at Microsoft, for example, have begun teaching computer science in high school classrooms, either supplementing existing classes or teaching the class themselves where there is a need. Likewise, it is important for *college and university faculty to have a solid understanding of industry workplaces*, to become more familiar with the environments in which their students will be employed. Workshop participants suggested several specific types of activities in this regard. Industry can organize site visits designed to increase faculty and administrators' knowledge of regional companies: Beth Ingram, provost of North Dakota State University, described the value of organized faculty visits to industry as a way to help faculty learn about what a company does, who it hires, and how industrial processes work. Companies can offer faculty fellowships or design exchange programs, giving faculty the opportunity to spend a more extended time in the workforce, gaining skills or undertaking collaborative research. For example, M. Javed Khan, head of the Aerospace Science Engineering Department at Tuskegee University, spoke highly of Boeing's faculty fellowship program, which had previously funded faculty to spend time in industry settings during the summer months so that they may stay apprised of industry's needs.

For skills widely in demand in the regional workforce, *companies can assist colleges and universities in overall curriculum design* that increases the value and usefulness of the skills graduates take with them into the regional economy.[40] Arizona State University partnered with Intel and Motorola in an effort to equip students with new skills needed by a planned corporate expansion, and the university proposed that the two companies fund short-term faculty research projects to familiarize faculty with industry problems and give them experience with short-term, outcomes-focused research. These experiences enabled faculty to align curricula more closely with current and projected problems facing the two companies. Similarly, the head of the Aerospace Science Engineering Department at Tuskegee University described Design, Build, and Fly, a two-semester program bringing together students at the Georgia Institute of Technology, Purdue University, Embry-Riddle Aeronautical University, and Brigham Young University. The program implements the latest approaches employed by the industry and gives students the social skills for working in virtual, multidisciplinary teams.

Numerous workshop participants discussed the importance of involving employers in shaping curricula at colleges and universities. While the committee believes there is great value in such efforts, there are also risks. It is important that institutions of higher education (and, for that matter, their business partners) develop strong conflict-of-interest policies—and ensure that they are followed. Both partners must ensure that the sole or primary interests being advanced from a company's direct intervention in an institution's curricula and programs are those of the students and the institution—not the profits and long-term market prospects of the company.

Workshop participants raised the importance of *physical spaces on campuses or in the community where students, faculty, and employers undertake collaborative, real-world projects*. In Cleveland, Case Western Reserve University and Cleveland Clinic are creating the think[box] Center, a 50,000-square-foot facility where a wide range of people, including students and faculty from Case Western and community colleges, members of the community, and people from the medical community and wider business community, can gather and experiment. The center emphasizes cross-disciplinary and cross-sector collaborations that endeavor to solve real-world problems. Students benefit from interacting with future employers and engaging in project-based learning and entrepreneurial thinking—experiences that will serve them well in northeast Ohio's high-tech workforce. In North Dakota, Doosan Bobcat recently opened its own collaborative space, an "acceleration center" where employees from many fields work together to develop new products (see Box 4-10). The company's experience highlights the way in which such spaces can also be used to train new employees in general technical skills and innovative thinking.

[40] Firms like Jobs for the Future, Burning Glass, The Conference Board, Help Wanted OnLine, Geographic Solutions, and others have methodologies that can help educators analyze curriculum and course offerings based on employers workforce needs.

BOX 4-10 Doosan Bobcat's Acceleration Center

Bobcat Company and Doosan's new product development in North America takes place in the company's Acceleration Center in Bismarck, North Dakota. The $28 million, 190,000-square-foot innovation center opened in 2014 and includes offices, laboratories, classrooms, and space for product demonstrations. Working in the center are 175 employees who use computer simulation to test concepts, do initial product design, and engineer and manufacture prototypes.

The Bismarck location's human resources manager noted how they realized early in the process of designing the facility to foster creativity and innovation that they needed to give employees permission to be creative: "We went into it thinking we were designing a facility, and we realized we were designing a culture." New employees—recent graduates holding engineering degrees—were accustomed to following directions to arrive at a predetermined conclusion. But the demands of the marketplace require a more creative approach, and Doosan Bobcat came to see that it needed to explicitly encourage employees to work differently, to think "outside of the box."

The Acceleration Center also plays an important role in the company's efforts to reach out to K-12 students. Doosan Bobcat recently participated in "Introduce A Girl to Engineering Day," inviting 50 sixth- and seventh-grade girls to the Acceleration Center for a day of meeting professional engineers and doing problem-solving activities. The program's success in capturing the girls' attention and increasing their interest in engineering has led the company to expand its STEM efforts in all locations and include children of other critical ages.

Applied and experiential learning opportunities. A unifying message heard at all five regional workshops was the importance of experiential learning. Project-based, team-based activities in the classroom and internships and cooperative arrangements play central roles in both retaining students in STEM fields and meeting a region's workforce needs. Applied learning activities have been shown to increase student learning of both technical and employability skills.

Consistent with prior research and efforts to understand the dynamics of regional STEM workforce development ecosystems,[41, 42] meeting participants discussed *course redesign* as a way to increase student learning and the numbers of students in STEM courses. The design of courses—especially first-year, or "gateway," courses—has a profound effect on student learning and engagement as well as the likelihood that they will continue in the field of study. Research studies have shown that project-based formats in STEM courses, as opposed to lecture-based classes, engage students' attention, increase learning, and increase retention, particularly of women and minority students.[43, 44] Participants at the

[41] President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President.
[42] Business-Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.
[43] For a comprehensive review of such studies, see President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President.
[44] National Academies of Sciences, Engineering, and Medicine. (2016). *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways*. Washington, DC: The National Academies Press.

regional meetings described a number of efforts to carry out such course redesign (see Box 4-11.)

BOX 4-11 Applied Learning Opportunities and Support Services for STEM Students

First-Year Undergraduate STEM Experience (FUSE) at California State University, Dominguez Hills

California State Dominguez Hills is employing several interventions that are demonstrated to increase student success in STEM fields.[a] FUSE, begun in 2015, provides incoming students with immersive educational experiences beginning the summer before college and continuing throughout their first year on campus. Students begin with a summer bridge course designed to prepare them for their college-level STEM courses. The program uses peer mentors, emphasizes learning communities, and employs active learning in first-year, or "gateway," courses to provide students with support both in and outside of the classroom.

EdPlus at Arizona State University (ASU)

ASU has begun redesigning its gateway courses in STEM—"service courses" that prepare large numbers of students to continue into a great variety of STEM majors. The redesign shifts their function from one of so-called weeding out all except for A-plus students to providing a place where all strong students are welcome and experience an environment designed to engage them in real-world STEM problems and help them excel.

The ASU redesign has emphasized the "flipped classroom" model of instruction. In a flipped classroom, the transfer of knowledge (lectures and background reading) occurs outside of the classroom, while the application of that knowledge (problem sets, active questioning, and facilitated discussion) occur during class time. In such a redesign for a freshman math or physics course, lectures are posted online for students to view before coming to class. Class time is then devoted to students working in small groups on applied problem solving facilitated by instructors.

Adaptive learning platforms employ technology to engage students in interactive learning—computers are used to adapt the presentation of material according to the learning needs of students as indicated by their performance on learning assessments.

When a first-year ASU physics course employed a flipped classroom and adaptive learning platform, the percentage of students earning a grade of C or higher rose from about half to almost 90 percent.

[a]Association of American Colleges and Universities (2012). *Ramping Up for STEM Success: Pathways for Student Transfer*; and President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Executive Office of the President. See also National Academies of Sciences, Engineering, and Medicine (2016), *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Diverse Student Pathways*. Washington, DC: The National Academies Press.

Internships and cooperative education programs outside of the classroom expose students to career opportunities, mentors, and role models; allow them to develop and apply technical and employability skills; and provide them with experiential, project-based learning opportunities. Pedagogical approaches that transcend disciplinary silos and embed a STEM subject in real-world challenges more closely reflect the environment that students will experience after they leave higher education. Project-based, multidisciplinary

learning also fosters in students an "innovative" mindset that can be valuable in the workforce. Consistent with research that has demonstrated that applied learning experiences and internships decrease attrition rates among STEM students,[45, 46, 47] and conclusions from prior efforts to understand the factors that strengthen STEM workforce development,[48, 49] a number of participants at the regional workshops emphasized the value of applied and experiential learning beginning early in a student's course of study and continuing throughout.

In addition to allowing employers to assess whether a given individual is a good match for the company's culture and mission, internships and cooperative education programs constitute a valuable communication channel between faculty and industry, contributing to effective feedback loops that benefit both partners.[50, 51] Meeting participants emphasized the importance of interns being given meaningful work and suggested that internships be structured to allow students an opportunity to make meaningful contributions to the company's mission. Martin Abraham, interim provost of Youngstown State University, described how the university created an Office of Professional Practice in the College of Science, Technology, Engineering, and Mathematics specifically to oversee internships because of the critical role they play in the education of students in STEM. Ed Castile, director of Alabama Industrial Development Training in the Alabama Department of Commerce, described a mechatronics partnership between Shelton State Community College and Mercedes-Benz as an "apprenticeship on steroids." This program has placed more than 200 students in internships at the Mercedes facility in Tuscaloosa. Students can enter the program immediately after high school or from Shelton State, and they spend 2 years at the Mercedes facility applying their mechatronics skills and knowledge. In Fargo, Wayde Sick, director of the Workforce Division of the North Dakota Department of Commerce, described the division's Operation Intern program, which aims to assist employers in building an internship program and to encourage interns to remain in the regional workforce. In this matching internship program, employers apply for funds to support an intern, and the division matches them 50/50, up to $3,000 per employer.

Participants noted that internships and formal mentorships, when done well, are time-intensive for students' mentors in both sectors, and can be especially difficult for small

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[45] Business-Higher Education Forum (2013). *The U.S. STEM Undergraduate Model: Applying System Dynamics to Help Meet President Obama's Goals for One Million STEM Graduates and the U.S. Navy's Civilian STEM Workforce Needs*. Washington, DC.
[46] Business-Higher Education Forum (2013). *The National Higher Education and Workforce Initiative*. Washington, DC.
[47] Jaeger, A. J., M. K. Eagan, and L. G. Wirt (2008). Retaining Students in Science, Math, and Engineering Majors: Rediscovering Cooperative Education. *Journal of Cooperative Education and Internships* 42(1):20–31.
[48] Lee, J. A., et al. (2014). *Cracking the Code on STEM: A People Strategy for the State of Nevada*. Washington, DC: The Brookings Metropolitan Policy Program.
[49] TIP Strategies (2015). *Regional Workforce Study: Greater Fargo/Moorhead Region*.
[50] Malsberry, S. (2014). The Relationship of Skilled Aerospace Manufacturing Workforce Performance to Training. Ph.D. dissertation. Walden University, Minneapolis, MN.
[51] Packard, B. W. (2011). Effective Outreach, Recruitment, and Mentoring into STEM Pathways: Strengthening Partnerships with Community Colleges. In National Research Council (2012), *Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit*. Washington, DC: The National Academies Press.

businesses or entrepreneurial start-ups. Individuals in industry as well as higher education have explored a number of alternative formats to the traditional internship experience that attempt to capture the benefits for all parties while demanding less time and fewer resources of mentors, to make this mechanism more sustainable over time and able to serve much larger numbers of students. Participants' suggestions included weekly, off-site sessions where students, faculty, and employees gather to discuss companies' needs and culture (a collaboration between Intel, Arizona State University, and regional community colleges); single-day student visits to companies (Ventana Medical Systems' afternoon session with women bioscientists and engineers in Phoenix); and student visits to companies 1 day per week.

State and Local Policies to Support Workforce Development Partnerships

Efforts by institutions of higher education and regional employers take place in a policy environment that can support or hinder the two sectors' efforts to strengthen the regional workforce. Governments can play an important role through policies that prioritize STEM education and increase the ease with which institutions of higher education and K-12 education can meet students' needs and workforce needs. Workshop participants from both sectors discussed several policies that can be implemented by state or local governments to expand educational and career pathways and better meet regional STEM workforce needs. First, economic development strategic plans having STEM as a priority can be beneficial to efforts under way in both sectors. In 2008, Alabama created its first statewide strategic plan, identifying STEM as a priority and bringing together K-12 education, the 2-year and 4-year systems of higher education, chambers of commerce, members of business and industry, and communities across the state. The visibility of this priority can prompt the involvement of a wider range of individuals and organizations in strengthening the STEM-related workforce.

Policies allowing for dual enrollment, where high school students are able to take classes for college credit, may be useful for attracting and retaining students in STEM majors and eventually STEM careers. Studies in Florida, California, and New York City demonstrated that students participating in dual-enrollment programs had higher rates of college enrollment and persistence and higher college grade point averages.[52] Although most dual-enrollment studies have not focused specifically on STEM students and majors, increasing numbers of community college Career and Technical Education (CTE)[53] programs are offering dual-enrollment options. Research on these CTE dual-enrollment programs has demonstrated a positive correlation between dual enrollment and greater college persistence.[54] At the time of the regional meeting in Los Angeles, a bill was going through

[52] Community College Research Center (2012). What We Know About Dual Enrollment. *Research Overview,* Columbia University.

[53] CTE is a program of the Office of Career and Technical Education at the U.S. Department of Education. CTE programs can be found at high schools, community and technical colleges, and 4-year universities and prepare students for a range of high-skilled and technical careers, many with clear links to traditional STEM disciplines.

[54] Karp, M. M., et al. (2007). *The Postsecondary Achievement of Participants in Dual Enrollment: An Analysis of Student Outcomes in Two States*. National Research Center for Career and Technical Education, University of Minnesota.

the California assembly—Concurrent Dual Enrollment Assembly Bill 288—that would allow high school students to enroll in community college classes free of charge, and this law was passed in October 2015.

Stackable credentials are degrees, certificates, diplomas, licenses, or other credentials that can be accumulated by an individual over time as he or she moves along an educational and career pathway with multiple entry and exit points. Stackable credentials can fulfill a wide range of students' needs for training according to current opportunities in the regional workforce. Gary Cates, senior vice chancellor of the Ohio Board of Regents—a coordinating agency working with colleges and universities, state and career technical education centers, and a program for adult basic literacy education—described the current high degree of collaboration among institutions of higher education and the board's goal of creating a seamless portfolio across Ohio. The goal is the creation of an educational network where a person can enter through any institution and complete his or her education anywhere in the system with all credits transferring. Gene Dudley, director of career and technical education in the Alabama Community College System, noted how most of the colleges' work involves stackable certificates and credentials, a structure particularly beneficial for first-time college attendees.

Chapter 5
Findings and Recommendations

A compilation and analysis of the information and insights collected at the five workshop sites, even with the vast and rich set of ideas and experiences that emerged, does not constitute sufficient evidence to provide the basis for recommending time-tested "best practices." Although numerous participants in the regions expressed the desire for access to such findings, a future study with a more systematic methodology would be required to identify such evidence-based best practices. There is, in any case, no "silver bullet" that can transform a limited partnership between universities and regional employers into a strong and effective relationship overnight. However, the committee heard from participants in the regional meetings that certain concrete steps can be taken that, over time, enable both sectors to collaborate in a sustained basis in ways that benefit students, business and industry, and colleges and universities, broadly strengthening the regional economies in science, technology, engineering, and mathematics (STEM) narrow and STEM broad occupations alike. Such steps—such *promising practices*—are the focus of the findings and recommendations of this report.

We provide our concise findings and recommendations here, organized into five themes and presented in priority order, in the hope that the stakeholders will explore strategies to implement these ideas and test their efficacy in their communities. In addition to these findings and recommendations, we include Box 5-1 (at the end of this chapter), which identifies specific actions that key stakeholders within regional STEM workforce development ecosystems can take to build, strengthen, and sustain partnerships. The recommendations were shaped by both the findings and the committee members' expertise at the higher education/industry nexus.

THEME A
STEM WORKFORCE DEVELOPMENT ECOSYSTEMS: ATTRIBUTES OF EFFECTIVE PARTNERSHIPS

Findings

Finding A1 – Well-structured formal university-employer partnerships are more successful in the long term than collaborations based on ad hoc relationships. Sometimes the partnerships rely on individual leaders (such as a university president or dean, or a local business executive) to initiate and sustain the relationship; in other cases, partnerships are activated and facilitated by an intermediary organization such as a chamber of commerce, a local business association, a government entity, or a nonprofit organization dedicated to building such connections. A robust and productive ecosystem requires proactive steps on behalf of university leaders, local employers, and intermediary organizations.

Finding A2 – It is incumbent on leaders within both sectors to foster a culture of collaboration and partnership organized around shared goals of building a strong STEM ecosystem, centered on a workforce well equipped with the knowledge, skills, and abilities that contribute to a region's economic competitiveness.

Finding A3 – It is incumbent on intermediary organizations (e.g., chambers of commerce, workforce investment boards, economic development organizations, industry consortia) to facilitate the creation and maintenance of the workforce development ecosystem, by promoting organization, communication, and collaborative activities among universities and employers. The intermediary will be useful in facilitating the development of the ecosystem and ensuring that the following actions are undertaken by cross-sector partners.

Finding A4 – In effective partnerships, each actor recognizes that employers and higher education institutions have different cultural practices around reward systems, time lines, and risk taking; these partnerships are designed to overcome such differences through frank and open communication pathways.

Finding A5 – Attributes of successful partnerships include a high-level commitment (e.g., by a company chief executive officer [CEO] or local division head and university president or dean) between partners that is institutionalized and expressed at multiple levels within each organization; single and well-identified points of contact; continual feedback loops; and a sustainability plan that ensures continuity when key individuals leave the organization.

Finding A6 – More effective collaboration between employers and university partners can be achieved when partnerships promote the joint development of curricula, research projects, and experiential and applied learning opportunities for students, faculty, and industry representatives. The activities can take advantage of new developments in educational technology and redesigned textbooks.

Finding A7 – Advisory boards can be useful for initiating workforce development partnerships among employers and universities, but effective partnerships transcend the traditional unidirectional focus characteristic of many of these boards. Effective boards should engage employers more directly in the design and adaptation of curricula and programs to give students hands-on, experiential learning opportunities that will develop both technical and employability skills.

Finding A8 – Obligations and requirements of universities, departments, and individual faculty members can potentially pose systemic constraints on efforts to build stronger partnerships with the regional employer community. For example, accreditation—with its requirements for mandated course credits—can become a barrier to the development of innovative applied learning experiences such as internships and apprenticeships.[1] In

[1] For example, ABET (Accreditation Board for Engineering and Technology, Inc.) is a not-for-profit, nongovernmental accrediting agency for programs in applied science, computing, engineering, and engineering technology and is recognized as an accreditor by the Council for Higher Education Accreditation. ABET accreditation provides assurance that a college or university program meets the quality standards of the profession for which that program prepares graduates. More than 3,400 programs at nearly 700 colleges

addition, individual faculty members may be discouraged from engaging in experiential activities of their own, such as spending time in employer settings and working in employer labs, despite the potential benefits to their students.

Finding A9 – This may be especially true for adjunct faculty who are increasingly hired to deliver lectures to large course sections and who are evaluated on their coverage of topics and achieving enrollment targets. Furthermore, because many faculty at research universities must raise funds to support their research projects and salaries, their priorities may be on research that will be funded, rather than workforce preparation or employer partnerships.

Finding A10 – Efforts to protect intellectual property often serve as obstacles to collaboration between universities and employers.

Recommendations

Recommendation A1 – Leadership Matters: We recommend that university presidents and provosts assume a high-profile leadership role. They should actively reach out to regional employers, establish a strong and sustained presence in the local business community, and cultivate business engagement in college/university academic programs (beyond the traditional fundraising support). These leaders must make it known widely that their institutions are eager to embrace formal partnerships with the local employer community—and that specific policies and strategies can usually be implemented without the need for governing board approval, often by individual deans and faculty. At the same time, business leaders and other employer executives should openly encourage partnerships with universities by taking the initiative to reach out to presidents, deans, and faculty. Employers should identify specific ways in which they can support curriculum development and labs on campus, involve faculty and students in hands-on learning opportunities in their businesses, and encourage joint ventures that simultaneously support student learning and employer productivity goals. For example:

- Deans and faculty from STEM departments should organize regular meetings that bring employers to campus to meet with faculty and students; discuss current and prospective workforce needs using real-time labor market data; gather the business community's input into curricula and lab experiences; review and adapt to local needs existing standardized curricula and training programs such as those developed by scientific and professional societies; and provide forums for discussion of opportunities for formal student and faculty engagement in local businesses and other local employers through internships, apprenticeships, and faculty exchanges.
- Local employer executives should designate at least one individual to serve as a liaison to local universities; that person should maintain a high profile on

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and universities in 28 countries have received ABET accreditation. Approximately 85,000 students graduate from ABET-accredited programs each year, and millions of graduates have received degrees from ABET-accredited programs since 1932. See http://www.abet.org/accreditation/. Accessed January 23, 2016.

campuses—regularly engaging with deans, department heads, and faculty to identify specific strategies for formal alliances.

- Just as university presidents and deans often cultivate deep interpersonal relationships with current and prospective major donors, they should do so with local business leaders, with the goal of securing formal relationships with employers that provide direct and frequent communication between business and university academic departments.
- Business and university leaders should consider ways to incentivize faculty to engage in partnerships, perhaps by providing summer salary or research support.

Recommendation A2 – Intermediary Organizations are Essential: We recommend that regional third-party organizations (e.g., chambers of commerce or regional economic development organizations) take an active role in facilitating the creation and maintenance of university-industry partnerships and regional STEM workforce development ecosystems. They can do this by establishing lines of communication among partners: organizing convening events; helping employers and universities understand the region's competitive advantages by addressing data and information needs; and perhaps most importantly, bringing promising partnership activities to scale. Third-party intermediaries will be most effective when they help establish and sustain a cross-sector collaborative. The high-functioning intermediary works to plan, convene, connect and broker, and measure and evaluate the collaborative's activities and progress in developing the STEM workforce development ecosystem. The intermediary is essential to the collaborative, performing the following functions that help to develop, maintain, and sustain the collaborative, and thereby make comprehensive, systemic changes:

- Planning, which involves building awareness among partners and working toward a common, sustained vision and regular establishment of shared goals; mapping existing programs; gathering labor market information and conducting sector analysis; and providing short- and long-term strategic planning.
- Convening, which includes engaging local leaders, stakeholders, higher education partners, and industry partners; sharing best practices; and defining the mission and purpose of the collaborative effort.
- Connecting and brokering, which entails connecting services and programs while transcending possible conflicts and competition among partners; linking employers, higher education institutions, and students so that students and job seekers participate in contextualized education and training, and employers enjoy a pool of qualified, skilled workers; and aligning funding and resources such that integrated funding streams leverage the effort and activities/services that are aligned.
- Measuring and evaluating, which requires identifying and defining indicators in order to measure progress against goals, establishing quality standards agreed upon by partners, and facilitating systematic program evaluations.

Recommendation A3 – Faculty Time in Employer Settings: We recommend collaboration among university administrators and local business and government employers to create more formal opportunities for faculty to gain experience in the workplace. Short-term and long-term residential placements, summer internships, and

occasional 1-day or 2-day participation in lab or worksite activities can give faculty a realistic sense of the knowledge, skills, and attributes necessary for their students' success in the workplace across a variety of industries and occupations—and enable them to adapt their own curricula, instructional practices, and labs accordingly.

Recommendation A4 – Applying Lessons Learned from Community Colleges: Drawing on successful employer engagement and partnership models used at community colleges, we recommend that more 4-year colleges and universities, including research universities, pursue formal partnerships with local/regional employers to create opportunities for education and training experiences on the ground at worksites. Such initiatives can have the dual benefit of better aligning university curricula and labs with regional workforce needs and simultaneously contributing to productivity and efficiency in employer operations, which can enhance the economic strength of the employers and the health of the local economy. We also recommend that community colleges offer dual-enrollment options to expand pathways to STEM credentials and careers. While doing so, create appropriate "conflict-of-interest" policies and procedures that ensure that when employers are directly involved in shaping curricula and labs, and even serving as instructors and mentors, the interests of the students and the institutions remain paramount—not the profit interests of the employers.

Recommendation A5 – Use a Self-Assessment Tool: We recommend that universities, employers, and intermediary organizations use a self-assessment rubric/checklist aligned to the above recommendations (see Boxes 5-2 and 5-3, at the end of this chapter, for one such self-assessment tool as developed by the committee). Universities could use this tool to explore the development of stronger partnerships with employers and then create a roadmap for establishing such relationships. Such an "audit" mechanism might help universities create plans, strategies, targets, and benchmarks for aligning their programs/curricula with regional workforce needs and for engaging in more formal and more intensive ways with local employers. Employers, in turn, could use the tool to guide decisions and priorities for how best to engage with universities and overcome cultural and other factors that often impede the development of effective local partnerships. Boxes 5-2 and 5-3 provide an initial framework for the development and adoption of such a self-assessment tool—one for universities, and one for employers.

Recommendation A6 – Focus on Diversity. Colleges and universities must remain vigilant in their efforts to recruit and retain underrepresented minority students and females into STEM majors and pathways. They should provide support systems—drawing on local employers, where possible—that enable minority and female students to engage regularly with mentors and peers who might have faced, or are currently facing, similar challenges in meeting the demands of the curriculum. Institutions should explore the development of "early warning" systems to monitor student progress and alert faculty to challenges that minority students and female students are facing and may have difficulty addressing themselves without some kind of intervention and support.

THEME B
INFORMATION AND DATA NEEDS

Findings

Finding B1 – Many institutions of higher education struggle to identify real-time STEM workforce needs in their local and regional communities. Similarly, many employers struggle to describe their workforce needs in ways that are actionable by colleges and universities. Finally, existing national and regional data are insufficient to assess the effectiveness of higher education institutions in educating STEM-trained workers in response to workforce needs.

Finding B2 – Acquiring and analyzing real-time labor market information can be an important starting point for the creation of regional university-employer partnerships. Important elements of this initial step include efforts to compile the precise demands—current and future—for particular types of STEM narrow and STEM broad jobs, and identifying occupational areas in which a region has a competitive advantage. The availability of accurate information on the jobs and careers that will drive the regional economy in the years ahead is vital to ensuring that the STEM workforce development ecosystem is adaptable to changing economic conditions. This information is also essential to aligning education and training programs on local campuses with current and future workforce needs.

Finding B3 – The landscape around outcomes measurement of higher education is shifting and bending toward consideration of comprehensive data on student outcomes, including job placements and student earnings after graduation. More robust career outcomes measurement systems may be increasingly important and relevant for colleges and universities.

Recommendation

Recommendation B1 – Make Data Collection and Analysis a Priority. We recommend that universities, local/regional businesses, and local governments place a high priority on identifying current and future skills and jobs needs in the regional economy—using both traditional and real-time labor market information when available. Areas of competitive advantage can serve as a focal point for partners. By intentionally organizing their efforts around these occupations and skill sets, the partners can maximize their success in aligning the knowledge and skills that students acquire on campus and the knowledge and skills they must bring to the workforce to be successful in jobs and careers. It is imperative that employers communicate their needs in an actionable and realistic manner, so that the expectations of both partners are aligned. Moreover, universities should collect information on, and make public, the number of STEM degrees among their graduates matched against regional market data for STEM jobs. This is also consistent with the need to collect and report data on career pathways, career outcomes, and gainful employment

opportunities, as reflected in the new federal College Scorecard announced by the U.S. Department of Education in summer 2015.[2]

THEME C
APPLIED LEARNING: APPRENTICESHIPS, INTERNSHIPS, COOPERATIVE EDUCATION, AND EXPERIENTIAL LEARNING OPPORTUNITIES

Findings

Finding C1 – Internship and cooperative programs can provide authentic, problem-based learning experiences that benefit both students and future employers. The importance of internships and cooperatives for strong STEM workforce development partnerships was noted by participants at all five regional workshops. The need for *paid* internships was seen as especially vital for low- and moderate-income students who often work to support their education.

Finding C2 – While all students benefit from richer, more rigorous academic experiences, and from more hands-on authentic learning, the needs of underrepresented minority students and female students must be paramount if we are to close the achievement gaps and participation gaps in STEM majors and careers.

Finding C3 – Hands-on, experiential learning in the classroom (across K-16) is an important pedagogical approach for attracting and retaining students in STEM fields as well as for giving them the necessary skills to thrive in the workforce. Moreover, it is important that such engagement begin soon after students enroll at the university (i.e., their freshman and sophomore years) and continue to degree completion. Hands-on, experiential learning is particularly important for underrepresented minority students and female students, who, too often, are "turned off" of science and engineering (in middle school, high school, and even in college) because the course experiences are not made relevant to their interests and to the real world of work.

Finding C4 – Because there are not enough paid slots among local employers for internships, apprenticeships, cooperative education, and other work-based learning for all interested students, colleges and universities must be more intentional and committed to creating applied learning experiences on campus. These experiences can be in courses or through extracurricular activities that use simulation and modeling of real-world work scenarios to expose students to such opportunities.

Finding C5 – Faculty members themselves often need hands-on experiential learning opportunities to fully understand local and regional workforce needs. These experiences enable faculty to keep current with developments in the types of skills most in demand in

[2] See https://collegescorecard.ed.gov/.

different industry sectors and can help faculty update or redesign their curricula and pedagogy in response to industry trends.

Recommendations

Recommendation C1 – Apprenticeships, Internships, and Cooperative Education: We recommend that local employers and universities explore ways to give many more students the hands-on, experiential learning opportunities they require in a work setting. We further recommend expanding apprenticeship, internship, and cooperative education opportunities—including scholarships for students to serve for at least one semester in a business, particularly a laboratory or other setting that involves working with a team to address one or more STEM-related challenges. These programs should recognize the need for broadening participation in STEM educational and career pathways.

Recommendation C2 – Sponsorships of Internship Opportunities: Building upon the above recommendation, we urge universities and businesses to investigate the efficacy of adapting the model successfully used by many universities to create donor-sponsored athletic scholarships—and apply that model to apprenticeships and internships for students. When they understand the value of internships and apprenticeships, alumni, local businesses, local community foundations, and perhaps other prospective donors may be motivated to sponsor programs that can give students the work-based experiential learning they need for future workplace success and incentivize their persistence in important STEM pursuits.

Recommendation C3 – Mentors are Key: We recommend that employers and universities develop strategies for identifying and training more mentors from local businesses and government entities and assigning them to undergraduate students. The benefits of "one arm around one child" are well known and widely accepted in elementary, middle, and high school. They can be equally valuable to university students who might be succeeding in the classroom but have little understanding of what is expected in a work setting. Such mentoring is of particular importance for women students and students from underrepresented minorities, who often lack a sense of "belonging" in the STEM-related workforce and who may not have had exposure to role models (as faculty or as peers) in the science with whom they can directly identify.

Recommendation C4 – Applied, Experiential Learning—On Campus: Universities should create—or adopt—on-campus models that simulate real-world laboratory and employment settings, either in courses or extracurricular activities. Giving students applied learning experiences that closely resemble the conditions and situations they will face in the workplace can help them think critically, adapt to unanticipated obstacles, work as members of teams, communicate effectively, and overcome failure. Faculty with some industrial or business experience can be useful here in bringing first-hand knowledge of these activities.

THEME D
EMPLOYABILITY SKILLS

Findings

Finding D1 – Employability skills are the attitudes, behaviors, motivational states, and skills that employers deem as critical for workplace success, including collaboration and teamwork, effective communication (oral and written), problem-solving, empathy and trustworthiness, and interdisciplinary thinking. A consistent and powerful message from employers at all five regional meetings was that these skills, are among the most vital skills for a graduate to thrive in the workplace—at least as important, if not more so, than technical knowledge and skills. Employers frequently noted that students who enter the workforce with some level of proficiency in these skills are usually more effective and trusted colleagues than those who have had little or no opportunity to develop these skills.

Finding D2 – Professional scientific and engineering societies often provide courses and webinars on employability skills. Local student or campus chapters of such societies can give students the opportunity to learn and apply a range of employability skills first-hand, and encouraging undergraduate students to be involved in professional societies can be a first step toward life-long learning.

Recommendations

Recommendation D1 – Research on Employability Skills: In recognition of the need to strengthen the employability skills of students before they enter the workforce, we recommend that employers, government agencies such as the National Science Foundation and the U.S. Departments of Education and Labor, and philanthropic foundations fund research to (1) better understand the relationship between mastery of employability skills while in undergraduate and graduate education on the one hand, and early success in a STEM career in the other; (2) better understand the most effective classroom, laboratory, and extracurricular strategies on campus, and through work-based learning experiences, that support the development of those skills in undergraduate and graduate students; and (3) better understand how employability skills are best measured and assessed, by both educators and employers. In particular, we recommend further research that investigates the importance of the following skills in the STEM workforce and identifies potential strategies for helping students become proficient in these areas:

- Ethical behavior and trustworthiness
- Self-confidence, a positive outlook, sincerity, civility, and accepting responsibility
- Perseverance and "grit"
- Effective communication, including advocacy and persuasion
- Effective collaboration, including leadership, teamwork, and consensus building
- Entrepreneurial mindset and associated business acumen
- Interdisciplinary and multidisciplinary thinking

- Creativity, curiosity, and design
- Empathy and social responsibility
- Global awareness and perspective[3]

Recommendation D2 – Cultivating Employability Skills in Students: We recommend that universities and employers work together to create regionally focused, applied learning activities that draw on real-world workplace challenges and can only be solved using a combination of technical and employability skills. Such activities can be integrated into the curricula and labs of STEM departments; can be made available to local college and university students through local competitions and extracurricular programs; can be part of student internships and apprenticeships; and can be made available online to students who can work in teams comprising other students, faculty, and employers. We also recommend encouraging students to be active in local and regional chapters of professional scientific and engineering societies. Among the characteristics of programs that could help students develop stronger employability skills are the following:

- Project-based learning activities on campus that require students to draw on their STEM skills to address the technical challenge, but also encourage them to develop their teamwork skills by working in collaboration with others and their communication skills by preparing written and oral presentations on their project activities and project outcomes.
- Work-based learning activities (e.g., internships and apprenticeships) that require students to work jointly with professionals and other students on a work-based challenge, to devise a business plan (including budgets and strategic plans) to undertake a project, to present their plans to senior executives in writing and orally, to assume leadership roles that include supervisory and managerial responsibilities, and to develop solutions to problems that may not have a single "right" answer—or no right answer at all.
- Participation in "Maker" projects, such as robotics competitions, grand challenges competitions, and other activities in which students work with teams to build a product, solve a real-world problem, or persuade others to take a course of action.

THEME E
PUBLIC POLICY

Findings

Finding E1 – State and local governments can implement policies and programs to catalyze, support, and sustain effective and sustainable workforce development partnerships between universities and employers, which in turn can contribute substantially to a region's economic development.

[3] Miller, R. K. (May 2015). Why the Hard Science of Engineering is No Longer Enough to Meet the 21st Century Challenges.Olin College of Engineering.

Finding E2 – While effective collaboration may most often be initiated by individuals and groups in universities and in businesses, effective partnerships can also be launched and sustained by state and local government agencies.

Recommendations

Recommendation E1 – State and Local Public Policies to Support University-Business-Government Partnerships: We recommend that state legislators and local

development, public funding can create the conditions in which partnerships may be launched and can thrive. government officials explore the following types of policies that can create conditions that enhance the viability and productivity of existing and future partnerships and alliances:

- Public funding that encourages state and local partnerships between higher education and industry remains an important lever for career development and economic growth. While government support is not the sole or perhaps even the primary driver of education, training, and economic Recognizing that federal and state dollars are likely to become even less available in the future than they have been in the past, we still urge that states and communities make strategic and stable investments that can leverage greater private support for collaboration.
- State legislatures or governors should focus on initiatives that encourage local college/university-employer partnerships, including providing better real-time labor market information.
- County commissioners or city councils should consider designating a local government official charged with fostering local partnerships by serving as a broker between college/university leaders and business leaders, and by encouraging the initiatives cited above, such as scholarships for internships/apprenticeships, stronger mentoring opportunities, and faculty exchanges.
- State and local governments should recognize the costs associated with new or expanded programs to stimulate STEM education and training—both because the average cost to educate STEM undergraduates is generally higher than the average cost of educating humanities undergraduates and because the costs of educating STEM workers will increase as more and more students are attracted into STEM fields of study.

Recommendation E2 – Governors, Mayors, and Other Policy Makers as "Champions" of Collaboration: High-profile policy leaders should be strong advocates for robust university-industry partnerships. Of course, funding and legislative policies that incentivize such collaboration are important, but so too are public statements and public events that showcase the important benefits of university-industry partnerships. We urge governors, mayors, and other executives to assume high-visibility roles in championing such collaboration.

- **Recommendation E3 – Federal Policy and Action:** Consistent with the goals and recommendations of *Rising Above the Gathering Storm* and legislation such as the America COMPETES Act, we recommend that the National Science Foundation; U.S.

Departments of Labor, Education, and Defense; and other federal agencies use their grant-making capabilities to encourage greater collaboration between universities and industries that can enhance both education and job creation. The National Science Foundation's Advanced Technological Education program is an example of a promising model that establishes partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. This is a federal program worth exploring for further replication or expansion.

BOX 5-1 Specific Steps for Each Key Actor in Regional STEM Workforce Development Ecosystems

BUSINESS LEADERS

- Foster a spirit of collaboration with local and regional higher education institutions so that employees are empowered to engage in collaborative workforce-building activities.
- Reach out to university presidents and deans and offer to build over time a university-business partnership that strengthens the local economy, enhances business operations, and creates more learning opportunities for students—many of whom will be the future employees of the business.
- Designate a high-level executive to serve as the initial point of contact with one or more local universities, and give this individual the power and authority to enter into formal relationships with local institutions (and, where appropriate, with third-party intermediaries). Make this effort a high-profile, high-priority activity of the business. The position should be established within the CEO's office as a business development function, rather than in the company's human resources division.
- Work with one or more local higher education leaders, government officials, or third-party intermediaries to conduct a regional assessment of the economy that includes multiple sources of labor market data and employers' assessment of the current and future workforce needs, and identifies the specific steps that are under way (and/or that need to be launched or expanded) to support stronger collaboration among partners—with the dual goals of enhancing the local economy and strengthening student preparation for success in the regional workforce.
- Prioritize the development of as many work-based learning opportunities as possible for students and faculty—including paid internships, apprenticeships, and other experiences that provide hands-on, experiential learning at the worksite. Ensure that these opportunities include stipends or wages and emphasize diversity and the inclusion of groups traditionally underrepresented in STEM fields.
- Reach out to other businesses in the region with the same technical skill needs and develop collaborative programs to enlarge the region's STEM-capable workforce. Consider joining or creating sector-focused consortia.
- Encourage employees to serve as mentors to local college and university students—especially to underrepresented minority students and female students who may not have exposure to many role models pursuing this career pathway. Urge mentors to meet regularly with students, and even bring them to the worksite regularly to participate in meetings, projects, and other activities.

UNIVERSITY PRESIDENTS

- Foster a spirit of collaboration with local and regional businesses, including empowering faculty to engage in cooperative and workforce-building activities.
- Work with one or more local business leaders, government officials, or third-party intermediaries to conduct a regional assessment of the economy that includes multiple sources of labor market data and local employers' assessment of the current and future workforce needs, and identifies the specific steps that are under way (and/or that need to be launched or expanded) to support stronger collaboration among partners—with the dual goals of enhancing the local economy and strengthening student preparation for success in the regional workforce. Make this a high-profile exercise to work with local business leaders and others to "take stock" of local employer workforce needs, and make a public commitment to better aligning the university's education programs, labs, curricula, and applied learning experiences to future STEM workforce projections.
- Designate a high-level administrator or faculty member to serve as the initial point of contact with local businesses and give this individual the power and authority to enter into formal relationships with them (and, where appropriate, with third-party intermediaries). Make this effort a high-profile, high-priority activity of the university. Among the responsibilities of this individual should be coordinating departmental STEM advisory boards.
- Organize and host a regional meeting on campus involving prospective partners, including business leaders, government agencies, chambers of commerce, individual entrepreneurs, and civic associations—focused on creating and sustaining a regional STEM workforce development ecosystem that shares the common goals of improving the local economy and strengthening human capital resources in the region.
- Encourage the creation of one or more STEM advisory boards on campus—housed in various academic departments and coordinated by the individual with responsibility for serving as the point of contact for business—for the purpose of regularly and deliberately engaging the local employer community in discussions about current and prospective workforce needs, collaboration, engagement, and mutual support. Ensure that these advisory boards are sufficiently diverse and emphasize the importance of broadening participation in STEM.
- Using student migration analyses, track attrition in STEM courses and majors in the first 2 years of undergraduate education, and create a plan for increasing completion rates in STEM majors, especially for female and underrepresented minority students. Make use of the variety of evidence-based interventions known to improve student retention and persistence in STEM majors and occupations.

UNIVERSITY DEANS AND FACULTY

- Work with third-party intermediaries to create a regional advisory board that involves both business leaders and employees to ensure that the knowledge, skills,

and attributes that students are gaining through their educational experiences are aligned with current and future workforce needs. If necessary, involve local industry officials in the redesign or creation of curricula, labs, and other campus-based experiences.

- Seek out opportunities for both faculty and students to secure internships, apprenticeships, and other work-based learning experiences in local industry and government agencies and labs. In addition, bring local business leaders and employees into the classroom and campus labs as visiting instructors on how industry works to remain current in rapidly changing fields.
- When internships and apprenticeships are limited, create simulated real-world applied learning experiences on campus that mirror the experiences in local worksites, so that students have exposure to workplace conditions and challenges and ensure that accreditation requirements do not become a barrier to the development of innovative applied learning experiences. Recognize that the workplace is often characterized by challenging multilayered problems that require teamwork and collaboration and good interpersonal relationships to identify possible solutions.
- Remain vigilant with efforts to recruit and retain underrepresented minority students and females into STEM majors and pathways. Provide support systems that enable minority and female students to engage regularly with mentors and peers who might have faced, or are currently facing, similar challenges in meeting the demands of the curriculum. Create an early warning system to monitor student progress and alert faculty to challenges that students are facing and may have difficulty addressing themselves without some kind of intervention and support.
- Track enrollment and attrition in STEM courses and majors in the first 2 years of undergraduate education, and create a plan for increasing completion rates in STEM majors, especially for female and underrepresented minority students. Make use of the variety of evidence-based interventions known to improve student retention and persistence in STEM majors and occupations.
- Ensure that appropriate incentives are in place for faculty who champion collaborative partnership activities: tenure, salary, summer funding, and infrastructure and personnel resources as needed. Consider grants for workforce development activities as having similar levels of prestige as those for research activities.

STATE AND LOCAL GOVERNMENT AGENCIES

- Work with a third-party intermediary to organize and facilitate a rigorous data collection and analysis effort that attempts to understand the current and future workforce needs in the region, and communicate the findings with both university officials and local businesses.
- Collaborate with third-party intermediary organizations focused on the creation of university-industry partnerships.
- Use legislation and, where possible, funding to incentivize partnerships, collaboration, internships, and other activities that bring students and faculty into

regular and sustained contact with local employers. Even relatively modest investments of federal, state, or local dollars can encourage employers and institutions to dedicate time and resources to fostering creative partnerships that can then be sustained over time.

THIRD-PARTY INTERMEDIARIES
(e.g., Chambers of Commerce, Workforce Investment Boards, Economic Development Organizations, Industry Consortia)

- Prioritize the importance of broadening participation in STEM education and workforce development pathways by helping to organize, support, and sustain cross-sector partnerships for workforce preparation.
- Facilitate the creation of effective workforce development partnerships among local employers and universities by
  - Bridging some of the cultural and communication barriers that can present obstacles to partnerships;
  - Establishing lines of communication between partners;
  - Organizing convening events;
  - Helping employers and universities understand the region's competitive advantages by addressing data and information needs;
  - Bringing promising partnership activities to scale; and
  - Assisting with securing outside sources of funding, as appropriate.
- Fulfill strategic functions of planning, convening, connecting and brokering, and measuring and evaluating collaborative efforts in order to promote the development, maintenance, and long-term sustainability of the STEM workforce development ecosystem.

BOX 5-2 . Initial Framework for a Self-Assessment Inventory of the Strength of Workforce Partnerships: Institutions of Higher Education

Partnership Activity I: ***Structured Partnership with Local Employers, as Reflected by a Strong Commitment from University Administrators and Faculty***
Strong Connections

- Strong support from and active engagement with the business community, with a concrete set of goals/outcomes that are measured and updated regularly.
- Department budgets within the university are dedicated to formal partnership activities—and include funding for outreach, student work-based learning, and faculty exchange.
- Collection, analysis, and sharing of data on projected workforce needs (and identification of the competitive economic advantages in the region) to map out an action plan involving local employers, universities, government agencies, and intermediaries to undertake a local economic development strategy.
- Formal work-based learning programs for students and faculty are pursued and created in close collaboration with local employers.

Moderate Connections

- Occasional announcements, memos, or events that attempt to spark interest in stronger collaboration with local/regional employers.
- Ad hoc arrangements between a few departments and a few local employers, but with little focus on formal collaboration and the development of formal work-based learning programs for students and faculty.
- Some analysis of graduation and job placement data, but little or no effort to connect the data to local economic development conditions.
- Occasional opportunities for faculty employment in local businesses.

Weak Connections

- Lack of institutional support from high-level administrators (provost, dean, department chairs).
- Infrequent engagement between university faculty and local business executives and/or employees.
- No plan—formal or informal—for collaboration with local employers.
- Inadequate or no data on STEM graduation rates, job placement information, or the value of the institution's contributions to the local economy.
- The local university is not widely viewed as having an integral and sustained role in the local economic development strategy and the local "STEM workforce development ecosystem."

Comment: Such a partnership can be initiated from the highest levels (e.g., university president) or launched by faculty and/or department chairs. The key is to get buy-in promptly across all levels of the campus administration regardless of where the initial trigger occurs—and to ensure that funds are set aside to support partnership activities, especially those involving student work-based learning and faculty exchange programs.

Partnership Activity II: ***Designated Individual(s) Appointed to Serve as an Initial and Sustained Point of Contact with Local Employers***

Strong Connections

- Designated faculty or administrator appointee(s) within a college or department; the appointee(s) compensated for this extraordinary role and a dedicated budget for outreach; high-profile, highly visible role for the individual(s) within the employer community.

Moderate Connections

- Designated faculty or administrator appointee(s) within a college or department, but insufficient authority or incentive to engage with employers, and little accountability.

Weak Connections

- No designated appointee on campus, or a designated appointee who is not active or visible in the local employer community

Comment: The appointees' job descriptions need to be updated to reflect this formal role, and they need to be held accountable for their actions and inactions in the performance review process.

Partnership Activity III ***Active Advisory Board that Includes Broad Representation from Local Employers***

Strong Connections

- Active advisory board that includes a mix of high-level executives and "on-the-ground" workers from local businesses, government agencies, and nonprofit intermediaries; may involve the creation of multiple boards on campus that are embedded in various

departments.
- Possibly cochaired by an employer and a university official.
- A budget for the board's activities—cofunded by both the university and the employers.

Moderate Connections
- Advisory board that meets occasionally, mainly for ceremonial or fundraising purposes—or on an ad hoc basis for specific activities or programs, but without a long-term action plan.
- An advisory board that includes midlevel university administrators and midlevel business executives, but no or few people with high-level authority on campus or in the businesses.

Weak Connections
- No advisory board, or an advisory board that meets infrequently or solely for social occasions.

Comment: The board should hold occasional high-profile events both on campus and in the community to showcase this collaborative partnership. It may create subcommittees that addresses various challenges and needs—for example, updating curricula or lab activities, creating internships and apprenticeships, and creating metrics for measuring the growth (and impact) of the partnership over time.

Partnership Activity IV: ***Employer Input into the Development and Design/Redesign of University STEM Curricula and Labs***

Strong Connections
- Regular meetings of a formal body composed of department or college faculty and local employers with deep knowledge of currency in the STEM fields to examine and evaluate the course curricula and labs.
- Focused on updating and enhancing the curricula and labs to reflect current knowledge and research.
- Joint development of project-based learning experiences in curricula and labs.

Moderate Connections
- Ad hoc relationships in which some individual faculty members and some employers meet regularly to consider updating course curricula or labs.
- Appointment of a study group or task force (including both faculty and local business people) to periodically review the curricula and lab experiences of students and provide general input and advice.
- Insufficient reliance on research and data to drive the updating of labs and curricula and making them current.

Weak Connections
- No employer/industry input into course curricula and labs.

Comment: There are many opportunities for local employers to influence the process of updating and strengthening curricula and labs. Faculty exchange programs and programs whereby employers serve as visiting instructors and/or mentors to faculty are an important and valued activity. But more formal efforts that rely on deep examination of the research on latest advances in the disciplines and in the work-based practices can yield more evidence-based means of updating and strengthening course curricula and labs.

Partnership Activity V: ***Faculty Appointments in Industry/Employer Sites for Short-term Periods***

Strong Connections

- Multiple, customized arrangements whereby faculty spend a few weeks, a summer, or a semester in a paid "detail" to a local industry or government agency employer.
- Faculty receive real-time, supervised experience in the work setting or the lab learning and experiencing the latest developments in the field and understanding the knowledge, skills, and attitudes that their own students will need to develop in order to be prepared for STEM careers.

Moderate Connections

- Ad hoc relationships with employers that enable faculty to gain some experiences in industry settings, for example, for a day, a few weeks, or a summer.
- Occasional exchanges between faculty and local employers whereby the faculty spends a day or two in a local business setting (or lab) and a business person delivers lectures or leads lab work on campus.

Weak Connections

- No faculty engaged in an active and meaningful way with local STEM employers—even informally.

Comment: The aforementioned faculty-employer exchanges can be valuable, particularly when the exchanges are systematic and structured, with faculty spending a dedicated set of time in the business/government worksite (and are supervised and mentored), and business/government employees spend a significant amount of time on campus as instructors, project leaders, mentors, and so forth.

Partnership Activity VI: ***Apprenticeships and Internships for Students***

Strong Connections

- Multiple formal apprenticeships, internships, and other work-based experiences for students in local industries or government worksites—preferably for pay.
- Such work-based learning experiences have these three characteristics: (1) a formal agreement between the employer, the university, and the students on the term of appointment, work requirements, and compensation; (2) a meaningful employment experience that advances the student's learning and supports the mission and business plan of the employer; (3) a formal evaluation of the student's performance and of the structure of the relationship, both during the term of the appointment and at the end of the experience.

Moderate Connections

- Few opportunities for internships and apprenticeships for students; unstructured and not-well-supervised experiences for students that are not directly linked to course curricula and labs.
- No mentors or weak mentor relationships for the students.

Weak Connections

- No or very few formal apprenticeships or internships.

Comment: The opportunity for more work-based learning was frequently cited by our workshop participants as among the highest priorities for developing the well-prepared workforce for the 21st century in STEM fields.

Even on those occasions in which there are not enough slots for paid internships and fellowships among local employers, university faculty and administrators can engage with employers to create simulated work-based learning experiences on campus—giving students exposure to real work challenges even without spending time in an employer setting.

Partnership Activity VII: ***Joint University/Industry Focus on the Development of Employability Skills or Professional Skills of Students and Workers***

Strong Connections

- Active efforts to involve local employers in campus-based project learning and real-world problem solving that encourages students to work collaboratively and that fosters creativity, strong communication skills, and critical thinking.

Moderate Connections

- Occasional discussions with employers about the relevance of employability skills in the workforce and the need to introduce these skills into regular campus-based experiences.

Weak Connections

- No efforts to extend learning beyond basic STEM knowledge and skills development in a meaningful and sustained way—in a manner that better reflects the realities of the 21st century workplace.

Comment: This is related to the topic above focused on more collaboration between industry and universities in constructing more real-world, "grand challenges" types of learning experiences for students.

BOX 5-3 Initial Framework for a Self-Assessment Inventory of the Strength of Workforce Partnerships: with Local Employers—Businesses, Nonprofits, Government Agencies

Partnership Activity I: ***Structured Partnership with Local Universities, as Reflected by a Strong Commitment from All Levels of the Employer—Starting with the CEO***

Strong Connections

- Strong statements and actions of support for partnerships with local universities from the CEO—and active roles for the CEO, senior executives, and line staff in collaborative programs with one or more local universities.
- Includes regular and frequent interactions about strategies to align the curricula, labs, and programs on campus with the current and future workforce needs of the employer.
- Characterized by a formal, joint effort to use data on current/projected workforce needs (and identification of the competitive economic advantages in the region).

Moderate Connections

- Infrequent announcements, memos, or events that attempt to engage local universities in collaborative efforts.
- Creation of a committee or board charged with developing stronger ties to the higher education community—but lacking in sufficient follow-through and not designated as a high priority.
- Providing modest grants to support equipment or facility purchases, but little engagement beyond financial contributions.

Weak Connections

- Only occasional (or no) engagement with local universities, and no formal plans and procedures to work jointly with local higher education institutions.

Comment: An important element of this is *sustaining* the engagement. Too often there is an initial burst of energy around the design and execution of a formal partnership—which might include a public signing ceremony. But the key is a sustained collaboration that includes regular discussion on how to align campus experiences for students and faculty with employer workforce needs and opportunities.

Partnership Activity II: ***Designated Individual(s) Appointed to Serve as an Initial and Sustained Point of Contact with Local Universities***

Strong Connections

- Designated senior executive within the company or organization who has direct ties to the CEO and is an active partner with university administrators, faculty, and students.
- The designee has a high-profile, highly visible role within the STEM (and other) departments and colleges on campus as an advisor, facilitator, and program implementer.

Moderate Connections

- Designated appointee(s) who have little overall organizational authority (although may have authority or influence within a unit or division of the industry).
- Occasional contact with university faculty or officials, often for ceremonial events, but rarely for the purposes of helping inform university programs based on regional workforce priorities and needs.

Weak Connections

- No designated appointee, or a designated appointee who is not active or visible in the campus community.

Comment: The senior executive appointees' job descriptions should be updated to reflect this formal role, and they should be held accountable for their actions and inactions in the performance

review process. Their presence on campus should be regular and frequent—and should involve meaningful engagement in curriculum design and program redesign.

Partnership Activity III: ***Employer Input into the Development and Design/Redesign of University STEM Curricula and Labs***

Strong Connections

- Regular meetings of a formal body composed of local employer officers and line workers (including mainly STEM workers and managers) as well as department or college faculty.
- Joint development of more project-based learning experiences in course curricula and labs that reflect interdisciplinary, convergence, team science, and other real-world models of STEM disciplines.

Moderate Connections

- Occasional input into curricula and/or labs on campus.
- Participation in a study group or task force (including both employers' staff and executives and university faculty) to periodically review the curricula and lab experiences of students and provide general input and advice.

Weak Connections

- No employer/industry input into course curricula and labs.

Comment: Employers need to manage intellectual property and proprietary information carefully, and may need a formal, legal agreement with university officials that addresses how to handle the exchange of such information. Intellectual property issues can become a roadblock to strong collaboration and therefore should be addressed early in the relationship.

Partnership Activity IV: ***Employer Manager and Staff Appointments as Visiting Instructors, Adjunct Faculty, or Occasional Lecturers***

Strong Connections

- Multiple, customized arrangements whereby employers' managers and staff spend a few weeks, a summer, or a semester in a paid instructional and researcher role on campus—or at his/her worksite, but involving students and faculty.
- Courses and labs led by these employer staff on campus are offered for credit and bring to bear new knowledge about disciplines, provide students and faculty with exposure to new skill sets, and support team-based and project-based learning in a way that reflects the real world of work.

Moderate Connections

- Employers appointed as faculty or lecturers on occasion, but little opportunity for a systemic, sustained change in the way courses are taught or labs are designed.
- Ad hoc or infrequent exchanges between faculty and local employers whereby the faculty spends a day or two in a local business setting (or lab) and a business person delivers a few lectures or leads some lab work on campus.

Weak Connections

- No employers engaged in an active and meaningful role as instructors.

Comment: The aforementioned faculty-employer exchanges can be valuable, particularly when the exchanges are systematic and structured, with faculty spending a dedicated set of time in the business/government worksite (and are supervised and mentored), and business/government employees spend a significant amount of time on campus as instructors, project leaders, mentors, and so forth.

Partnership Activity V: ***Apprenticeships and Internships for Students***

Strong Connections

- Employers, recognizing the value and benefit of work-based learning experiences for undergraduate and graduate students, create multiple formal apprenticeships, internships, and other experiences for students in their worksites—preferably for pay.

Moderate Connections

- Some internships, unpaid or paid, but without significant structure or oversight that aligns with students' academic and career goals, and without a formal plan that enhances and updates the arrangements based on changing workforce needs.

Weak Connections

- No and very few formal apprenticeships or internships.

Comment: The opportunity for more work-based learning was frequently cited by our workshop participants as among the highest priorities for preparing the well-prepared workforce of the 21st century in STEM fields.

Partnership Activity VI: ***Joint University/Industry Focus on the Development of Employability Skills or Professional Skills of Students and Workers***

Strong Connections

- Active efforts by local employers to create and implement campus-based project learning and real-world problem solving that encourages students to work collaboratively and that fosters creativity, strong communication skills, and critical thinking.
- Sponsorship of programs or competitions (e.g., such as robotics contest or "Maker-Movement" activities whereby students are invited to work as teams to solve real-world problems in the workplace and present their findings to panels of employer managers and staff.

Moderate Connections

- Occasional visits by employers to campuses to deliver lectures or workshops on the importance of employability skills to workplace success.
- Some efforts to provide information and advice to students on the employability skills they will be expected to bring to the workplace. But the activities are in the form of information sharing, lecturing, or handouts that describe those skills but do not necessarily give students an experiential learning opportunity to practice them.

Weak Connections

- No efforts by employers to engage students and faculty in an understanding of the need to extend learning beyond basic STEM knowledge and skills development in a meaningful and sustained way—in a manner that better reflects the realities of the 21st century workplace.

Comment: This is related to the topic above focused on more collaboration between industry and universities in constructing more real-world, "grand challenges" types of learning experiences for students.

Appendixes

Appendix A
Biographical Information of Committee and Staff

COCHAIRS

RICHARD CELESTE is president emeritus of Colorado College. Mr. Celeste served two terms as governor of Ohio, from 1982 to 1990, and previously as lieutenant governor of Ohio. He also served as managing partner of Celeste and Sabety Ltd., an economic development consultancy, director of the U.S. Peace Corps, and from 1997 to 2001 was the U.S. ambassador to India. Mr. Celeste is a lifetime National Associate of the National Academies. He formerly served on the boards of the North American Advisory Board for BP Oil, the Secretary of Energy's Advisory Board, Navistar International, Republic Engineered Steels, the Carnegie Corporation of New York, the American Council on Education, and the National Association of Independent Colleges and Universities. He also cochaired the Pacific Council's International Policy Task Force for Study on India. Mr. Celeste earned his B.A. in history from Yale University and studied as a Rhodes Scholar at Oxford University.

TERESA SULLIVAN is the University of Virginia's (UVA) eighth president. Since taking office in 2010, she has led UVA through a period of significant progress. In fall 2012, she launched a planning effort to provide a roadmap for the university's future, while gathering input from 10,000 alumni, parents, students, faculty, staff, and others. This effort produced a new strategic plan for the university, the Cornerstone Plan. President Sullivan developed a new financial model for the university to ensure stability and transparency and to spur innovation in a period of significant financial pressure in higher education. President Sullivan is a respected scholar in labor force demography. The author or coauthor of six books and many scholarly articles, her most recent research has focused on measuring productivity in higher education. President Sullivan came to UVA from the University of Michigan, where she was provost and executive vice president for academic affairs. Prior to her work at Michigan, Dr. Sullivan was executive vice chancellor for academic affairs for the University of Texas System from 2002 until May 2006. She served as a faculty member at the University of Texas at Austin from 1981 to 2006. She is a graduate of Michigan State University's James Madison College, and earned her doctoral degree in sociology from the University of Chicago.

MEMBERS

RITA COLWELL is distinguished university professor both at the University of Maryland, College Park, and at Johns Hopkins University Bloomberg School of Public Health; senior advisor and chairman emeritus, Canon U.S. Life Sciences, Inc.; and president and chief executive officer of CosmosID, Inc. Her interests are focused on global infectious diseases, water, and health, and she is currently developing an international network to address emerging infectious diseases and water issues, including safe drinking water for both the developed and developing world. Dr. Colwell served as the 11th director of the National Science Foundation (NSF), 1998–2004. In her capacity as NSF director, she served as

cochair of the Committee on Science of the National Science and Technology Council. Dr. Colwell has held many advisory positions in the U.S. government, nonprofit science policy organizations, and private foundations, as well as in the international scientific research community. She is a nationally respected scientist and educator, and has authored or coauthored 17 books and more than 750 scientific publications. She produced the award-winning film *Invisible Seas*, and has served on editorial boards of numerous scientific journals. Before going to NSF, Dr. Colwell was president of the University of Maryland Biotechnology Institute and professor of microbiology and biotechnology at the University of Maryland. She was also a member of the National Science Board from 1984 to 1990. Dr. Colwell has previously served as chairman of the board of governors of the American Academy of Microbiology and also as president of the American Association for the Advancement of Science, the Washington Academy of Sciences, the American Society for Microbiology, the Sigma Xi National Science Honorary Society, and the International Union of Microbiological Societies. She is a member of the National Academy of Sciences; the Royal Swedish Academy of Sciences, Stockholm; the Royal Society of Canada; the American Academy of Arts and Sciences; and the American Philosophical Society. She is immediate past president of the American Institute of Biological Sciences. Dr. Colwell has also been awarded 55 honorary degrees from institutions of higher education and received numerous awards. Born in Beverly, Massachusetts, Dr. Colwell holds a B.S. in bacteriology and an M.S. in genetics from Purdue University, and a Ph.D. in oceanography from the University of Washington.

BRIAN FITZGERALD is the Business-Higher Education Forum's (BHEF) chief executive officer, developing long-term strategy for the membership organization. Under Dr. Fitzgerald's leadership, BHEF's National Higher Education and Workforce Initiative (HEWI) has emerged as the organization's signature enterprise. Through the collaboration of its business and academic members, the HEWI includes regional projects focused on strategic business–higher education partnerships in regions across the country, as well as on a national initiative that disseminates the learning from the projects and scale-effective practices. The initiative deploys a model of strategic business engagement in higher education to address members' high-skill, high-priority workforce needs. Prior to joining BHEF, Dr. Fitzgerald served as staff director for the federal Advisory Committee on Student Financial Assistance, which advises Congress on higher education and student aid policy. Dr. Fitzgerald has written extensively on policies to improve college access and success. He also served as an adjunct associate professor of government at American University, teaching advanced studies courses on the politics of education. In the private sector, Dr. Fitzgerald held senior project management positions for large-scale education research projects for federal agencies. Earlier in his career, he served as assistant dean and as a lecturer in education at Bates College in Lewiston, Maine. Dr. Fitzgerald earned his master's degree and doctorate from the Harvard Graduate School of Education, where he also served on the alumni council for 4 years and as chairman. He currently serves on the Dean's Leadership Council. He received his bachelor's degree from the Massachusetts College of Liberal Arts, which named him Distinguished Alumnus and awarded him an honorary doctorate in public service.

ELSA GARMIRE is Sydney E Junkins Professor of Engineering Sciences at Dartmouth College, Hanover, New Hampshire. Professor Garmire served as dean of the Thayer School of Engineering at Dartmouth College from 1995 to 1997. Professor Garmire has been elected member of the National Academy of Engineering and the American Academy of Arts and Sciences. She is a fellow of the Institute of Electrical and Electronic Engineers, the Optical Society of America, the American Physical Society, and the Society of Women Engineers. She received the Society of Women Engineers Achievement Award (their highest award), has been a Fulbright Scholar, and was elected an honorary member of Phi Beta Kappa. Dr. Garmire's research has focused on lasers and optics, including optoelectronics, nonlinear optics, optical devices, fiber optics, quantum electronics, device fabrication, and semiconductors. She has held numerous technical consulting appointments in industry and government laboratories. Dr. Garmire has advised government policy makers through service on advisory boards and panels for the Department of Energy, the Air Force, the National Science Foundation, and through the public affairs committees of the American Physical Society and the American Institute of Physics. Most recently, she has served on the Committee on Science, Engineering, and Public Policy of the National Academies. Prior to coming to Dartmouth, Dr. Garmire was William Hogue Professor of Electrical Engineering, professor of physics, and director of the Center for Laser Studies at the University of Southern California. Dr. Garmire received her A.B. in physics at Harvard and her Ph.D. in physics at the Massachusetts Institute of Technology and served on the research staff at the California Institute of Technology for 9 years.

WILLIAM KIRWAN, chancellor emeritus of the University System of Maryland, is a nationally recognized authority on critical issues shaping the higher education landscape. He served as president of Ohio State University for 4 years and president of the University of Maryland, College Park, for 10 years. Prior to his presidency, he was a member of the University of Maryland faculty for 24 years. A respected academic leader, Dr. Kirwan is a sought-after speaker on a wide range of topics, including diversity, access and affordability, cost containment, innovation, higher education's economic impact, academic transformation, and financial aid. Currently, Dr. Kirwan chairs the National Research Council Board on Higher Education and Workforce, chairs the College Board Advocacy and Policy Center Advisory Committee, and cochairs the Knight Commission on Intercollegiate Athletics. He also serves on the Business-Higher Education Forum. In Maryland, Dr. Kirwan is a member of the boards of the Maryland Chamber of Commerce, Greater Baltimore Committee, Economic Alliance of Greater Baltimore, and the Maryland Business Roundtable for Education. In 2013, the U.S. Senate Education Committee named Dr. Kirwan cochair (with Vanderbilt University Chancellor Nicholas Zeppos) of its new Task Force on Government Regulation of Higher Education, and the Association of Governing Boards of Universities and Colleges appointed Chancellor Kirwan to its newly formed National Commission on College and University Board Governance. In 2012, the Maryland Chamber of Commerce presented Dr. Kirwan with its second annual Maryland Public Service Award. In 2010, Dr. Kirwan was appointed to the National Advisory Committee on Institutional Quality and Integrity and was also named chair of the College Board Advocacy and Policy Center Advisory Committee. Dr. Kirwan received his bachelor's degree in mathematics

from the University of Kentucky and his master's and doctoral degrees in mathematics from Rutgers and the State University of New Jersey, in 1962 and 1964, respectively.

SUSAN LAVRAKAS is a consultant to the Aerospace Industries Association (AIA) on STEM education and workforce matters. She served as the director of workforce for the AIA from 2011 to January 2015. In that role, she led AIA's STEM education and workforce development activities. Ms. Lavrakas has more than 40 years' experience in national security affairs. Having studied political science and international affairs, she started her career at the Central Intelligence Agency. She did graduate studies at the University of Southern California, conducted research at the RAND Corporation, and was recruited into the defense industry by the Northrop Grumman Corporation, where she was employed for nearly two decades. From 2003 to 2011, Ms. Lavrakas worked in government relations at BAE Systems. She chaired the AIA Industrial Base and Workforce Committee from 2007 and was also a member of the AIA Workforce Steering Committee from its founding in 2009 until she joined the AIA staff in 2011. She simultaneously served as vice president for legislative liaison of the STEM Workforce Division of the National Defense Industrial Association. Ms. Lavrakas is a member of the board of directors of the National Girls Collaborative, the STEM Equity Pipeline National Advisory Board of the National Alliance for Partnerships in Equity, the board of trustees of the Center for Excellence in Education, the board of directors of the Arts Council of Fairfax County (Virginia), the board of directors of the National Coalition for Aviation and Space Education, and the Education Committee at the Wolf Trap Foundation.

MARY WRIGHT is the senior program director of demand side engagement and analytics at Jobs for the Future (JFF) and directs JFF initiatives that help low-skilled adults move into and through postsecondary education and on to careers that pay family-sustaining wages. One such initiative is Credentials That Work, which seeks to utilize innovations in the collection and use of real-time labor market information to better align investments in education and training with the needs of the economy. Ms. Wright has more than 20 years of experience in municipal finance, government affairs, and workforce development. Before joining JFF, she served as director at the Conference Board in New York City, driving its work in workforce readiness, business, and education partnerships, as well as improving the employment outcomes for people with disabilities through research and convenings. During her tenure at the Conference Board, she also served on the boards of three Boston-area nonprofits that support educational opportunities for underrepresented youth, housing options for low-income families, and the arts. Ms. Wright has an M.B.A. in public/nonprofit management from Columbia University and a bachelor's degree in urban affairs from Connecticut College.

STAFF

ELIZABETH (LIBBY) O'HARE, Ph.D., is a program officer with the Board on Higher Education and Workforce at the National Academies of Sciences, Engineering, and Medicine. Her current portfolio includes projects that address STEM workforce development, the competitiveness of American research universities, and the higher education regulatory environment. Prior to joining the Academies, she served as a

legislative assistant for Representative Rush Holt (NJ-12), where she handled energy, science, and education policy issues and staffed Rep. Holt in his role as the senior Democrat on the Energy and Mineral Resources Subcommittee, House Committee on Natural Resources. Dr. O'Hare got her start in science policy after being selected by the Society for Research in Child Development as a 2010 American Association for the Advancement of Science Congressional Science Policy fellow. She holds a Ph.D. in neuroscience from the University of California, Los Angeles, and an A.B. in psychology from Bryn Mawr College.

TOM RUDIN is the director of the Board on Higher Education and Workforce at the National Academies of Sciences, Engineering, and Medicine—a position he assumed in mid-August 2014. Prior to joining the Academies, Mr. Rudin served as senior vice president for career readiness and senior vice president for advocacy, government relations and development, at the College Board from 2006 to 2014. He was also vice president for government relations from 2004 to 2006 and executive director of grants planning and management from 1996 to 2004 at the College Board. Before joining the College Board, Mr. Rudin was a policy analyst at the National Institutes of Health in Bethesda, Maryland. In 1991, Mr. Rudin taught courses in U.S. public policy, human rights, and organizational management as a visiting instructor at the Middle East Technical University in Ankara, Turkey. In the early 1980s, he directed the work of the Governor's Task Force on Science and Technology for North Carolina Governor James B. Hunt, Jr., where he was involved in several new state initiatives, such as the North Carolina Biotechnology Center and the North Carolina School of Science and Mathematics. He received a B.A. degree from Purdue University, and he holds master's degrees in public administration and in social work from the University of North Carolina at Chapel Hill.

NINA BOSTON is a research associate in the Policy and Global Affairs Division at the National Academies of Sciences, Engineering, and Medicine. Ms. Boston supports the Board on Higher Education and Workforce, the InterAcademy Council, and Development, Security, and Cooperation. She earned her B.A. in anthropology at Elon University and is currently pursuing her M.P.P. at the University of Maryland School of Public Policy.

IRENE NGUN is a research associate with the Board on Higher Education and Workforce at the National Academies of Sciences, Engineering, and Medicine. Before joining the National Academies, Ms. Ngun was a congressional intern with the House Science, Space, and Technology Committee's Democratic Office and also served the office of her district congresswoman, Ms. Eddie Bernice Johnson (TX-30). Ms. Ngun holds an M.A. in international relations from Yonsei Graduate School of International Studies and a B.A. in biochemistry and economics from Goshen College.

Appendix B
Committee Meeting Agendas

MEETING 1
WASHINGTON, DC
SEPTEMBER 23-24, 2014

WEDNESDAY, SEPTEMBER 23, 2014

CLOSED IN ITS ENTIRETY

THURSDAY, SEPTEMBER 24, 2014

CLOSED SESSION 8:15 – 9:45 AM

OPEN SESSION

10:00 **Welcome and Overview of the Meeting**
Cochair: Terry Sullivan, University of Virginia
Cochair: Dick Celeste, Colorado College

10:05 **Discussion of the Study Charge with the Sponsor**
Speaker: Ryan Kelsey, Helmsley Charitable Trust

10:35 **Project Context**
Speakers:
Kevin Eagan, UCLA Higher Education Research Institute
Nicole Smith, Georgetown University Center on Education and the Workforce
Matthew Hora, Wisconsin Center for Education Research
Jason Owen Smith, University of Michigan

12:15 Continued Discussion with Speakers (lunch is served)

12:45 **Perspective from Industry**
Speakers:
Regina Schofield, Corporate Engagement & Education Outreach, Battelle
Vernon Ross, Jr., STEM, Generations, and Higher Education, Lockheed Martin
Gayle Gibson, Engineering, DuPont (WebEx)

2:15 Break

CLOSED SESSION 2:30 PM – 5:30 PM

MEETING 2
WASHINGTON, DC
SEPTEMBER 30 – OCTOBER 1, 2015

MEETING CLOSED IN ITS ENTIRETY.

Appendix C
Regional Workshop Agendas and Participants Lists

REGIONAL WORKSHOP 1

PHOENIX, ARIZONA

ARIZONA STATE UNIVERSITY
BIODESIGN INSTITUTE
727 E. TYLER ST, TEMPE, AZ

JANUARY 22-23, 2015

THURSDAY, JANUARY 22, 2015

3:30 **Registration**

4:00 **SESSION I: Welcome and Orientation**
Sethuraman "Panch" Panchanathan, Arizona State University

4:10 **Overview of the National Research Council and its Study on Improving Higher Education's Responsiveness to STEM Workforce Needs**
Dick Celeste, Study Cochair and Former Governor of Ohio

4:30 **SESSION II: Phoenix's STEM Economy**
STEM Degree Production and Effectiveness
Kevin Eagan, UCLA Higher Education Research Institute

5:00 Perspectives from the Labor Market
Lois Joy, Senior Project Manager, Jobs for the Future

5:30 **Discussant Responses**
Chris Camacho, Interim President, Greater Phoenix Economic Council
Jaime Casap, Global Education Evangelist, Google

6:00 **Reception for Attendees**
A tour of the Biodesign Institute will be available during the reception.

FRIDAY, JANUARY 23, 2015

8:00 **Breakfast available**

8:15 **SESSION III: Address from President Michael Crow**
President, Arizona State University

8:45 **SESSION IV: Existing Policies and Practices for STEM Workforce Development**
What policies and practices are used by Phoenix area educational institutions and employers to identify the knowledge, skills, and competencies required by local businesses? How do educators and employers initiate, develop, and sustain effective STEM workforce development partnerships that ensure that 2-year and 4-year graduates possess those attributes upon entry into the workforce?

Moderator: Brian Fitzgerald, Study Committee Member and CEO, Business-Higher Education Forum

Panelists:
- Cathleen Barton, Education Manager, Intel Arizona
- Randy Kimmens, Associate Vice Chancellor for Workforce Development, Maricopa County Community College District
- Tammy McLeod, Vice President, Energy Resource Management, Arizona Public Service Company
- Sethuraman "Panch" Panchanathan, Senior Vice President of the Office of Knowledge Enterprise Development, Arizona State University

10:15 **Break**

10:30 **SESSION V: Barriers and Opportunities to Creating Effective Partnerships**
What barriers exist to creating the appropriate conditions for effective workforce development partnerships and what are potential opportunities to overcome these barriers?

Moderator: Elsa Garmire, Study Committee Member and Sydney E. Junkins Professor of Engineering, Dartmouth College

Panelists:
- Mara Aspinall, Member, Board of Directors, Science Foundation Arizona
- Carlos Castillo-Chavez, Regents Professor and Director, Mathematical, Computational, and Modeling Sciences Center, Arizona State University
- Michael Mobley, Executive Director, Center for Integrated Science, Engineering, and Technology, Grand Canyon University
- Mitzi Montoya, Vice President and University Dean for Entrepreneurship and Innovation, Arizona State University

12:00 Lunch available

1:00 **SESSION VI: Fostering Improved Partnerships**
What specific actions, programs, or frameworks are needed to assist Phoenix's educational institutions, employers, and policy makers in fostering improved linkages between educational resources and STEM workforce needs?

Moderator: Susan Lavrakas, Study Committee Member and Consultant, Workforce, Aerospace Industries Association

Panelists:
- Rosalyn Boxer, Vice President, Workforce, Arizona Commerce Authority
- Dave Cano, Senior Engineering Manager, Medtronic
- Paul Johnson, Dean, Ira A. Fulton Schools of Engineering, Arizona State University
- Heather Weber, Dean Occupational Education, Estrella Mountain Community College

2:30 **Break**

2:45 **SESSION VII: Working Group Sessions (concurrent)**
In small group discussions, attendees will generate responses to the following questions: What are specific programs and processes now in place—and what are those that need to be put into place in the near future—to ensure that the knowledge, skills, and competencies of STEM graduates from Phoenix-area colleges and universities (2-year and 4-year) align with the workforce skills needed by Phoenix-area employers?
Locations: Biodesign B205A; ISTB4, rooms 492 and 692

4:00 **Working Groups Report (reconvene in meeting room)**

4:30 **General Discussion**

5:00 **Adjourn**

PHOENIX PARTICIPANT LIST

First Name	Last Name	Affiliation
Michelle	Amado	FSM Training Program Manager, Intel Corporation
Ron	Askin	Director, School of Computing, Informatics, and Decision Systems Engineering, Arizona State University
Mara	Aspinall	Science Foundation Arizona
Jeffrey	Banner	Assistant Director, College of Liberal Arts and Sciences, Arizona State University
Cathleen	Barton	Education Manager, Intel Arizona
Kristin	Bennes	Program Advisor, Glendale Community College
Peter	Bennett	Physics Department Chair, Arizona State University
Al	Boggess	Director, School of Mathematical and Statistical Sciences, Arizona State University
Rosalyn	Boxer	Vice President, Workforce Development, Arizona Commerce Authority
Samantha	Brunhaver	Assistant Professor of Engineering, Arizona State University
Chris	Camacho	Greater Phoenix Economic Council
Dave	Cano	Senior Engineering Manager, Medtronic
Jaime	Casap	Global Education Evangelist, Google
Jennifer	Cason	Director, Graduate Education Student Support Initiatives, Arizona State University
Carlos	Castillo-Chavez	Regents Professor, Arizona State University
Michael	Crow	President, Arizona State University
Gerry	Deren	Executive Director, Business Development & Consulting, Siemens
Hansa	Done	Graduate Research Associate – Environmental Security, Biodesign Institute, Arizona State University
Seth	Dyson	Maricopa County Community College District

Julie	Engel	Greater Yuma Economic Development Corp
Denise	Eribes	Microchip Senior Academic Marketing Engineer
Faye	Farmer	Office of Knowledge Enterprise Development, Arizona State University
Katie	Fischer	Director, Legal and Federal Affairs, Arizona Chamber of Commerce and Industry
Carol	Glaub	Associate Director, Research Operations, Biodesign Institute, Arizona State University
Everett	Greenli	Arizona Council of Engineering and Science Associations
Angie	Harmon	Social Investment Manager, Freeport MacMoRan
Lisa	Herrmann	Consultant, Science Foundation Arizona
Jacqueline	Hettel	Assistant Director ASU IHR Nexus Lab, Arizona State University
Maureen	Howell	Senior Economic Analyst, Greater Phoenix Economic Council
Jane	Jackson	Codirector, Modeling Instruction Program, Physics Department, Arizona State University
Bert	Jacobs	Interim Director, School of Life Sciences, Arizona State University
Usha	Jagannathan	Internet Technology Lecturer, Arizona State University
Paul	Johnson	Dean, Ira A. Fulton Schools of Engineering, Arizona State University
Lois	Joy	Senior Program Manager, Jobs for the Future
Ken	Kay	Chief Executive Officer, Edleader21
Ryan	Kelsey	Helmsley Charitable Trust
Randy	Kimmens	Maricopa County Community College District
Amy	Landis	Associate Professor, Arizona State University Ira A. Fulton Schools of Engineering
Rachel	Levinson	Director, National Research Initiatives, Arizona State University

Cecilia	Mancero	STRATCO, Inc.
Tom	McCarthy	Vice President, Engineering , TJM Electronics
Ann	McKenna	Professor and Director, The Polytechnic School, Arizona State University
Tammy	McLeod	Arizona Public Service
Beth	McMullen	Vice President, Global Information Systems, Avnet, Inc.
Jose	Mendez	Professor of Economics, Arizona State University
Geri	Mingura	Arizona Public Service, Strategic Workforce Development Partnerships & Pipelines
Mike	Mobley	Grand Canyon University
Mitzi	Montoya	Vice President and University Dean, Arizona State University
Tsafrir	Mor	Associate Professor, School of Life Sciences and Biodesign Institute, Arizona State University
Sethuraman	Panchanathan	Senior Vice President, Arizona State University
Marla	Parker	Postdoctoral Research Assistant, Center for Organization Research and Design, School of Public Affairs, Arizona State University
Mehul	Patel	Proposal Manager, Office of Knowledge Enterprise Development, Arizona State University
Sara	Pennak	Director of Program Development, Department of Psychology, Arizona State University
Bill	Petuskey	Associate Vice President, Arizona State University
Kevin Reinhart	Reinhart	Director, Project Management Office, Office of Knowledge Enterprise Development, Arizona State University
Blake	Sacha	Encore Fellow, Science Foundation Arizona
Thomas	Schildgen	Professor, Polytechnic School, School of Engineering, Arizona State University
Ron	Schott	Arizona Technology Council
Steven	Semken	Associate Professor, School of Earth and Space

		Exploration, Arizona State University
Jon	Sherbeck	Assistant Research Technologist, School for Engineering of Matter, Transport & Energy, Arizona State University
Jennifer	Sniegowski	Lecturer, Arizona State University
Bill	Storie	Asset Management, Siemens
Caroline	VanIngen-Dunn	Science Foundation Arizona
Kurt	VanLehn	Professor, School of Computing, Informatics, and Decision Systems Engineering, Arizona State University
Gustavo	Ventura	Chair, Department of Economics, Arizona State University
James	Voska	Career Coach, Yavapai College
Elieen	Walker	Association of University Research Parks
Andrew	Webber	Vice Provost, Graduate Education, Arizona State University
Heather	Weber	Estrella Mountain Community College
Eric	Wertheimer	Associate Vice Provost, Graduate Initiatives, Arizona State University
Derrill	Wolkins	Director, Product Development, Medtronic

REGIONAL MEETING 2
CLEVELAND, OH

OHIO AEROSPACE INSTITUTE
22800 CEDAR POINT ROAD
CLEVELAND, OH 44142
APRIL 1, 2015

WEDNESDAY, APRIL 1, 2015

7:30 **Registration (breakfast available)**

8:30 **SESSION I: Welcome and Orientation**
Mike Heil, President, Ohio Aerospace Institute

8:35 **Overview of the National Research Council and its Study on Improving Higher Education's Responsiveness to STEM Workforce Needs**
Dick Celeste, Study Cochair and former Governor of Ohio

8:45 **SESSION II: Roundtable Discussion of Ohio's STEM Economy**
Moderator: Mary Wright, Study Committee Member and Senior Program Director, Demand Side Engagement and Analytics, Jobs for the Future

Discussants:
Lois Joy, Senior Project Manager, Jobs for the Future
Grace Kilbane, Executive Director, Cleveland/Cuyahoga County Workforce Investment Board
Chris Spence, Principal, New Growth Group

9:45 **SESSION III: Existing Policies and Practices for STEM Workforce Development**
What policies and practices are used by Ohio educational institutions and employers to identify the knowledge, skills, and competencies required by local businesses? How do educators and employers initiate, develop, and sustain effective STEM workforce development partnerships that ensure that 2-year and 4-year graduates possess those attributes upon graduation from college and entry into the workforce?

Moderator: Brian Fitzgerald, Study Committee Member, and CEO, Business-Higher Education Forum

Panelists:
- William (Bud) Baeslack, Provost and Executive Vice President, Case Western Reserve University
- William Gary, Executive Vice President, Workforce and Economic Development Division, Cuyahoga Community College

- Marguerite Group, Medical Director, Center for Health Sciences Education, Cleveland Clinic

11:15 **Break**

11:30 **SESSION IV: Goals/Instructions for Focus Groups and Initial Conversations**

12:00 **Lunch**

1:00 **SESSION V: Fostering Improved Partnerships**
What specific actions, programs, or frameworks are needed to assist Ohio's educational institutions, employers, and policy makers in fostering improved linkages between educational resources and STEM workforce needs?

Moderator: Susan Lavrakas, Study Committee Member, and Consultant, Workforce, Aerospace Industries Association

Panelists:
- Martin Abraham, Interim Provost, Youngstown State University
- Gary Cates, Senior Vice Chancellor, Ohio Board of Regents
- Margot Copeland, Chair and CEO, KeyBank Foundation
- Terri Sandu, Executive Director Workforce Development & Director Entrepreneurship Innovation Institute, Lorain County Community College

2:30 **Break**

2:45 **SESSION VI: Focus Groups**
Through a moderated discussion, attendees will generate responses to the following questions: What are specific programs and processes now in place—and those that need to be put into place in the near future—to ensure that the knowledge, skills, and competencies of STEM graduates from Ohio colleges and universities (2-year and 4-year) align with the workforce skills needed by Ohio employers?

4:15 **Working Groups Report (reconvene in Meeting Room)**

4:45 **General Discussion**

5:15 **Adjourn**

CLEVELAND PARTICIPANT LIST

First Name	Last Name	Affiliation
Jason	Abbott	Director, Resource Development, Cuyahoga Community College
Martin	Abraham	Interim Provost, Youngstown State University
Bud	Baeslack	Provost and Executive Vice President, Case Western Reserve University
Mike	Benzakein	Director, Aerospace and Aviation, Ohio State University
Lisa	Camp	Associate Dean, Strategic Initiatives, Case Western Reserve University
Gary	Cates	Senior Vice Chancellor, Ohio Board of Regents
Andy	Chang	Professor, Youngstown State University
George	Chatzimavroudis	Associate Dean, Washkewicz College of Engineering, Cleveland State University
Margot	Copeland	Chair and Chief Executive Officer, KeyBank Foundation
Mike	Costarell	Professor, Youngstown State University
Judith	Crocker	Executive Director, Workforce and Talent Development, MAGNET
Christopher	Cullis	Professor and Chair of Biology, Case Western Reserve University
Colin	Drummond	Professor and Assistant Chair, Biomedical Engineering, Case Western Reserve University
Julie	Farr	Account Manager, Sales, TimkenSteel
Drew	Ferguson	President, PHASTAR Corporation
Steve	Giangiordano	STEM Advisory Committee Youngstown State University
Carlos	Grodsinsky	Chief Operating Officer, ZIN Technologies
Marguerite	Group, M.D., MBA	Medical Director, Center for Health Sciences

		Education, Cleveland Clinic
Michael	Heil	President, Ohio Aerospace Institute
Michael	Hoag	VP, Workforce Development, WIRE-Net
John	Holcomb	Cleveland State University
Anwarul	Islam	Professor and Chair, Youngstown State University
Mosca	Joseph	Dean, College of Health and Human Services, Youngstown State University
Lois	Joy	Senior Project Manager, Jobs for the Future
Mark	Kankam	University Affairs Officer, NASA Glenn Research Center
Shilpa	Kedar	Program Director, Economic Development, Cleveland Foundation
Kathryn	Kelley	Ohio Manufacturing Institute
Grace	Kilbane	Executive Director, Cleveland/Cuyahoga County Workforce Investment Board
Larry	Knauer	ECCL Aerospace Services Founder
Carol	Lamb	Director, School of Engineering Technology, Youngstown State University
Robert	LaSalvia	Division Chief, Office of Education, NASA Glenn Research Center
Tuwhanna	Lewis	Associate Director, Cleveland Engineering Society
Blaine	Lilly	Associate Professor, Engineering, Ohio State University
John	Mullaney	Executive Director, The Nord Family Foundation
Paul	Penko	Adjunct Professor, Baldwin Wallace University
Debbi	Perkul	Senior Workforce Development Professional, University Hospitals
Terri	Pope	Westshore Campus President, Cuyahoga Community College
Sandi	Preiss	STEM Coordinator, Dayton Regional STEM Center

Alicia	Prieto Langarica	Youngstown State University
Michael	Salkind	Principal, Indus International
Terri Burgess	Sandu	Executive Director, Workforce Development, and Director, Entrepreneurship Innovation Institute, Lorain County Community College
Jenny	Shields	Program Coordinator, Aerospace and Aviation
David	Singer	Professor, Case Western Reserve University
Angela	Spalsbury	Associate Professor and Chair, Department of Mathematics and Statistics, Youngstown State University
Chris	Spence	Principal, New Growth Group
Mark	Sutherland	Vice President, Public Affairs, The Lubrizol Corporation
Mark	Turner	Associate Professor, University of Cincinnati
Andrea	Vullo	Community Relations Manager, GE Lighting
Chad	Watchorn	Executive Director, Regional STEM Collaborative
Monique	Wilson	Executive Director, Cuyahoga Community College Center for IT Training
Lam	Wong	Associate Dean of Engineering, Cuyahoga Community College
Tom	Zorc	Senior Manager, Advanced Steel Technology, Engineering Management

REGIONAL MEETING 3
MONTGOMERY, AL

ALABAMA STATE UNIVERSITY
1055 TULLIBODY DR
MONTGOMERY, AL 36104
MAY 11, 2015

MONDAY, MAY 11, 2015

8:00 **Registration (breakfast available)**

8:30 **Welcome and Orientation**
Leon Wilson, Provost and Vice President for Academic Affairs, Alabama State University

8:35 **Overview of the National Research Council and its Study on Improving Higher Education's Responsiveness to STEM Workforce Needs**
Teresa Sullivan, Study Cochair and President, University of Virginia

8:45 **Alabama's STEM Economy**
This session will review the results of real-time labor market analyses commissioned for the workshop. Panelists will discuss the skills that are most in demand by local and regional employers and the career fields for which Alabama has a competitive advantage.

Moderator: Tom Rudin, Director, Board on Higher Education and Workforce, National Academy of Sciences

Panelists:
Lois Joy, Senior Project Manager, Jobs for the Future
Sheron Rose, Vice President Community Strategies, Montgomery Area Chamber of Commerce
Jim Searcy, Executive Director, Economic Development Association of Alabama

10:00 **Small group discussions and coffee break**

10:30 **Existing Policies and Practices for STEM Workforce Development**
What policies and practices are used by Alabama educational institutions and employers to identify the knowledge, skills, and competencies required by local businesses? How do educators and employers initiate, develop, and sustain effective STEM workforce development partnerships that ensure that 2-year and 4-year graduates possess those attributes upon graduation from college and entry into the workforce?

Moderator: Susan Lavrakas, Study Committee Member, and Consultant, Workforce, Aerospace Industries Association

Panelists:
Legand Burge Jr., Dean, College of Engineering, Tuskegee University
Ed Castile, Director, Alabama Industrial Development Training, Alabama Department of Commerce
Leon Wilson, Provost and Vice President for Academic Affairs, Alabama State University

11:45 **Small group discussions and coffee break**

12:15 **Lunch available**

1:15 **Fostering Improved Partnerships**
What specific actions, programs, or frameworks are needed to assist Alabama's educational institutions, employers, and policy makers in fostering improved linkages between educational resources and STEM workforce needs?

Moderator: Rita Colwell, Study Committee Member and Distinguished University Professor, University of Maryland and Johns Hopkins University

Panelists:
Gene Dudley, Director, Career and Technical Education, Alabama Community College System
Gregory Fitch, Executive Director, Alabama Commission on Higher Education
Melvin Greer, Senior Fellow and Chief Strategist, Lockheed Martin

2:30 **Break into groups**

2:45 **Focus Groups**
Through a facilitated discussion, attendees will generate responses to the following question: What are specific programs and processes now in place—and those that need to be put into place in the near future—to ensure that the knowledge, skills, and competencies of STEM graduates from Alabama colleges and universities (2-year and 4-year) align with the workforce skills needed by Alabama employers?

4:00 **Working Groups Report (reconvene in Meeting Room)**

4:30 **General Discussion**

5:00 **Adjourn**

MONTGOMERY PARTICIPANT LIST

First Name	Last Name	Affiliation
Anthony	Adams	Dean, College of Liberal Arts and Sciences, Alabama State University
Le-Quita	Booth	Dean, College of Business Administration, Alabama State University
Curtis	Brown	Vice President, Sales, Conference America, Inc.
Legand	Burge	Alabama State University
Gisela	Buschle-Diller	Professor, Polymer and Fiber Engineering, Auburn University
Vivian	Carter	Chair, Psychology and Sociology Department, Tuskegee University
Ed	Castile	Director, Alabama Industrial Development Training, Alabama Department of Commerce
Steven	Chesbro	Dean, College of Health Sciences, Alabama State University
Jennifer	Cox	Chemistry Specialist, Alabama Science in Motion
Sue	Cui	Associate Program Officer, Helmsley Charitable Trust
Gene	Dudley	Director of Career and Technical Education, Alabama Community College System
Gregory	Fitch	Executive Director, Alabama State Commission on Higher Education
Michelle	Foster	Associate Professor of Mathematics, Alabama State University
Melvin	Greer	Senior Fellow, Lockheed Martin
Dean	Hendrix	Associate Professor and Undergraduate Program Director, Computer Science and Software Engineering, Auburn University
Jeremy	Hodge	Director of Career Services, Alabama State University

Tommi	Holsenbeck	Physics Specialist, Science in Motion, Alabama State University
Harvey	Hou	Associate Professor, Alabama State University
Yiyun	Jie	Director, Office of Institutional Research, Alabama State University
Cadavious	Jones	Assistant Professor of Mathematics, Alabama State University
Diann	Jordan	Professor of Biology, Alabama State University
Lois	Joy	Senior Project Manager, Jobs for the Future
M. Javed	Khan	Professor, Aerospace Engineering, Tuskegee University
Tiffany	Larcheveaux	Biology Specialist, Alabama Science In Motion
Joe	Majdalani	Professor and Chair, Department of Aerospace Engineering, Auburn University
Manoj	Mishra	Associate Professor of Biology, Alabama State University
Audrey	Napier	Chair, Biological Sciences, Alabama State University
Charles	Nash	Vice Chancellor for Academic and Student Affairs, University of Alabama System
Peter A	Noble	Professor of Microbiology, Alabama State University
Carl	Pettis	Interim Associate Dean, College of Science, Mathematics, and Technology, Alabama State University
Shreekumar	Pillai	Professor of Biology, Department of Biological Sciences, Alabama State University
Constance	Relihan	Associate Provost for Undergraduate Studies, Auburn University
Sheron	Rose	Vice President, Community Strategies, Montgomery Area Chamber of Commerce
Albert	Russell	Associate Professor and Chair, Department of Chemistry
Sabita	Saldanha	Assistant Professor of Biology, Alabama State University
Karyn	Scissum Gunn	Associate Provost for Academic Affairs, Alabama State

		University
Jim	Searcy	Economic Development Association of Alabama
Carolyn	Simmons-Johnson	Associate Professor of Mathematics, Alabama State University
Janet	St. Clair	Professor, Department of Mathematics and Computer Science, Alabama State University
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Roberta	Troy	Director, Tuskegee University Health Disparities Institute for Research and Education
Komal	Vig	Associate Professor of Biology, Alabama State University
Robert	Villafane	Professor of Microbiology, Alabama State University
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Kennedy	Wekesa	Dean, College of Science, Mathematics and Technology, Alabama State University
Olan L.	Wesley	Director of Continuing Education, Alabama State University
Keshia	Williams	Science Teacher, Robert E. Lee High School
Leon	Wilson	Provost and Vice President of Academics, Alabama State University
Hongzhuan	Wu	Associate Professor of Biology, Department of Biological Sciences, Alabama State University
Ralph	Zee	Associate Dean for Research, Auburn University

REGIONAL MEETING 4
LOS ANGELES, CA

CALIFORNIA SCIENCE CENTER
700 EXPOSITION PARK DRIVE
LOS ANGELES, CA 90037
MAY 27, 2015

WEDNESDAY, MAY 27, 2015

8:00 **Registration and continental breakfast**

8:25 **Introduction**

- David Rattray, Executive Vice President, Education & Workforce Development, Los Angeles Area Chamber of Commerce
- Richard Celeste, former Governor of Ohio and Cochair, National Academies Committee on Regional STEM Workforce Development

8:30 **Panel: The STEM Landscape in Southern California**
Facilitator: Kate Yalung, Partnerships and Business Development Outcomes, General Assembly

Panelists:
- Rafael de Anda, Research Project Manager, Beacon Economics
- Sean Arian, Vice President, Innovation & Emerging Technologies, Bixel Exchange
- Chris Rico, Director of Innovation, Los Angeles County Economic Development Corporation
- Richard Verches, Executive Director, Los Angeles County Workforce Investment Board

9:30 **Panel: Education and Industry Partnerships for STEM Education and Workforce Development**
Facilitator: Tom Sayles, Senior Vice President, University Relations, University of Southern California

Panelists
- Albert Alfaro, Retired, Director of Spacecraft Products , Boeing Space & Intelligence Systems
- Ellen Junn, Provost and Vice President of Academic Affairs, California State University Dominguez Hills
- Francisco Rodriguez, Chancellor, Los Angeles Community College District

10:30 **Roundtable Discussions**

Track A: Exploring and Excelling in STEM Careers: Creating equity and increasing diversity in STEM
Facilitator: Gigi Ragusa, Ph.D., Division of Engineering Education, Viterbi School of Engineering, University of Southern California

Track B: Exploring and Excelling in STEM Education: STEM workforce development partnerships
Facilitator: Brian Fitzgerald, CEO, Business-Higher Education Form and Member, National Academies Committee on Regional STEM Workforce Development

11:45 **Roundtable Groups Report Out and General Discussion**

12:15 **Adjourn**

LOS ANGELES PARTICIPANT LIST

First Name	Last Name	Affiliation
Yan	Adutwum	New Designs Educational Group
Patricia	Alarcon	Los Angeles Theatre Academy
Albert	Alfaro	Society of Hispanic Professional Engineers
Tangelia	Alfred	Los Angeles Southwest Community College
Emily	Allen	California State University. Los Angeles
Eugene	Allevato	Woodbury University
Lupe	Alvarado	Great Minds in STEM
Lia	Andika	AAPA
Casper	Andrews	Los Angeles County Office of Education
Sean	Arian	Bixel Exchange
Paula	Arvedson	California State University
Stephanie	August	Loyola Marymount University
David	Bader	Cumming Construction Management, Inc.
Gilbert	Baez	HMC Architects
Elizabeth	Bayne	University of Southern California

Rex	Beaber	University of Wisconsin-Madison
Avery	Bell	Para Los Niños
Matt	Bennett	Teach For America
Jasmine	Berry	University of Southern California
Michele	Biagioni	Los Angeles County Office of Education
Cara	Bibbiani	Encorps STEM Teachers
Joan	Bissell	California State University System
Nina	Boston	National Academy of Sciences
Katya	Bozzi	Star Education
Daphne	Bradford	Mother Of Many
Lena	Bradshaw	ABC Unified School District
Jessica	Carbajal	Tiger Woods Foundation
Raul	Carpio	Los Angeles County Office of Education
Damian	Carroll	Vision To L earn
Dick	Celeste	Colorado College
Pedro	Cevallos	College-Bridge
Lynn	Cevallos	College-Bridge
Gina	Chan	Los Angeles Area Council, Career Exploring, Learning for Life
Martin	Cheeseborough	The Media Aid Center
Weixiang	Chen	NewMet Data
Francis	Cholle	The Human Company
Barbara	Christie	Los Angeles Harbor College
Steven	Cocca	El Camino College
Joseph	Cocozza	University Of Southern California
Edward	Colacion	Los Angeles Unified School District

Marion Jane	Colston	Metro
Katrina	Corbosiero	Teach For America
Lynn	Crandall	University of Southern California
Rachel	Crawford	Bedrock Creek
Andrea	Damian	Swag Promo
Linda	Daniels	Managed Career Solutions
Salomon	Davila	Pasadena City College
Veronica	Dayag	The Children's Center, California Institute of Technology
Rafael	de Anda	Beacon Economics
Sebastian	De Vivo	Managed Career Solutions
Carol	Dedrich	Girl Scouts of Greater Los Angeles
Luminita	Denisiu	University of California, Los Angeles
Bailee	DesRocher	Natural History Museum of Los Angeles County
Lindsay	DeVeny	Loyola Marymount University
Dawn	Digrius	Office of the Chancellor, California State University
Carlos	Donato	Big Brothers Big Sisters of Greater Los Angeles
Heather	Doyle	Heal the Bay
Carrie Lynne	Draper	The Children's Center, California Institute of Technology
Karla	Duarte	Los Angeles County Arts Commission
Imelda	Duenas	Boy Scouts of America
Kevin	Duong	The Durfee Foundation
Ray	Edwards	PNDULUM
Joel	Escobar	LAUSD Sunrise Elementary School
Joel	Escobar	Sunrise Elementary

Allison	Faris	UCLA Anderson School of Management
Lorna	Ferrell	C2Education
Brian	Fitzgerald	Business-Higher Education Forum
Arlene	Flesch	AAA T.L.C. Health Care, Inc.
Gabriela	Flores	Cedars-Sinai Health System
Paco	Flores	City Year Los Angeles
Frank	Flores	Northrop Grumman Corporation
Jennifer	Frank	MENTORS International
Sherri	Franklin	Urban Design Center
Lori	Gage	Hitachi, Ltd., Los Angeles Office
Angela	Gallegos	Loyola Marymount University
Aura	Garcia	AP Group
Daniel	Gentry	Port of Los Angeles
Jesse	Gilbert	Woodbury University
Andy	Glatfelter	Lancaster School District
Scott	Golden	Star Education
Melissa	Gonzales	Roll Global
Tahra	Goraya	ZERO TO THREE, Western Office
Darin	Gray	Los Angeles Unified School District
Lawrence	Gustafson	THINK Together
Rod	Halimi	Challengeastudent.org
Anne Marie	Hand	Girl Scouts of Greater Los Angeles
Leah	Hanes	Trash for Teaching
Bob	Harris	College Bridge
Philip	Hart	Friends of Hollywood Central Park
Brenda	Hernandez	YMCA of Metropolitan Los Angeles

Jim	Herr	California Community Foundation
Cathleen	Hession	The Carol and James Collins Foundation
Jacquelyn	Honore	Los Angeles Job Corps Center
Sonia	Hooks	Los Angeles County
Sonia	Hooks	Los Angeles County
Sonia	Hooks	Los Angeles County
Karelyn	Hoover	Mt. San Antonio College
Rochelle	Howard	Pasadena City College
Michael	Hoy	Pearson Education
Sabrina	Hsu	PVJOBS-Playa Vista Job Opportunities and Business Services
Theresa	Huerta	Raytheon
Leonard	Hyman	Los Angeles Area Chamber of Commerce
Judy	Impiccini	California State University, College of Professional and Global Education
Jo Ann	Isken	UCLA Center X Teacher Education Program
Bill	James	Avery James, Inc.
Michele	James	Avery James, Inc.
Bill	Jason	Sims Recycling Solutions
Bahar	Jeldi	Big Brothers Big Sister of Greater Los Angeles
Matthew	Judd	Mt. San Antonio College
Barbara	Juncosa	Citrus College
Jacob	Kantor	C2 Education Brentwood Center
Michael	Kenny	Garvey School District
Caroline	Kim	Big Brothers Big Sisters of Greater Los Angeles
Amy Hee	Kim	Iridescent
Romi	Kim	Texas Instruments

James	King	College Bridge
Lee Ann	Kline	STEM Advantage
Tina	Koneazny	University of Southern California Joint Educational Project
Philip	LaPolt	California State University, Los Angeles
Suzanne	Larson	Loyola Marymount University
Larry	Lim	University of Southern California
Raymond	Lo	Star Education
Jesse	Lopez	Los Angeles County Office of Education
Adrienne	Luce	HMC Architects, Los Angeles
Anthony	Maddox	University of Southern California
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Pedro	Manrique	DeVry University
Eric	Marinez	California State University, Long Beach
Marvin	Martinez	Office of Workforce Education, East Los Angeles College
Alice	Martini Doyle	Loyola Marymount University
Karin	Matchett	National Academy of Sciences
Beverly	Matthews	The Media Aid Center
Ray	Mawhinney	LaserZone 1, Inc.
Carmen	Mayor	Los Angeles County Metropolitan Transportation Authority
Pat	Means	AltaSea at the Port of Los Angeles
Brittany	Mejia	Los Angeles Chamber of Commerce
Gerald	Melendez	Los Angeles County Office of Education
Katie	Mills	University of Southern California Viterbi School of Engineering
Derrick	Mims	Office of Assemblymember Reggie Jones-Sawyer

Luis	Mora	Beyond the Bell, Los Angeles Unified School District
Marlon	Morales	Liberty Hill Foundation
Wilma	Morales-Franco	I Have A Dream
Makiko	Morduchowicz	Star Education
Patrick	Morris	New Designs Educational Group
Diana	Munoz	ABC Unified School District
Gina	Napolitano	Omni Nano
Imelda	Nava	University of California, Los Angeles
Gregory	Nicholson	Project Tomorrow
Dan	Nieman	Teach For America
Christina	Nigrelli	ZERO TO THREE, Western Office
Elizabeth	O'Hare	National Academy of Sciences
Stela	Oliveira	LA's BEST After School Program
Tonikiaa	Orange	University of California, Los Angeles
Bethany	Orozco	EnCorps STEM Teachers Program
Jorge	Orozco	Para Los Niños
Tara	Pak	Girl Scouts of Greater Los Angeles
Travares	Parker	South Bay Workforce Investment Board
Martha	Pelayo	Society of Hispanic Professional Engineers
Jonathan	Peralez	Challengeastudent.org
Michelle	Perrenoud	Los Angeles County Office of Education
Jeff	Phillips	Loyola Marymount University
Trena	Pitchford	Burbank Arts for All Foundation
Elliot	Ponchick	William C. Bannerman Foundation
Diedra	Porche	JPMorgan Chase Bank, N.A.

Yolande	Porter	Techies2b.org
Julia	Potter	California State University, Northridge
Beverly	Powell	Star Education
Mai	Quach	Los Angeles County Office of Education
Gigi	Ragusa	University of Southern California
Steve	Ramsey	Los Angeles County Metropolitan Transportation Authority
Milton	Randle	Randle Enterprises
Susan	Rhi-Kleinert	Los Angeles Harbor College
Annette	Ricchiazzi	Los Angeles Universal Preschool
Connie	Richardson	AAA T.L.C. Health Care, Inc.
Chris	Rico	Los Angeles County Economic Development Corporation
Kimberly	Rodriguez	City of Los Angeles
Summer	Rogers	South Bay Workforce Investment Board
Carol	Rowe	Specialty Family Foundation
Tom	Rudin	National Academy of Sciences
Cynthia	Ruiz	Loyola Marymount University
Jill	Rutan Hoffman	Looking Skyward
Scott	Sakamoto	Garvey School District
Gail	Scanlan	Los Angeles City College Foundation
Candi	Schreuders	Strafford School
Marta	Segura	Southern California Leadership Network
Monica	Serrano	Water Replenishment District of Southern California
Brandon	Shamim	Beacon Management Group
Jody	Sherman	AAA T.L.C. Health Care, Inc.

Kim	Silverstein	Green Dot Public Schools California
Kristen	Simon	Girl Scouts of Greater Los Angeles
Michael	Sinclair	Bravo Medical Magnet High School
Lisa	Small	Los Angeles Area Chamber of Commerce
Philip	Starr	Managed Career Solutions
Larry	Tash	UNITE-LA, Los Angeles Area Chamber of Commerce
Mary	Taylor	PVJOBS-Playa Vista Job Opportunities and Business Services
Brandon	Thomas	Galileo Learning
Sue	Thotz	Common Sense Education
Scott	Toohey	Farmers Insurance Group of Companies
Tino	Truong	UCLA Extension
Todd	Ullah	Pearson Education
Olman	Valverde	Luna & Glushon
Jennifer	Vasquez	Society of Hispanic Professional Engineers
Viktor	Venson	No Right Brain Left Behind
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Mary	Villa	Los Angeles County Office of Education
Patricia	Villasenor	Human Relations Commission
Angela	von Ruden	American Cancer Society
Michael	Wagner	Pacific Hills School
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Jessica	Wilkerson	AAA T.L.C. Health Care, Inc.
Michael	Williams	World Mentoring Academy

Joe	Womac	Specialty Family Foundation
Marguerite	Womack	Jewish Vocational Service
Susan	Wood	California Institute of Technology
David	Wright	DEWright Inc.
Kat	Yalung	General Assembly
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Shanon	Yu	Los Angeles County Office of Education
Christina	Zeitountsyan	University of Southern California

REGIONAL MEETING 5
FARGO, ND

NORTH DAKOTA STATE UNIVERSITY
1241 NORTH UNIVERSITY DR.,
FARGO, ND 58102
JUNE 30, 2015

TUESDAY, JUNE 30, 2015

8:00 **Registration (breakfast available)**

8:30 **Welcome and Orientation**
Beth Ingram, Provost, North Dakota State University

8:35 **Overview of the National Research Council and its Study on Improving Higher Education's Responsiveness to STEM Workforce Needs**
Teresa Sullivan, Study Cochair and President, University of Virginia

8:45 **North Dakota's STEM Economy**
This session will review the results of real-time labor market analyses commissioned for the workshop. Panelists will discuss the skills that are most in demand by local and regional employers and the career fields for which North Dakota has a competitive advantage.

Moderator: Mary Wright, Study Committee Member and Senior Program Director, Demand Side Engagement and Analytics, Jobs for the Future

Discussants:

- Tifanie Gelinske, Vice President, Workforce Development, Greater Fargo Moorhead Economic Development Corporation
- Lois Joy, Senior Project Manager, Jobs for the Future

9:45 **Break and small group discussions**

10:00 **Existing Policies and Practices for STEM Workforce Development**
What policies and practices do North Dakota educational institutions and employers use to identify the knowledge, skills, and competencies required by local businesses? How do educators and employers initiate, develop, and sustain effective STEM workforce development partnerships that ensure that 2-year and 4-year graduates possess those attributes upon graduation from college and entry into the workforce?
Moderator: Tom Rudin, Director, Board on Higher Education and Workforce, National Academy of Sciences

Panelists:
- Stacey Breuer, Human Resources Manager, Doosan Bobcat Company
- Beth Ingram, Provost, North Dakota State University
- Harvey Link, Vice President, Academic and Student Affairs, North Dakota State College of Science
- Perry Lubbers, Vice President of Manufacturing, Trail King Industries

11:30 **Break and small group discussions**

11:45 **Keynote Remarks**
Don Morton, Site Leader, Microsoft Fargo

12:30 **Lunch**

1:30 **Fostering Improved Partnerships**
What specific actions, programs, or frameworks are needed to assist North Dakota's educational institutions, employers, and policy makers in fostering improved linkages between educational resources and STEM workforce needs?

Moderator: Susan Lavrakas, Study Committee Member, and Consultant, Workforce, Aerospace Industries Association

Panelists:
- Greg Lardy, Associate Vice President for Agricultural Affairs and Head, Department of Animal Sciences, North Dakota State University
- Bob Pawloski, STEM Field Coordinator, University of North Dakota
- Wayde Sick, Director, Workforce Division, North Dakota Department of Commerce

3:00 **Break**

3:15 **Focus Groups**
Through a moderated discussion, attendees will generate responses to the following questions: What are specific programs and processes now in place—and those that need to be put into place in the near future—to ensure that the knowledge, skills, and competencies of STEM graduates from North Dakota colleges and universities (2-year and 4-year) align with the workforce skills needed by North Dakota employers?

4:30 **Working Groups Report (reconvene in Meeting Room)**

4:45 **General Discussion**

5:15 **Adjourn**

FARGO PARTICIPANT LIST

First Name	Last Name	Affiliation
Ryan	Aasheim	Program Manager, North Dakota STEM Network
Houda	Abdelrahman	Student (alumna), North Dakota State University
Nicole	Ashe	Student Recruitment and Outreach Specialist, North Dakota State College of Science
Yong	Bai	Chair and Professor, Construction Management and Engineering Department, North Dakota State University
Sreekala	Bajwa	Department Chair, North Dakota State University
Dilpreet	Bajwa	Associate Professor, North Dakota State University
Barbara	Bang	Dean, North Dakota State University
Cheryl	Bombenger	Elementary Teacher, Fargo Public Schools and TADA (Teaching Activities Done Aesthetically)
Ganesh	Bora	Assistant Professor and Interim-Director, Agricultural and Biosystems Engineering, North Dakota State University
Susan	Bornsen	Assistant Professor, Mathematics and Science, North Dakota State College of Science
Stacey	Breuer	Human Resources Manager, Doosan Bobcat Company

D'Aulan	Bussman	Assistant Principal and Career and Technical Education Director, Mandan High School
Dong	Cao	Assistant Professor, North Dakota State University
Debasis	Dawn	Assistant Professor, North Dakota State University
Beth	Demke	Executive Director, Gateway to Science
Benton	Duncan	Associate Professor and Chair, Department of Mathematics, North Dakota State University
Holly	Erickson	STEM Outreach Coordinator, North Dakota State University
Steve	Erickson	Academic Dean, Minnesota State Community and Technical College
Marcia	Foss	Director, Career Services and Internships, Valley City State University
Carey	Fry	Fargo Job Service Manager, Job Service North Dakota
Tifanie	Gelinske	Vice President, Workforce Development, Greater Fargo Moorhead Economic Development Corp.
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Peder	Gjovik	Chair, Department of Technology and Codirector, Don Mugan Career and Technical Education Leadership Center, Valley City State University
Tony	Grindberg	Manager, Appareo
Greg	Haakenson	Maintenance Superintendent, Minn-Dak Farmers Cooperative
Roger	Haberman	Vice President, Construction, North Dakota State College of Science
Roxann	Hanson	Human Resources Manager, Tecton Products, LLC
Gaylord	Hibl	Machinist Instructor, North Dakota State College of Science
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Jen	Janecek-Hartman	Executive Director, North Dakota Association of Tribal Colleges

Kristi	Jean	Faculty, North Dakota State College of Science
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Gary	Ketterling	Curriculum Coordinator, Great Plains STEM Education Center, Valley City State University
Patty	Kline	Dean of Outreach, North Dakota State College of Science
Dean	Knudson	Associate Professor, North Dakota State University
Jay	Kostelecky	Product Support Manager, Butler Machinery
Joan	Krush	Advisor and Lecturer, North Dakota State University
Nikolas	Kukert	Enrollment Services Specialist, North Dakota State College of Science
Jeff	Kukert	Chair, Mechanical Systems Department, North Dakota State College of Science
Wayne	Kutzer	Director, North Dakota Department of Career and Technical Education
Ron	Lawler	Director, Sanford Health EMS Education and North Dakota State College of Science
Steve	Light	Associate Vice President for Academic Affairs, University of North Dakota
Harvey	Link	Vice President for Academic and Student Affairs, North Dakota State College of Science
Perry	Lubbers	Vice President of Manufacturing Operations, Trail King Industries
Ivan	Maas	Electrical Department Chairman, North Dakota State College of Science
Ronald	Marsh	Associate Professor and Chair, Computer Science Department, University of North Dakota
Sylvio	May	Associate Professor and Chair, Physics, North Dakota State University
Carla	McGarry	Human Resources Representative, Caterpillar Remanufacturing. Drivetrain LLC

Emily	McKay	Director, Great Plains Energy Corridor, and Project Director, TREND Consortium, Bismarck State College
Larry	Merbach	Professor of Mathematics, North Dakota State College of Science
Ashley	Mickelson	Teacher, Northern Cass School
Eric	Murphy	Faculty Advisor, State Board of Higher Education, and Associate Professor, North Dakota University System and University of North Dakota
Rachel	Myhre	Recruiter, KJL Engineering
Nancy	Nelson	Administrative Officer and Recruitment Coordinator, University of North Dakota
Ilene	Odegard	Director, Career Services, University of North Dakota
Martin	Ossowski	Director, Center for Computationally Assisted Science and Technology, North Dakota State University
Connie	Ova	Chief Executive Officer, Jamestown/Stutsman Development Corporation
Ann	Pollert	Career and Technician Developer, General Equipment and Supplies
John	Richman	President, North Dakota State College of Science
Rick	Ross	Career and Technical Education Coordinator, Valley City State University
Richard	Rothaus	Director, Academic Programs, Research, and Accreditation, North Dakota University System
Cathleen	Ruch	Dakota Precision Agriculture Center, Lake Region State College
Trish	Schrom	Dean of Extended Learning, North Dakota State College of Science
Wayde	Sick	Director of Workforce Division, North Dakota Department of Commerce
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Deven	Smith	Administrative Assistant, Jamestown/Stutsman Development Corporation

Ashley	Smoley	University Relationship Representative, Doosan Bobcat Company
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Teather	Sundstrom	Assistant Professor, Valley City State University
Sherm	Syverson	Executive Director, F-M Ambulance Service
Jason	Trainer	Director of Admissions, University of North Dakota
Amber	Unser	Director, Human Resources, Marvin Windows and Doors - Integrity and Tecton Products
Mark	Vaux	Executive Vice President, Partner, Greater Fargo Moorhead Economic Development Corporation
Tori	Weisbeck	Human Resources Specialist, RDO Equipment Co.
Jamie	Wirth	Director, Great Plains STEM Education Center, Valley City State University
Kevin	Wolf	President, Laney's Inc.
Charlene	Wolf-Hall	Vice Provost for Academic Affairs, North Dakota State University
Annie	Wood	Director of Community Programs, Emerging Prairie – The Speaker's Bureau
Takayuki	Yamauchi	Assistant Professor of Mathematics, Valley City State University

Appendix D
Supplemental Material on K-12 Education and Its Role in the Regional STEM Workforce Development Ecosystem

To be eligible and capable to pursue postsecondary science, technology, engineering, and mathematics (STEM) courses and careers, students must receive a strong foundational education in grades K-12. A number of promising practices exist to increase both the numbers of students interested in STEM and the likelihood of their success in higher education and beyond. Workshop participants indicated that K-12 schools, science centers, businesses, collaborative groups, and parents all can play important roles in encouraging students to contemplate STEM educational and career pathways. According to numerous participants, the following practices can increase students' interest in STEM, increase their proficiency in STEM subjects, and expand their understanding of the career opportunities available to them regionally. Of particular interest are practices and programs that reach students from populations traditionally underrepresented in STEM fields to ignite their interest and foster persistence in STEM studies and careers. A recent report highlights the critical role that afterschool programming can play in supporting many of the activities and objectives described below.[1]

Recognition has spread that hands-on, project-based learning is especially effective in engaging K-12 students in STEM subjects. Many companies sponsor extracurricular STEM competitions and programs because they are shown to spark excitement that motivates young people to learn—and enjoy—math and science. Interest and confidence in STEM subjects grows as students explore STEM concepts in the context of solving real challenges. When a 10th grader realizes that she must understand certain mathematical or scientific principles in order to build a robot, she no longer tends to ask how these subjects are relevant to her life or why she needs to study them.

The demonstrated effectiveness of afterschool project-based activities in inspiring student interest and achievement is leading more schools to adopt hands-on learning approaches in the classroom. For example, the Macon County Alabama School District has worked with the Aerospace Science Engineering Department at Tuskegee University, along with faculty from its mathematics and psychology departments, to develop math and science modules for K-12 students using a flight-simulation environment.

Meeting participants discussed how the quality of STEM education can be improved by ensuring K-12 instructors have a firm grounding in STEM disciplines as well as a solid understanding of effective teaching practices for keeping students interested and

[1] Afterschool Alliance (2015). *Full STEM Ahead: Afterschool Programs Step Up as Key Partners in STEM Education*. Washington, DC.

increasing their confidence. California State University Dominguez Hills brings K-12 teachers, particularly from lower-income, underutilized neighborhoods, to campus and trains them in the pedagogy of problem-based learning—real-world problem solving—in their classrooms. In North Dakota, the Department of Public Instruction, the North Dakota Science Teachers, and the North Dakota Council of Teachers of Mathematics held a joint conference in 2014 called Full STEAM Ahead (and in 2015 were joined by the North Dakota STEM Network),[2] bringing together K-12 teachers to explore effective pedagogies for STEM disciplines and the arts. A vice president of the aerospace company Northrop Grumman noted the value of Project Lead the Way, a national nonprofit providing project-based engineering curricula for K-12 students as well as teacher training.[3]

Another critical factor to attract K-12 students into STEM fields is concerted effort to introduce and familiarize them with industries and professions about which many of them have never heard. Young people cannot envision careers—and teachers and parents cannot encourage students to pursue careers—of which they have never heard. Workshop participants spoke to the importance of students, parents, and teachers being exposed widely to the particular STEM-related career opportunities in their region.

For many companies, their sponsorship of and involvement with extracurricular STEM programs provides the venue and vehicle for their executives and employees to interact with students, teachers, and parents. As they volunteer to support student teams, these professionals have the opportunity to serve as role models and mentors to young people who may never have heard about their company or line of work. By sharing information about the corporation and their career path and experiences, the STEM professionals can demystify the educational pathways and excite students, parents, and teachers about career opportunities.

Other special programs and events are designed to accomplish similar objectives. At the Los Angeles regional meeting, the director for Robotics and LEGO for STAR Education described STEAM Nation,[4] a day-long event in Los Angeles County designed to spark students' interest in STEM and the arts and help them see themselves as future innovators; it reaches 2,500 students from underserved, underutilized groups in the region. In an initiative serving teachers desiring to familiarize themselves with industry's needs, the North Dakota Department of Commerce, the Greater Fargo Moorhead Economic Development Corporation, and a faculty member at North Dakota State University formulated a legislative request to expand a pilot program offering teachers a 4-week externship with a local company, focused on STEM. A representative of the Greater Fargo Moorhead Economic Development Corporation described Education That Works, an initiative to educate the community—parents, educators, and business people—about 21st century skills, the value of STEM education, and career opportunities in the region. The economic development organization formed a partnership with local schools and the United Way, and created a video describing, for a variety of industries, what job types are available, what they pay, and what employers look for in new hires.

[2] STEAM is a common acronym for Science, Technology, Engineering, Arts, and Mathematics.
[3] See Project Lead The Way website: https://www.pltw.org/our-programs.
[4] See STEAM National website: http://www.steamnation.org.

Generally speaking, more opportunities need to be created for K-12 students to spend time with STEM professionals including, importantly, women and minorities. Participants emphasized that students particularly need to be introduced to STEM professionals who look like themselves. Potential groups of people to bring into the classroom (or with whom students can be connected digitally) include college and university students, early-career STEM professionals, and retired STEM professionals.

Currently, connections between K-12 teachers and STEM professionals are often made on an ad hoc basis; many people in both sectors are unsure how to locate the right people in the other. Mechanisms are needed to make it easier for teachers to locate STEM professionals and for interested STEM professionals to identify teachers who would welcome a connection with industry. National initiatives like US2020[5] and FabFems[6] are seeking to make those connections easier to achieve, and a number of states have begun more geographically targeted programs.

Other promising mechanisms highlighted by workshop participants included teachers' contacting midlevel STEM professionals through professional societies who may be able to facilitate a visit to the company or be willing to visit the classroom; teachers reaching out to companies via LinkedIn (particularly effective for start-up and technology companies); and using Google Chat or other online platforms to allow groups of students to talk with a STEM professional. Examples offered by workshop participants of organizations or platforms that can play a facilitating role include local school-business partnerships (Montgomery), science centers (e.g., Gateway to Science in Bismarck, North Dakota), and online platforms or databases (such as the North Dakota STEM Exchange).

Finally, participants in the regional workshops expressed the need to strengthen students' transition from high school to college or university. Participants in Cleveland and Montgomery reported that too many bright students interested in STEM careers opt not to attend college or to take advantage of other academic opportunities because they lack a sense of belonging—in STEM or in higher education overall. When students lack support from their families and communities because higher education is not expected or encouraged, K-12 instructors are in a good position to provide the necessary support. Meeting participants in Phoenix, Cleveland, and Montgomery spoke enthusiastically about dual-enrollment programs, in which students simultaneously complete their high school education and take college-level courses for credit. Students begin to experience early success at the college level and increase their familiarity with, and sense of belonging in, college or university campuses and the campus culture.

In Phoenix, a faculty member in mathematics at Arizona State University described a residential, tuition-free math and science honors program serving 80 low-income high school students, 70 percent of whom are Native American, hailing from the worst-performing schools in Arizona. These students take college-level courses each summer during the last 3 years of their high school education, and the vast majority go on to college—approximately half attend Arizona State University and half go out of state.

[5] See U.S. 2020 website: us2020.org.
[6] See FabFems website: fabfems.org.

Participants in Cleveland also described successful dual-enrollment programs. Lorain County Community College runs an early-college high school program annually involving 100 first-generation students, who receive their associate's degree concurrently with their high school diploma. The college is now taking the early-college model into the high schools through a program called My University. Also in Cleveland is MC^2 High School, a STEM-focused high school, where students spend academic years on-site at the Great Lakes Science Center (9th grade), General Electric (10th grade), and Cleveland State University (11th and 12th grades).

Third-party intermediaries can also play a role in facilitating connections between employers and the K-12 sector. The LA Regional STEM Hub has been instrumental in linking Los Angeles businesses and civic institutions to local students, classrooms, and schools to develop capacity for system-wide transformation of STEM education and the 21st century workforce. The STEM Hub convenes Los Angeles stakeholders dedicated to making progress toward a set of regional goals through collaborative action groups; helps develop STEM teachers, administrators, and afterschool providers professionally through a Peer Learning Network; and provides a communications platform for shared resources around the Common Core Standards and Next Generation Science Standards. Every year, the STEM Hub hosts a State of STEM event, where more than 200 participants from business and industry, elementary and secondary schools, institutes of higher education, government agencies, the philanthropic community, nonprofits, and STEM program providers convene to discuss how the community can work together to meet the needs of the 21st century STEM workforce in Los Angeles.