RESEARCH REPORT

Sub-baccalaureate STEM Education and Apprenticeship

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# Contents

## Contents

<table>
<thead>
<tr>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgments</td>
<td>v</td>
</tr>
<tr>
<td><strong>Executive Summary</strong></td>
<td>6</td>
</tr>
<tr>
<td>Sub-baccalaureate STEM Education Programs</td>
<td>6</td>
</tr>
<tr>
<td>STEM Apprenticeship</td>
<td>8</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td>10</td>
</tr>
<tr>
<td>Defining Sub-baccalaureate STEM</td>
<td>11</td>
</tr>
<tr>
<td>Is There a “Hidden” Middle-Skills STEM Workforce?</td>
<td>14</td>
</tr>
<tr>
<td><strong>Sub-baccalaureate STEM Education Programs</strong></td>
<td>15</td>
</tr>
<tr>
<td>Trends in Sub-baccalaureate STEM Degree and Certificate Completions</td>
<td>16</td>
</tr>
<tr>
<td>Community College Structure and Funding</td>
<td>23</td>
</tr>
<tr>
<td>Community College Funding and Accreditation</td>
<td>23</td>
</tr>
<tr>
<td>Noncredit and Continuing Education</td>
<td>25</td>
</tr>
<tr>
<td>For-Profit Colleges</td>
<td>26</td>
</tr>
<tr>
<td>The 90/10 Rule</td>
<td>27</td>
</tr>
<tr>
<td>The Gainful Employment Rule</td>
<td>27</td>
</tr>
<tr>
<td>Federal Investments in Sub-baccalaureate STEM Education</td>
<td>30</td>
</tr>
<tr>
<td>Perkins Grants</td>
<td>30</td>
</tr>
<tr>
<td>TAACCCT</td>
<td>32</td>
</tr>
<tr>
<td>ATE Grants and Centers</td>
<td>33</td>
</tr>
<tr>
<td>National Laboratories</td>
<td>35</td>
</tr>
<tr>
<td>Educational Barriers for STEM Students</td>
<td>38</td>
</tr>
<tr>
<td>Need for Child Care Support</td>
<td>39</td>
</tr>
<tr>
<td>Lack of College Preparedness</td>
<td>41</td>
</tr>
<tr>
<td>Drug Testing and Criminal Background Checks</td>
<td>42</td>
</tr>
<tr>
<td><strong>STEM Apprenticeship</strong></td>
<td>43</td>
</tr>
<tr>
<td>Trends in STEM Apprenticeships</td>
<td>44</td>
</tr>
<tr>
<td>Meeting Apprenticeship Sponsors’ Needs</td>
<td>49</td>
</tr>
<tr>
<td>The Role of Intermediaries and National Occupational Frameworks</td>
<td>49</td>
</tr>
<tr>
<td>Related Technical Instruction</td>
<td>50</td>
</tr>
<tr>
<td>Looking Ahead: The Trump Administration and Apprenticeship</td>
<td>51</td>
</tr>
<tr>
<td><strong>Conclusion</strong></td>
<td>52</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Notes</td>
<td>54</td>
</tr>
<tr>
<td>References</td>
<td>56</td>
</tr>
<tr>
<td>About the Authors</td>
<td>60</td>
</tr>
<tr>
<td>Statement of Independence</td>
<td>61</td>
</tr>
</tbody>
</table>
Acknowledgments

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Executive Summary

It is universally accepted that a skilled science, technology, engineering, and mathematics (STEM) workforce is essential to innovation and economic growth. However, many peoples’ image of the STEM workforce is narrowly restricted to scientists with doctorates or engineers with bachelor’s or master’s degrees. Technicians and other STEM workers with sub-baccalaureate credentials are considered less frequently, despite their substantial contributions to the science and engineering enterprise. To fill this gap, this report explores the delivery of sub-baccalaureate STEM education in the United States, including both college-based programs and registered apprenticeships.

We begin with a discussion of the difficulties around defining what credentials and jobs count as STEM. We advocate a relatively broad definition of STEM that includes precision production and health. Automation and technological advances have elevated technical competencies required in advanced manufacturing and health care, so that training in these fields has become increasingly STEM intensive. Our definition of sub-baccalaureate STEM education is composed of five subfields: (1) science and engineering, (2) science and engineering technicians, (3) computer science and information technology, (4) near-STEM technical fields, and (5) health professions and related programs.

Sub-baccalaureate STEM Education Programs

Each STEM subfield has experienced different credential completion trends over the last 30 years, and across credential type. Science and engineering credential awards have been heavily concentrated in associate’s degrees from nonprofit institutions. Near-STEM technical awards have been similarly concentrated in nonprofit institutions, but these students typically earn certificates rather than associate’s degrees. Science and engineering technology awards were primarily associate’s degrees 30 years ago, but in recent years, about as many certificates in science and engineering technology have been awarded as associate’s degrees. Unlike most other subfields, which are dominated by nonprofit credential awards, computer science and information technology awards come from both nonprofit and for-profit programs and are highly cyclical, rather than experiencing steady growth. Health awards have been growing at both the certificate and the associate’s degree level, and in nonprofit and for-profit institutions.

After reviewing these trends, we discuss how the funding, accreditation, and regulation of community colleges and for-profit institutions affect the provision of high-quality STEM education. Sub-
baccalaureate STEM education is relatively expensive to deliver because of the equipment, lab space, and smaller class size requirements. When funding is tied to the number of full-time equivalent (FTE) students in a class, sub-baccalaureate STEM classes face a significant disadvantage compared to large lecture classes in other fields. Some of the best instructors for sub-baccalaureate STEM courses have industry experience rather than advanced degrees, which can run afoul of program accreditation requirements. Noncredit programs and for-profit institutions can sidestep many of these constraints on the delivery of high-quality sub-baccalaureate STEM education, but these programs face regulatory headwinds of their own from the federal government.

The federal government makes several key investments in sub-baccalaureate STEM education. We highlight four programs, each supported by a different federal agency, that target various STEM fields.

- **Perkins grants**, administered by the US Department of Education, provide federal funding to states and other grantees to improve career and technical education (CTE) in secondary and postsecondary programs.

- **Trade Adjustment Assistance Community College Career Training (TAACCCT) grants**, administered by the US Department of Labor, help community colleges build their capacity to provide education and training for in-demand technical jobs.

- **Advanced Technology Education (ATE) grants and centers** are funded by the National Science Foundation to support technician education in the United States.

- **National laboratories** are federally funded research and development centers overseen by the US Department of Energy. Although the primary mission of the national laboratories is research and development, all laboratories have formed partnerships with local colleges to improve technician education and provide research internships to community college students.

Each of these investments offers broader lessons for sub-baccalaureate STEM education, including how to sustain programs after grant funding has expired, establishing partnerships with employers, and building career pathways in technical fields.

Sub-baccalaureate STEM students face many barriers to success, just like any other student. A comprehensive policy for supporting STEM education needs to address these barriers. We highlight child care requirements, basic skill deficiencies, and drug testing and criminal background checks as important roadblocks for these students. Access to child care for these students can be improved by expanding drop-in care options and adjusting Child Care and Development Fund rules to better accommodate parents in education and training rather than employment, or who split their time
between education and work. Basic skill deficiencies affect sub-baccalaureate STEM students, who will use mathematics more frequently in class and on the job than non-STEM students. One of the most promising approaches to building basic skills is the integrated career pathway model, used in programs such as the Integrated Basic Education and Skills Training (I-BEST) model and Accelerating Opportunity (AO). These programs integrate basic skills education into technical training courses and ensure that students are guided through a well-structured career pathway. Integrated career pathway programs have been successful in improving the educational outcomes of CTE students, but less successful in consistently generating long-term labor market benefits.

**STEM Apprenticeship**

The apprenticeship training model combines on-the-job training and classroom instruction to build the skills of apprentices who are paid, productive employees of a company. Registered apprenticeship is a potentially valuable source of sub-baccalaureate STEM education, particularly if current federal and state expansion efforts succeed. Apprenticeship directly addresses STEM skills gaps by ensuring that the skills apprentices are taught are actively used on the job. Our analysis of administrative data on registered apprentices suggests that most STEM and near-STEM apprentices are in near-STEM technical fields, although many science and engineering technology and health professionals also complete apprenticeships.

Organizations that sponsor apprenticeship programs (often, though not always, employers) report that they would benefit from help in screening potential apprentices and identifying related technical instruction providers and a more expedited program registration process. We review the role played by intermediary organizations and national occupational frameworks in meeting these needs. STEM apprenticeship sponsors will likely have a particularly high demand for guidance on these issues since there is little prior experience with apprenticeship in those occupations.

The section on STEM apprenticeship concludes with a discussion of the steps taken by the Trump administration to invest in registered apprenticeship. The administration’s budget maintains funding for apprenticeship grants and Office of Apprenticeship administration at the same level as the last year of the Obama administration, so current expansion efforts are likely to be sustained, at least in the short term. President Trump also signed an executive order with plans for a new pathway to register apprenticeship programs through industry recognition, rather than exclusively relying on government agencies. Although details of industry recognition are not final, putting registration in the hands of
industry could be beneficial for STEM apprenticeship programs because STEM employers have less familiarity with the sometimes cumbersome federal and state registration systems. An industry-driven registration process could be easier to navigate for employers.

Sub-baccalaureate education and training is a critical component of a broader STEM workforce strategy. Policymakers need to understand the barriers these students face and the value they produce. This report reviews the landscape of sub-baccalaureate STEM education and highlights the strengths and weaknesses of the United States’ current approach to delivering these vital skills.
Introduction

A strong science, technology, engineering, and mathematics (STEM) workforce is the backbone of American innovation and growth, but the public often has a skewed view of who is in the STEM workforce. Often, STEM workers are equated with scientists doing cutting edge research in a university laboratory. While this type of frontier-pushing basic research is essential to innovation, technicians and other STEM workers with sub-baccalaureate credentials are also indispensable to the science and engineering enterprise. This report explores the education and training of STEM workers with sub-baccalaureate credentials, including college-based programs and registered apprenticeships. The report reviews trends in education and training across five subfields: (1) science and engineering, (2) science and engineering technicians, (3) computer science and information technology, (4) near-STEM technical fields, and (5) health professions and related programs.

This report draws on several data sources to describe the nature of sub-baccalaureate STEM education and trends in different types of education and training over time. The two primary data sources are the Integrated Postsecondary Education Data System (IPEDS) and the Registered Apprenticeship Partners Information Data System (RAPIDS) database. IPEDS includes information on postsecondary certificate and degree awards at accredited institutions that participate in the federal student financial aid programs. These data are used to compare certificate and associate’s degree awards in for-profit and nonprofit schools across the five STEM fields. RAPIDS is an administrative database that tracks registered apprentices and apprenticeship programs in 33 states.

This report begins by defining the fields included in our discussion of sub-baccalaureate STEM education. In the sub-baccalaureate education space, the boundaries between STEM education and non-STEM technical education are often unclear. We address these complexities and provide our own definition, which is broad but grounded in standard federal educational and occupational codes. The next section describes the wide range of sub-baccalaureate STEM education in the United States, including certificate and degree programs offered at traditional public community colleges and for-profit colleges. The section also reports on trends in college-based STEM education and important institutional and regulatory barriers to providing this education. Lastly, it reviews important federal investments in sub-baccalaureate STEM education, and key barriers faced by students. The final section of the report addresses the role of registered apprenticeship in providing high-quality STEM education and training, including trends in STEM apprenticeship over time, policies to meet the needs of apprenticeship sponsors, and the new approach of the Trump administration to registered apprenticeship training.
Defining Sub-baccalaureate STEM

Estimates of the size of the STEM workforce vary because of the lack of agreement on what occupations and fields of study fit under the STEM umbrella. Typical disagreements concern the treatment of health fields and the social and behavioral sciences. In the sub-baccalaureate STEM workforce, though, there is even less clarity on which middle-skill technical jobs count as STEM occupations. Automation and technological development have dramatically increased the technical skill requirements of many middle-skilled production, maintenance, and health care occupations, which are now aligning more closely with science and engineering technician occupations that are traditionally counted as STEM. This report takes a broad view of what counts as a STEM job. Our analysis includes health and technically oriented manufacturing, repair, and maintenance fields, in addition to the traditional core STEM fields. Our analysis includes five sub-baccalaureate STEM categories (1) science and engineering, (2) computer science and information technology, (3) science technicians and engineering technicians, (4) near-STEM technical fields, and (5) health professions and related programs.

Institutions of higher education are required to identify each of their programs of study using a Classification of Instructional Programs (CIP) code. CIP codes are defined by the US Department of Education and provide a taxonomy for organizing fields of study. The Department of Education collects data on the number of students who have completed degrees or certificates through the annual Completions Survey, which institutions must submit to the Integrated Postsecondary Education Data System (IPEDS), maintained by the National Center for Education Statistics. This report frequently draws on the IPEDS data to understand trends in sub-baccalaureate STEM education. Box 1 provides details on the CIP codes associated with each of the STEM fields included in this report.
The first sub-baccalaureate STEM category is science and engineering. Science and engineering students in community colleges are often, though not always, preparing for transfer to a bachelor’s degree program. Although theory-based science and engineering programs form the backbone of STEM education in bachelor’s and graduate degree programs, they play a smaller role in preparing students for entry into the sub-baccalaureate STEM workforce.

The second category, science technology and engineering technology, is in many ways the mainstay of sub-baccalaureate STEM education because the goal of these programs is direct entry into a technical workforce that is universally considered a STEM field. These programs are like science and engineering programs, but generally have more applied curricula. On the job, technicians may build, install, and maintain equipment or perform diagnostic tests, and those who advance in their field may help in the design, procurement, sales, and management of technology. Science technology and engineering technology programs are offered by some four-year colleges as well, with program
graduates frequently referred to as “technologists” to distinguish them from “technicians” educated at two-year institutions (NAE 2017). This distinction between “technician” and “technologist” is not always consistent or meaningful outside of engineering, where a doctoral-level worker may still hold the title of “technician” if he or she works in support of a principal investigator. This report includes only sub-baccalaureate credential completers in the category of science technology and engineering technology, and not the highly-educated lab technicians working in research institutes and universities.

The third category included in our analysis is computer science and information technology. Computer science is typically thought of as a STEM field, but it may not include all information technology certificate programs because these may be focused on information technology (IT) support roles. Certificates in business applications (which are sometimes counted as computer science and information technology) are typically not offered for college credit and therefore are not included in the federal education data presented in this report. Although this excludes most non-STEM business application credentials, this report may inadvertently count some of these programs as computer science programs due to data limitations, even though they are not STEM intensive.

The fourth category includes several “near-STEM” fields that are increasingly technical and have STEM content and skill requirements like those of engineering technology programs. In this report, “near-STEM technical fields” is a catchall term encompassing mechanic and repair technologies and precision production. Graduates of these programs enter the manufacturing sector or do maintenance work like that of engineering technicians. In some cases, it is difficult to distinguish between near-STEM technician programs and engineering technician programs. Automotive technology programs nicely illustrate these taxonomical difficulties. The Department of Education cross-references automotive mechanics technology programs (classified here as near-STEM because they are under CIP code 47) with automotive engineering technology programs (an engineering technology field, CIP code 15) because they offer similar content. This introduces uncertainty in how a given certificate or degree program is classified for students and employers (Kuehn 2016). For example, the Center for Advanced Automotive Technology in Warren, Michigan, is classified as an “engineering technology” ATE center but supports both automotive mechanics technology (“near-STEM” for the purposes of this report) and automotive engineering technology (“science technology and engineering technology”) programs at partner colleges. With no clear rules around the selection of a CIP code—this is left largely to the discretion of an institution—two programs with similar content could be assigned different CIP codes.

The fifth and final STEM category considered here is “health professions and related programs.” The tradition of excluding health from STEM classifications is both historical and cultural. Historically, medicine was considered more art than science, with caregiving emphasized over science in
occupational practice standards and by society. However, advances in medical diagnostics and therapeutics, pharmacology, molecular biology, imaging technologies, and microsurgical techniques serve as evidence that health fields now sit squarely in the domains of science and technology. The cultural barriers to including health fields in STEM may be the hardest to remove, given the continuing undervaluation of occupations viewed as caregiving or female-dominated (Folbre 1995; England, Budig, and Folbre 2002). Federal appropriations categories and federal science agency scope also help maintain these distinctions, with the National Science Foundation (NSF) seen as the guardian of STEM fields and the National Institutes of Health seen as the representative of medical sciences. Regardless, at the sub-baccalaureate level, health programs look very much like traditional science and engineering transfer degree programs in their focus on fundamental STEM courses and skills, and admissions to health programs is based largely on a student’s success in prerequisite STEM courses. Thus, we include health in this report.

Is There a “Hidden” Middle-Skills STEM Workforce?

In 2013, Jonathan Rothwell, then at the Brookings Institution, published a widely-discussed report on the existence of a large but “hidden” STEM workforce composed in large part of workers in middle-skill jobs. Rothwell’s (2013) emphasis on middle-skill jobs makes his definition of STEM and his findings particularly relevant to this discussion of sub-baccalaureate STEM education. Rothwell used data from the US Department of Labor’s O*NET database to classify occupations with higher-than-average STEM knowledge requirements in one STEM knowledge area as “high-STEM,” and those that require higher-than-average STEM knowledge in all knowledge areas as “super-STEM.” This approach classified 20 percent of all jobs as high-STEM, which is considerably higher than most estimates (Rothwell 2013).

The weakness of Rothwell’s analysis is that it identifies jobs that require some STEM competencies, and in many cases fairly modest levels of competency, as STEM jobs. Because many non-STEM jobs require the use of information technology or the application of a narrow set of math competencies, an above-average skill requirement in these areas may cause some jobs not traditionally considered STEM to be classified as STEM. For example, Rothwell’s definition of high-STEM fields includes funeral service managers and pest control workers. Funeral service managers may need above-average knowledge of anatomy and blood-borne diseases, and pest control workers are likely to need above-average knowledge of pest life cycles, chemical safety, and hazard mitigation practices. But neither job requires the worker to complete comprehensive training in biology or chemistry to perform their job safely and
effectively. These competencies only qualify funeral service managers and pest control workers as high-STEM in Rothwell’s analysis because few other jobs require the same competencies.

Rothwell’s analysis reinforces the broad societal benefits associated with strengthening STEM education beyond the narrower benefits of producing more bench scientists. People bound for careers in funeral service and pest control, even if these are not included in the category of STEM careers, benefit from an education system that successfully delivers math and science education. However, Rothwell’s approach does not identify STEM occupations as the term is commonly understood. Educational CIP codes and Standard Occupational Classification codes are used here because they more accurately differentiate between STEM and non-STEM fields. Our report reviews the production of sub-baccalaureate STEM workers in the United States not because the importance of STEM competencies is “hidden,” but because these fields have largely been neglected by policymakers and federal funding agencies that target their STEM attention on four-year and graduate degree programs.

Sub-baccalaureate STEM Education Programs

In many STEM fields, low-cost sub-baccalaureate education takes place in community or technical colleges. The organizational structure and funding of colleges that serve sub-baccalaureate students have an important impact on the number and size of sub-baccalaureate STEM programs available. The federal regulatory environment can also affect an institution’s decision to offer sub-baccalaureate STEM programs because these programs are often regulated differently from four-year degree programs and face different reporting requirements.

For-profit, or proprietary, colleges also have a long tradition of preparing middle-skill workers in STEM or near-STEM fields for about the same per-student cost as community colleges. However, because these institutions do not receive public subsidies in the form of annual appropriations, the burden of cost falls largely on students, resulting in higher tuition than community colleges’ (but not necessarily as high as four-year private institutions’). On the other hand, these institutions are designed to meet the unique needs of adult learners and offer more plentiful and flexible scheduling options; thus, they often have higher completion rates and lower nontuition opportunity costs than public two-year institutions do. This section provides a comprehensive review of the key elements of sub-
baccalaureate STEM education in nonprofit community colleges and for-profit institutions, including completion trends, funding models, and regulations.

Trends in Sub-baccalaureate STEM Degree and Certificate Completions

The most comprehensive data available for tracking trends in sub-baccalaureate STEM certificate and degree awards is the IPEDS. The IPEDS includes information on annual completions by field of study and degree level for all colleges, universities, and technical and vocational schools that participate in federal student financial aid programs. Thus, the IPEDS's coverage is not universal: it excludes programs and institutions that do not participate in federal student aid programs as well as noncredit credential completions.

The IPEDS also excludes credentials awarded by noncollege institutions. In some STEM fields, equipment vendors and trade associations make a sizeable contribution to sub-baccalaureate education. These institutions provide training or certification that may be held in higher regard by employers than traditional certificates or degrees. Unfortunately, most of those credentials are not reported to or tracked by federal databases, so it can be extremely difficult to estimate the size and nature of this segment of the sub-baccalaureate technical workforce. But IPEDS does represent an important segment of sub-baccalaureate education and training.

Figure 1 presents the share of STEM and near-STEM awards among the total number of less than one year and one to two year certificate awards and associate's degree awards reported to IPEDS from 1987 to 2015. For the entire period covered by figure 1, roughly 30 percent of associate's degrees were awarded in a STEM or near-STEM field. The STEM or near-STEM share of certificate awards grew from around 50 percent in the late 1980s to about 65 percent in 2010. After 2010, the STEM and near-STEM share of certificate awards began to decline, despite public concerns about the growing skills gap.
FIGURE 1
STEM and Near-STEM Share of Sub-baccalaureate Certificates (<1 year and 1-2 years) and Associates Awards, 1987–2015

Source: Authors’ calculations from the 1987–2015 IPEDS Completions File.
Note: STEM = science, technology, engineering, and mathematics. STEM and near-STEM awards are any awards associated with CIP codes 11, 14, 15, 26, 27, 29, 40, 41, 47, 48, or 51.

Figures 2 through 5 present the number of sub-baccalaureate credentials awarded by nonprofit and for-profit institutions for each of the STEM and near-STEM fields listed in box 1. Figure 2 presents the annual number of science and engineering awards. By far the largest number of science and engineering awards came from associate’s degree programs in nonprofit colleges. Between 5,000 and 6,000 science and engineering associate’s degrees were awarded by these colleges annually until the mid-2000s, when the number of awards started climbing rapidly, almost tripling over the next decade. Despite this recent growth, the total number of degrees and certificates awarded in science and engineering remains much lower than the number awarded in the other STEM and near-STEM fields.

It is not surprising that the for-profit sector contributes little to science and engineering completions, given the statutory requirement that these institutions offer only programs that lead to specific occupations or vocations. At the associate’s degree level, science and engineering programs are
typically designed for students who plan to transfer to a four-year institution instead of directly entering the workforce. Some of these students may even transfer without being awarded an associate’s degree. The IPEDS data cannot identify the percentage of students included in figure 2 who went on to earn a bachelor’s degree.

FIGURE 2

Source: Authors’ calculations from the 1987–2015 IPEDS Completions File.

Note: Science and engineering awards are certificate or associates awards associated with CIP codes 14, 26, 27, or 40. Nonprofit institutions include public community colleges as well as nonprofit private technical colleges.

Figure 3 presents the same set of awards for science technology and engineering technology. Nonprofit associate’s degree programs also generate the largest number of awards in these categories, although by 2015 nonprofit colleges awarded roughly as many certificates as associate’s degrees. A recent National Academies of Engineering report on engineering technology education documented this rapid increase in engineering technology certificates specifically, which exceeded the number of associate’s degrees in engineering technology by 2015 (NAE 2017). The production of science technology and engineering technology sub-baccalaureate credentials at for-profit colleges was more stable over this period, and lower than the production of comparable certificates in nonprofits. Some of
the decline in for-profit associate’s degrees after 2002 may be attributable to competition from the growing nonprofit sector.

Despite the predominance of nonprofit colleges in the production of science technology and engineering technology awards, individual for-profit colleges frequently produce large numbers of these awards each year, which may have a local or regional labor market impact. The National Academy of Engineering (2017) showed that four of the ten largest engineering technology associate’s degree producers in 2014 were for-profit colleges.

FIGURE 3

Source: Authors’ calculations from the 1987–2015 IPEDS Completions File.
Note: Science and engineering technology awards are certificates or associates awards associated with CIP codes 15, 29, or 41. Nonprofit institutions include public community colleges as well as nonprofit private technical colleges.

Figure 4 presents computer science and information technology awards. Computer science credentials post large gains from 1987 to 2000 in for-profit certificates, and to 2003 in all other credential types. After this peak, computer science awards from all sources begin to decline. The peak and decline may be related to the bursting of the dot-com bubble in 2001. Computer science awards
increased again after 2006. By 2011, for-profit associate’s degrees experienced another steep decline, coinciding with a period of increased legal and political pressure on the for-profit education sector.

Colleges have clearly responded to rising demand for information technology degree and certificate programs, which demonstrates these institutions’ ability to adapt to changing workforce and employer needs. However, information technology programs are generally less expensive to start or grow than laboratory-based STEM or near-STEM programs. Students typically purchase their own computers (Dahlstrom et al. 2012), so growth does not require the institution to make significant investments in equipment. Overall growth in the information technology sector, coupled with the relative ease of offering these programs online, could also make it easier to find instructors.

**FIGURE 4**

Sub-baccalaureate Awards in Computer Science and Information Technology, 1987–2015

Source: Authors’ calculations from the 1987–2015 IPEDS Completions File.

Note: Computer science and information technology awards are any awards associated with CIP code 11.

Completions from near-STEM technical programs, which include mechanic and repair technologies and precision production, are reported in figure 5. These awards consist mainly of certificates granted by nonprofit institutions. The number of certificates awarded by nonprofits rose sharply from about
20,000 in 1987 to over 80,000 in 2015, with most of the growth occurring after the year 2000. Every other provider of near-STEM technical credentials experienced growth during this period as well. However, their growth was not as substantial as the quadrupling of the nonprofit certificate programs.

**FIGURE 5**

Unsurprisingly, sub-baccalaureate health awards have grown in both the nonprofit and for-profit sector over the last 30 years (figure 6). This growth can be attributed in part to an aging population that demands more and better care, and in part to increased training requirements for workers in jobs that once required no formal education (Institute of Medicine, 2011; Snavely, 2016). Health certificate awards exceeded associate's degree awards in the for-profit sector as early as 1995, but certificate awards did not exceed associate's degrees in the nonprofit sector until after 2000. Starting in 2011, for-profit health awards began declining dramatically. This decline in for-profit health awards mirrors the decline in for-profit computer science awards reported in figure 4 and coincides with federal
pressure on for-profit institutions. Unlike nonprofit computer science awards, the nonprofit health awards also declined modestly after 2011.

**FIGURE 6**
Sub-baccalaureate Health Awards, 1987–2015

![Graph showing sub-baccalaureate Health Awards from 1987 to 2015.]

Source: Authors’ calculations from the 1987–2015 IPEDS Completions File.
Note: Health awards are any awards associated with CIP code 51.

Figures 2 through 6 demonstrate that different STEM and near-STEM fields have had dramatically different trends in sub-baccalaureate credential awards. Some fields, such as science and engineering, are dominated by two-year associate’s degrees. Others, such as near-STEM technical fields, have more certificate programs. Science and engineering technology, computer science and information technology, and health are high in both associate’s degree and certificate awards. Most fields show a marked decline in awards from for-profit institutions after 2010 or 2011. This decline coincides with declining enrollments and increased regulatory scrutiny, which is discussed in more detail below. Any discussion of sub-baccalaureate STEM education and training should keep in mind the underlying diversity of these fields.
Community College Structure and Funding

Community colleges are the primary producers of STEM and near-STEM credentials, so they have a major impact on the size and qualifications of the sub-baccalaureate STEM and near-STEM workforce. Many policy levers could be used to incentivize greater investments in community college programs that meet current workforce needs and to lower and remove policy barriers that prevent institutions from being more responsive to unforeseeable fluctuations in the demand for STEM skills. This section discusses the funding and accreditation of community colleges as it relates to the delivery of STEM education.

Community College Funding and Accreditation

The way that many publicly supported community and technical colleges are funded imposes constraints on the number and size of STEM programs offered. Community colleges receive most of their funding through state and local appropriations. The next largest source of revenue for community colleges is tuition. Nationally, tuition’s share of total community college revenue is 12 percent less than the share of revenue received from state and local appropriations, which illustrates the significant dependence of these institutions on taxpayer subsidies (Baime and Baum 2016). Community colleges also receive federal support through various extramural grants designed to expand specific programs or improve student outcomes.

State funding formulas typically allocate resources based on the number of FTE students enrolled, rather than on the actual cost of program delivery. This puts STEM programs, which typically have a higher per-student cost of delivery, at a significant disadvantage. Delivering STEM and near-STEM technical programs can cost between 50 and 500 percent more than the cost of delivering general arts and humanities programs, because of the high cost of equipment and facilities needed to teach hands-on courses, restrictions on class size, and the higher cost of recruiting and retaining qualified instructors in those fields (Shulock, Lewis, and Tan 2013). STEM and near-STEM technical courses also have higher operating costs because they frequently require expensive consumable supplies, a dedicated facility, and equipment maintenance and repair.

Some states are better at meeting program-specific funding needs through more nuanced funding formulas. Mullin and Honeyman (2007) provide a typology of state funding formulas that helps to summarize the differences between these models. Ten states are identified as having no formula for funding community colleges during the annual appropriations process. Nineteen states have a
“responsive” formula of one form or another that determines funding based on FTE student enrollment. The remaining 21 states\(^4\) use what Mullin and Honeyman (2007) call “functional component” funding, which is set according to the operating components of the college (e.g., instruction, research, student services). A subset of “functional component” states also vary funding by program to account for the fact that delivering instruction in some programs costs more than it does in others. These so-called “tiered functional component” states offer a potential solution to the problem of high per-student costs in STEM and near-STEM technical programs. Tiered functional component states identified by Mullin and Honeyman (2007) are Arkansas, Illinois, Kentucky, Massachusetts, Michigan, Minnesota, North Carolina, Ohio, Oklahoma, and South Carolina, although this list may have changed since their analysis.

It could be difficult to change state funding formulas wholesale from an FTE-based approach to one that accounts for differences in program costs. But funding formulas could be rebalanced incrementally so that they do not penalize STEM and near-STEM technical programs. For example, a STEM or technical FTE student could simply be reimbursed at a higher rate (or a higher “cost of education adjustment”) than other students. This would not represent a full shift from FTE reimbursement to funding the cost of delivery, but it would help to pay for expensive laboratories and equipment.

Other structural issues may make it difficult for some institutions to offer many STEM technical programs. First, publicly funded institutions may not have funding for the capital costs of designing facilities and procuring equipment for technical education programs. Second, even when federal funding is available to support one-time equipment acquisitions or program start-up costs, institutions may still lack sufficient funds to service that equipment or purchase the supplies necessary to use it. Third, because high-cost technical programs often have low enrollment (either because of facility or accreditation constraints or lack of student interest), these programs are low hanging fruit for budget analysts looking for funds for other institutional priorities (Reed 2015, Jones 2017).

Some elements of institutional accreditation also work against institutions offering technical programs. First, faculty governance requirements can make the development of a new curriculum or the modification of a current one too slow to keep pace with rapidly evolving technologies and related workforce needs. Academic institutions and businesses move at very different paces. Second, because accreditors prioritize faculty’s academic credentials over their workplace experience, institutions may have a hard time identifying instructors who have up-to-date technical skills and academic qualifications and who are willing to work for the typical adjunct wage or even the full-time faculty wage. Programmatic or specialized accreditation can create yet another barrier for institutions that wish to launch STEM or near-STEM programs in new or rapidly growing fields. Programmatic accreditation adds cost, delays program launch, requires more careful outcomes monitoring, and can
create quagmires around recruiting students, especially if initial accreditation can’t be granted until after the first cohort of students graduate (Jones 2017).

**Noncredit and Continuing Education**

To avoid the accreditation challenges associated with starting credit-bearing programs, to provide greater programmatic flexibility, and to ensure greater responsiveness to employer demands, colleges also offer STEM and near-STEM certificate programs through their noncredit divisions, which may be housed in specialized facilities within or outside the main campus. Although some noncredit programs are designed and offered independent of industry, many are tied to the needs of local employers who participate on advisory boards. Employers can also directly design or oversee the development of a noncredit program. This type of employer-directed training is known as “customized training” and is considered one of the most effective local economic development strategies (Bartik 1991, 2005). Customized training can be general, or it can be tailored to a very specific piece of equipment. Employers that invest in these noncredit customized trainings frequently donate facilities, equipment, and supplies to the program (Bailey and Morest 2004).

Although noncredit programs meet many of the needs of STEM students and employers, college credit typically cannot be issued for programs taught through a continuing education or workforce development department. Even if the community college grants credit for that work through a prior learning assessment, it is often difficult for those credits to transfer to a four-year institution. Prior learning assessment credits are often treated differently than regular credits in a two-year to four-year college transfer (Ryu 2013).

Data collection on noncredit education and training is much less systematic and reliable than for-credit education. For example, the IPEDS data presented above in figures 2 through 6 do not include noncredit completers, even though these programs typically result in some type of credential (usually a certificate). Thus, we know less about the scope or content of noncredit programs than we do about accredited Title IV–participating programs (Sykes and colleagues 2014). Even if noncredit programs were included in the IPEDS, many providers of noncredit programs do not participate in federal student aid programs and therefore have no reporting responsibilities to the IPEDS or any other federal agency.
For-Profit Colleges

For-profit colleges have a long tradition of preparing workers for jobs in the traditional trades and STEM and near-STEM fields. Data in figures 2 through 6 demonstrate that for-profit colleges play a role in sub-baccalaureate STEM education. These institutions offer flexible course schedules designed to meet the unique needs of adult learners and often have locations dispersed throughout the community or online, making them more accessible and inviting to working adults (Deming, Goldin, and Katz 2012).

Because for-profit institutions do not receive direct appropriations from the government, students bear the full cost of attendance through tuition and fees. This has generated concern among policymakers. For-profit institutions serve a student population that tends to be older and lower income than most community colleges (Deming, Goldin, and Katz 2012). These students not only have higher federal borrowing limits but also typically have greater need to borrow well beyond the cost of attendance to pay their living expenses. Concerns about for-profit students’ ability to repay their loans prompted regulatory pressure from state and federal governments.

Although high tuition rates and reliance on federal borrowing are causes for concern, they also give for-profit colleges greater flexibility to provide more expensive sub-baccalaureate STEM education. Because for-profit colleges rely on student tuition dollars rather than annual appropriations and because they are typically accredited by more programmatically flexible national accreditors, they can respond quickly to program demand and local workforce needs, much like noncredit programs at community colleges (U.S. Government Accountability Office 2017, Jones, 2017). In addition, the practice of setting program-based tuition rates, the ability to carry funds over from year to year, and the contributions of investors make it more likely that for-profits can afford to offer costlier STEM and near-STEM technical programs and maintain the equipment and facilities necessary to prepare students with up-to-date skills. But unlike many nonprofit institutions, which use general studies arts and humanities programs to cover the cost of expensive technical programs, most for-profit colleges do not offer such courses of study (Deming, Goldin, and Katz 2012). Thus, sub-baccalaureate for-profit institutions do not have low-cost programs with large enrollments to offset the cost of more expensive STEM programs with small enrollments. Students in STEM and near-STEM programs bear the cost in higher tuitions.

The aggressive marketing and management deficiencies of some for-profit institutions and the debate among policymakers over the role of for-profit entities in education have driven additional regulation of for-profits beyond that of other institutions of higher education. An unintended
consequence of some of these regulations is limited student access to STEM and near-STEM programs. We discuss two of these regulations: the 90/10 rule and the gainful employment rule.

The 90/10 Rule

Based loosely on a 1952 rule affecting veterans’ use of GI Bill benefits that required participating institutions to have nonveteran enrollment shares of at least 15 percent, the 90/10 rule requires for-profit institutions to obtain at least 10 percent of their revenue from non–Title IV sources. The 90/10 rule applies to entire institutions rather than individual programs of study. The current 90/10 ratio was added to the Higher Education Act in 1998 based on the assumption that the willingness of some students to pay their full tuition in cash (or of most students to pay some of their tuition in cash) would be a strong indicator of program quality (Riegel 2013). Although the “skin in the game” assumption makes sense in theory, the generosity of federal student aid programs and the institutions’ inability to interfere with a student’s right to borrow could have unintended consequences.

Adult students enrolled in an eligible postsecondary program could have as much as $17,000 in Title IV eligibility each year, with the amount borrowed exceeding tuition and fees issued to the student in the form of a cash (or loaded debit card) stipend. The only way a student can tap into the cash refund is to borrow beyond the cost of tuition and fees, so the loan program design incentivizes borrowing more than tuition costs, especially for students who cannot qualify for other forms of credit. For institutions that serve mostly low-income students, a straightforward way to satisfy the 90/10 rule is to set tuition above the level of federal aid eligibility. The 90/10 rule therefore exerts significant upward pressure on tuition and fees to comply with federal policy. Institutions that understand the value of reducing tuition, both to students and their own business model, may be unable to do so because they would fail the 90/10 requirement and lose Title IV eligibility. This may make high-quality STEM and near-STEM programs too costly relative to many students’ anticipated wages and therefore out of reach (Guida and Figuli 2012).

The Gainful Employment Rule

In 1972, amendments to the Higher Education Act added a new definition of “institution of higher education” to Title IV, providing subdegree (certificate and diploma) programs at nonprofit colleges and all certificate and degree programs at proprietary colleges full access to all federal student aid programs. These programs were required to provide “career and vocational” (e.g., technical) education
that lead to “gainful employment” in a recognized occupation. The term gainful employment had the clear meaning of a job that pays wages.

In 2014, the Obama administration used its regulatory authority to create a new definition of gainful employment that established bright-line standards for how much the average graduate who took student loans must earn, relative to average debt. To pass the new gainful employment test, the average debt-to-earnings ratio among program graduates who participated in Title IV must be below 8 percent, or the average debt-to-discretionary income ratio must be below 20 percent. Programs with debt-to-earnings ratios between 8 and 12 percent or debt-to-discretionary income ratios between 20 and 30 percent are identified as “in the zone.” A program that remains in the zone for three years is reclassified as failing. The Trump administration initiated negotiated rulemaking in 2017 to modify the gainful employment regulation and reduce the burden on for-profits. Negotiations fell apart in early 2018, and the administration will produce a proposed rule by November, 2018 (Kreighbaum 2018).

Cooper and Delisle (2017) argue that the gainful employment rule puts for-profits at a relative disadvantage by not accounting for the full social costs associated with nonprofits. Public colleges are subsidized by state and local governments, allowing them to reduce tuition below actual cost of delivery. Lacking these subsidies, for-profits charge higher tuition and fail the gainful employment rule at a higher rate than nonprofits. Cooper and Delisle’s simulations suggest that for-profit certificate programs would pass the gainful employment rule at 93 percent, rather than the actual pass rate of 76 percent, if they were subsidized at the same level as their nonprofit peers.

Much of the remaining difference in gainful employment pass rates is explained by the distinctive mix of programs offered by for-profits. Cooper and Delisle (2017) find that two-thirds of for-profit programs that fail the gainful employment rule are cosmetology programs, which are much less likely to be offered by public institutions but are essentially required by many state licensing boards. Excluding cosmetology programs—which are irrelevant to the STEM workforce—raises the for-profit pass rate in Cooper and Delisle’s simulations. For-profits also have a higher completion rate than their nonprofit counterparts, which raises the possibility that the debt-to-earnings ratio of nonprofits may be inflated by excluding the many public community college students who end up with debt but no credential. Community college programs do well in gainful employment calculations, largely because of the significant public subsidies those institutions receive, but the onerous reporting requirements associated with the rule could encourage these institutions to convert diploma and certificate programs to associate’s degree programs, simply to avoid being subject to gainful employment requirements. Associate’s degree programs at community colleges are not covered by the gainful employment rule, but similar programs at for-profit colleges are covered.
Table 1 presents gainful employment performance data for the STEM and near-STEM fields of study in for-profit certificate, for-profit associate’s, and nonprofit certificate programs. Performance measures reported by the Department of Education include the mean debt to total earnings, the mean debt to discretionary income, and the share of each group that is passing.

**TABLE 1**
Gainful Employment Performance of STEM Programs

<table>
<thead>
<tr>
<th></th>
<th>For-profit certificate</th>
<th>For-profit associate’s</th>
<th>Nonprofit certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean debt to total earnings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science and engineering technology</td>
<td>5.47</td>
<td>9.92</td>
<td>2.63</td>
</tr>
<tr>
<td>Computer science and IT</td>
<td>3.75</td>
<td>8.10</td>
<td>1.92</td>
</tr>
<tr>
<td>Near-STEM technical</td>
<td>5.57</td>
<td>7.43</td>
<td>1.27</td>
</tr>
<tr>
<td>Health</td>
<td>6.44</td>
<td>10.33</td>
<td>2.19</td>
</tr>
<tr>
<td>Non-STEM</td>
<td>6.31</td>
<td>11.04</td>
<td>1.51</td>
</tr>
<tr>
<td><strong>Mean debt to discretionary income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science and engineering technology</td>
<td>58.35</td>
<td>39.16</td>
<td>24.23</td>
</tr>
<tr>
<td>Computer science and IT</td>
<td>30.52</td>
<td>39.58</td>
<td>9.52</td>
</tr>
<tr>
<td>Near-STEM technical</td>
<td>37.53</td>
<td>34.28</td>
<td>5.62</td>
</tr>
<tr>
<td>Health</td>
<td>82.77</td>
<td>83.71</td>
<td>17.02</td>
</tr>
<tr>
<td>Non-STEM</td>
<td>88.66</td>
<td>83.77</td>
<td>21.47</td>
</tr>
<tr>
<td><strong>Percent in “pass” range</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science and engineering technology</td>
<td>85.33%</td>
<td>52.80%</td>
<td>90.91%</td>
</tr>
<tr>
<td>Computer science and IT</td>
<td>97.73%</td>
<td>73.91%</td>
<td>95.71%</td>
</tr>
<tr>
<td>Near-STEM technical</td>
<td>85.07%</td>
<td>70.91%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Health</td>
<td>81.54%</td>
<td>45.59%</td>
<td>95.71%</td>
</tr>
<tr>
<td>Non-STEM</td>
<td>69.22%</td>
<td>29.74%</td>
<td>97.50%</td>
</tr>
</tbody>
</table>

**Notes:** IT = information technology; STEM = science, technology, engineering, and mathematics. Authors’ calculations from the Department of Education’s 2015 gainful employment data. Science and engineering programs are not included because only one science and engineering associate’s degree program appeared in the data. Nonprofit associate’s degree programs are not included because degree programs at nonprofits are exempted from the gainful employment rule.

The 2015 gainful employment data indicate that poor for-profit performance on the gainful employment rule is heavily concentrated in non-STEM programs. Computer science programs at for-profits pass at very high rates, although health programs also fail at high rates. Health care wages for workers with certificates are typically low, but the cost of preparing students for these careers is high. For-profit colleges may be reluctant to create or expand these programs because STEM and near-STEM certificate programs are expensive to operate and gainful employment calculations limit how much of those costs can be passed on to students. Economies of scale and large enrollments in online programs can help offset the high cost of some technical programs, but many STEM or near-STEM sub-baccalaureate programs do not lend themselves to online instruction because they have significant hands-on components.
It is costly to deliver high quality, flexible STEM and near-STEM programs. For-profit colleges have many advantages in delivering these programs, but they face considerable political and regulatory headwinds. Policymakers should be mindful of the different funding structures of for-profits, the unintended consequences of the 90/10 rule, and the much stronger performance of STEM programs compared with non-STEM programs under the gainful employment rule.

Federal Investments in Sub-baccalaureate STEM Education

The federal government makes several different investments in STEM education, although most of these are at the four-year-degree or graduate level. This section profiles four federal investments that specifically target or make substantial investments in the sub-baccalaureate level: the Department of Education’s Perkins grant program, the Department of Labor’s Trade Adjustment Assistance Community College and Career Training (TAACCCT) grants, the National Science Foundation’s Advanced Technology Education (ATE) program, and the Department of Energy national laboratories’ investments in sub-baccalaureate technical education. The four programs highlighted here have been selected because they make broader investments across a range of STEM and near-STEM fields, although the federal government makes many other investments targeted to specific fields. As with many grant programs, a concern for TAACCCT and ATE grantees and their federal sponsors is the sustainability of the program after the end of the grant-funded period.

Perkins Grants

The federal government supports sub-baccalaureate STEM education primarily through the Carl D. Perkins Career and Technical Education (CTE) Act grant program. These grants are made to states, which then allocate funds to local education agencies, colleges, and universities that offer sub-baccalaureate CTE programs, area CTE centers, and institutions controlled by the Bureau of Indian Education. Since the 2006 version of the Act, Perkins grantees have been organized into 16 different programs of study, including several STEM and near-STEM programs. All CTE programs of study are expected to integrate academic and technical education and bridge the gap between grant-supported activities and either postsecondary education or the labor market. This approach gives states flexibility to design CTE programs and align them with other education and training activities in the state (Imperatore and Hyslop 2017).
Figure 7 presents the number of secondary and postsecondary Perkins CTE program concentrators in the three programs of study that most closely align with the STEM and near-STEM fields discussed in this report: IT, science technology, and health. By far the largest number of students enrolled in STEM or near-STEM fields are in postsecondary health programs of study, reflecting the high demand in health occupations. Each year, there are approximately 600,000 Perkins CTE health concentrators at the postsecondary level. In 2014, the most recent year with available data, the next most popular program of study was secondary health programs, which had approximately 300,000 concentrators. The next largest programs were IT and science secondary programs, followed by IT and science postsecondary programs.

**FIGURE 7**
Perkins STEM Concentrators

Source: Authors’ calculations from Perkins CTE concentrator enrollment data.

Note: IT = information technology.

The Perkins Act has not been reauthorized since 2006. As of this writing, the House of Representatives passed H.R. 2353, the Strengthening Career and Technical Education for the 21st Century Act, but the Senate has yet to act. Two of the major focal points for reauthorization are aligning...
the program more closely with the Workforce Innovation and Opportunity Act of 2014 (WIOA) and giving states more flexibility in spending CTE dollars. The Perkins Act could be aligned with the WIOA in several ways, including by encouraging or requiring Perkins participants to pursue industry-recognized credentials, requiring states to use labor market information produced by the workforce system to develop state CTE plans, aligning data systems and performance measures, and encouraging joint state planning with the workforce system. STEM and near-STEM programs would benefit significantly from better alignment with industry-recognized credentials and from clearer ties to employers and the labor market, precisely because sub-baccalaureate STEM pathways are so poorly understood and so frequently assumed to be only transfer pathways to four-year programs (NAE 2017). Industry-recognized credentials could be an important step toward clearer sub-baccalaureate STEM pathways to well-paying jobs rather than bachelor’s degrees.

**TAACCCT**

The Department of Labor’s TAACCCT grant program is one of the largest investments made over the last decade in technical education at community colleges. TAACCCT awarded about $2 billion in grants to community colleges across the country in four rounds from 2011 to 2014. TAACCCT’s purpose was to build the capacity of community colleges to provide industry-aligned programs to adult learners in a variety of career fields, including STEM and near-STEM technical fields, with grantees often training in multiple fields simultaneously (Mikelson and colleagues, 2017). TAACCCT grantees do not systematically report CIP codes for their programs in the published grant proposal material, but analysis of the reported occupational training areas reveals many grantees training in near-STEM technical fields (101 grantees across all four rounds), health (65), science technology and engineering technology (58), and computer science and information technology (34). Reflecting the pattern of sub-baccalaureate STEM education generally, many fewer grantees are offering training in science and engineering (8).9

TAACCCT grants are important investments in the sub-baccalaureate STEM workforce. The program provides a large infusion of federal funding to improve degree and technical training programs that impact tens of thousands of students, many of whom were enrolled in STEM or near-STEM programs (Durham and colleagues 2017). Because TAACCCT grants support capacity development, institutions can use the funds to purchase equipment, invest in facilities, and design new curricula and career pathways. Thus, these investments could have a lasting impact on sub-baccalaureate STEM education, although grantee capacity to sustain these programs beyond the funded period is unclear.
The large number of grants and the wide range of activities they support could provide important insight into what programs and interventions promote enrollment in and completion of STEM and near-STEM programs.

One of the major capacity-building efforts of TAACCCT is the dissemination of program material through the SkillsCommons website, a platform on which grantees can upload syllabi, workshop and training materials, reference materials, and assessment tools. There is currently no clear evidence on whether a substantial number of grantees or other colleges have used SkillsCommons.org to adopt or develop new programs. The website had a total of over 738,000 file downloads as of January 2018, and over 172,000 of those downloads were syllabi, or approximately 88 downloads per syllabus uploaded to the website. Faculty governance requirements enforced by accreditors make it unlikely that one institution will simply adopt curricula or materials developed at a different institution, although some institutions could adopt or expand on posted material. Nonetheless, if much of the work funded by TAACCCT can be sustained, this program could inch federal funding for sub-baccalaureate STEM programs toward parity with funding for bachelor’s and graduate degree programs.

**ATE Grants and Centers**

The ATE program has been the primary means by which the NSF has invested in sub-baccalaureate STEM workforce development since 1993. Led by institutions that award associate’s degrees, ATE grants encourage collaboration between two-year and four-year institutions, secondary schools, business, industry, and government, with a focus on improving science and engineering technician education. There are many grantee tracks, including Projects, National Centers, Regional Centers (focused exclusively on information technology and advanced manufacturing), Support Centers, Support Networks, and Targeted Research on Technician Education. National Centers focus on building national networks of academic institutions and industry partners, and Regional Centers serve as intermediaries to help bring together industry and institutions to promote economic development in specific fields and geographic regions. National Centers can receive up to 10 years of funding and Regional Centers up to seven, at which time they can become Support Centers that receive additional funds. Program evaluations suggest that ATE investments have a valuable impact on their host colleges and expand sub-baccalaureate STEM education opportunities (Reid et al. 2007; Henderson et al. 2012).

In 2016, there were 40 ATE centers organized around eight areas of focus, which are summarized in box 2. Most of these centers are located at community colleges, but a few are based at four-year institutions.
As with any grant program, the sustainability of ATE projects is a major concern. The NSF and the Department of Labor (for TAACCCT) know the challenges of program sustainability and require grantees to include in their proposals plans for continuing the program beyond the end of the grant period. The NSF funds sustainability research that has yielded several insights into the problem, at least with respect to the ATE program. Bailey and colleagues (2003) note that sustained institutional change cannot be expected from all ATE projects because grantees are expected to be innovative, and not all innovations are successful. However, they show that “process-oriented” grantees that bolster STEM education by restructuring how it is delivered by colleges are more successful at sustaining their activities than “output-oriented” grantees that are focused on producing products or other outputs. The authors recommend that ATE grant solicitations build in incentives to engage in more process-oriented innovation. NSF sustainability research also points to the importance of staff preparation and professional development in sustaining the work of the ATE center beyond the period of direct federal support (Lawrenz and Keiser 2001; Welch 2015).

The ATE program overlaps with the TAACCCT program on several dimensions, including many of its targeted fields of study and the educational institutions that are awarded grants. Unsurprisingly, many community colleges are grantees or partners under both the TAACCCT and ATE grant programs. Using funds from different agencies to do the same work is not permitted, but alternative grant funding sources can fill holes left by other grants, provide continued support after grants end, or connect grantees with a broader array of educational and employer partners. Examples of programs involved in both TAACCCT and ATE include the following:
The 360° Manufacturing and Applied Engineering ATE Regional Center of Excellence at Bemidji State University, which is a member of the Round 4 TAACCCT grant consortium in Minnesota led by South Central College. The TAACCCT grant, like the ATE grant, supports advanced manufacturing education and training in the state.

The Center for Systems Security and Information Assurance, an ATE Resource Center based at Moraine Valley Community College, led a team of three other ATE centers focused on IT in a Round 1 TAACCCT grant in 2011.

The National Center for Supply Chain Automation, an ATE National Center based at Norco College, is a partner in a Round 4 TAACCCT consortium headed by Chaffey College that focuses on advanced manufacturing.

Support from diverse funding sources puts these and similar programs on a stronger footing than many sub-baccalaureate STEM programs, but sustainability is a constant struggle. Later this year, the last round of TAACCCT grants will end, potentially resulting in reduced services or program offerings at some grantees.

National Laboratories

The Department of Energy's system of national laboratories represents an important federal investment in the US scientific enterprise. These labs have been critical to advancing scientific knowledge and technology, particularly in nuclear energy and particle physics. The national laboratories are a natural partner for science and engineering technician programs at local community colleges because these facilities have large staffs of technicians—unlike most university laboratories, which are run largely by graduate students focused on their own thesis work (National Research Council 2005; Stephan 2012). Over the last 20 years, the national laboratories have faced looming workforce needs, highlighted in the Chiles Report (Chiles and colleagues 1999), which described the strain on the nuclear workforce associated with the dramatic decline in hiring and related education and training at the end of the Cold War. In response, individual laboratories have established an array of relationships with local colleges and universities to secure their workforce pipeline. In some cases, this effort included partnering with local community colleges and sub-baccalaureate training institutions that supply technicians.

Sandia National Laboratories in Albuquerque, New Mexico, has a particularly active relationship with local institutions that prepare sub-baccalaureate STEM workers. Sandia has supported several
sub-baccalaureate STEM education efforts serving central New Mexico, including the Southwest Center for Microsystems Education and the Advanced Manufacturing Trades Training Program at Central New Mexico Community College, and the Manufacturing Training and Technology Center at the University of New Mexico. Although federal agencies are not eligible to compete for NSF grants, the laboratories can still benefit from these investments by partnering with local institutions that can and do receive federal support. For example, the Southwest Center for Microsystems Education is a current ATE center funded by the NSF, and the Advanced Manufacturing Trades Training Program is supported by a Perkins grant. These institutions all serve several microsystems and manufacturing firms in the Albuquerque area in addition to the Sandia and Los Alamos national laboratories (Osborn 2008; Pleil and Osborn 2008).

DEPARTMENT OF ENERGY INTERNSHIP PROGRAM

In addition to the ongoing efforts at individual laboratories, the Department of Energy supports an internship program that places bachelor’s and associate’s degree students at each of the national laboratories. The bachelor’s program is called the Science Undergraduate Laboratory Internship (SULI) and accepts approximately 700 students a year. The associate’s program, known as Community College Internships (CCI), is less than one-tenth the size of SULI.

Table 2 presents the total number of SULI and CCI interns from 2014 to 2016 at each national laboratory by postsecondary program type. The number of interns hosted and the share of interns from associate’s degree programs varies widely, but across all 17 national laboratories, almost 10 times as many interns came from bachelor’s degree programs as associate’s degree programs. The Fermi National Accelerator Laboratory accepted the largest share of their interns from associate’s degree programs between 2014 and 2016 (43.59 percent). The next largest share of associate’s degree interns were hosted by Sandia National Laboratories (26.67 percent) in New Mexico. However, the total number of interns at both laboratories was relatively small (39 and 30 interns over three years, respectively). The largest numbers of interns were hosted by Brookhaven National Laboratory (415) and Oak Ridge National Laboratory (373), each of which had associate’s degree intern shares roughly comparable to the weighted laboratory-wide average of 9.24 percent.
TABLE 2
National Laboratory Internship Programs Sorted by Associate’s Degree Share, 2014–16

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Interns from bachelor’s programs (SULI)</th>
<th>Interns from associate’s programs (CCI)</th>
<th>Associate’s program share of internships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermi National Accelerator Laboratory</td>
<td>22</td>
<td>17</td>
<td>43.59%</td>
</tr>
<tr>
<td>Sandia National Laboratories</td>
<td>22</td>
<td>8</td>
<td>26.67%</td>
</tr>
<tr>
<td>Pacific Northwest National Laboratory</td>
<td>156</td>
<td>31</td>
<td>16.58%</td>
</tr>
<tr>
<td>Lawrence Berkeley National Laboratory</td>
<td>219</td>
<td>35</td>
<td>13.78%</td>
</tr>
<tr>
<td>SLAC National Accelerator Laboratory</td>
<td>76</td>
<td>10</td>
<td>11.63%</td>
</tr>
<tr>
<td>Idaho National Laboratory</td>
<td>71</td>
<td>8</td>
<td>10.13%</td>
</tr>
<tr>
<td>Brookhaven National Laboratory</td>
<td>376</td>
<td>39</td>
<td>9.40%</td>
</tr>
<tr>
<td>Oak Ridge National Laboratory</td>
<td>343</td>
<td>30</td>
<td>8.04%</td>
</tr>
<tr>
<td>Los Alamos National Laboratory</td>
<td>104</td>
<td>9</td>
<td>7.96%</td>
</tr>
<tr>
<td>Ames National Laboratory</td>
<td>96</td>
<td>8</td>
<td>7.69%</td>
</tr>
<tr>
<td>Lawrence Livermore National Laboratory</td>
<td>89</td>
<td>7</td>
<td>7.29%</td>
</tr>
<tr>
<td>Princeton Plasma Physics Laboratory</td>
<td>68</td>
<td>5</td>
<td>6.85%</td>
</tr>
<tr>
<td>Argonne National Laboratory</td>
<td>250</td>
<td>12</td>
<td>4.58%</td>
</tr>
<tr>
<td>National Renewable Energy Laboratory</td>
<td>217</td>
<td>4</td>
<td>1.81%</td>
</tr>
<tr>
<td>General Atomics / DIII-D</td>
<td>20</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Savannah River National Laboratory</td>
<td>11</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Thomas Jefferson National Accelerator Facility</td>
<td>50</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,190</strong></td>
<td><strong>223</strong></td>
<td><strong>9.24%</strong></td>
</tr>
</tbody>
</table>


Notes: CCI = Community College Internships; SULI = Science Undergraduate Laboratory Internships.

Parity between bachelor’s degrees and associate’s degree students in the national laboratory internship program may not be realistic or desirable. The laboratories need scientists with high levels of expertise who generally hold advanced degrees in their fields. But the laboratories also must install and maintain the facilities and equipment to conduct “big science.” These activities require a skilled technician workforce.

Community college students residing locally may be more likely than bachelor’s degree students to apply for a technician position after their internship because these students often are more closely tied to their communities. Thus, some rebalancing of the Department of Energy internship programs toward community college students would be both feasible and desirable, and an important investment in sub-baccalaureate STEM education. Increasing the community college share of national laboratory internships would not add any additional costs and may even save money because of reduced travel and housing requirements.

Technicians are a critical part of the national laboratory workforce, so it is important to understand whether the disparity in internship opportunities is a problem of supply (i.e., not enough community
college students interested in or qualifying for these internships) or demand (i.e., too few internship opportunities available). Unlike many undergraduate students who attend college far away from home (and would be happy to relocate to participate in a summer internship), community college students may be less likely to relocate because of financial hardships, family obligations, or a permanent job at home that the student cannot quit, even for a paid summer internship for a few months. This is not to say that there are no community college students willing to relocate for a summer opportunity; over half of community college students are between the ages of 15 and 23 (Baime and Baum, 2016), and some may relish the opportunity to spend the summer away from home.

Given the unique needs of community college students, which may include sustained, year-round employment, the national laboratories should consider longer-term apprenticeship programs, as opposed to short-term internships, to prepare future technicians. Apprenticeships offer sustained employment and wages, so these opportunities could be more attractive to future technicians and may generate higher return on investment for the national laboratories because apprentices would remain productive employees of the laboratory for a longer period of time. Local community colleges could provide related technical instruction in conjunction with the work-based learning organized by the laboratory. By focusing on hands-on learning in an authentic work environment, the laboratories may tap into new talent pools that would not enroll in a college degree program or have the flexibility to serve as a summer intern.

Educational Barriers for STEM Students

Institutional structures, state funding formulas, and federal investments shape the sub-baccalaureate STEM and near-STEM workforce in important ways. But even the best-designed education and training programs grapple with the substantial barriers that many STEM and near-STEM students face. Three of the most important barriers to success for college students in sub-baccalaureate programs are difficulties finding affordable and reliable child care, inadequate math and reading skills, and drug and criminal background testing. None of these barriers are unique to STEM or near-STEM students, but each poses obstacles to a pipeline that generates an adequate supply of these workers.
Need for Child Care Support

Adult learners form an important pool of potential STEM and near-STEM workers because they are likely to understand the benefits of middle-skill jobs better than their younger counterparts, who often enter community college intending to transfer to a four-year institution. Adult students may have the maturity and commitment to succeed in demanding STEM courses, but they are also more likely to have child care needs that make attending college more challenging. Adams, Spaulding, and Heller (2015) highlight the misalignment of the child care needs of low-income parents in education and training with the child care options typically available to them. Parents in education and training face irregular schedules for classes, particularly if they are combining school and work. Class schedules often change from one semester to the next, making it more difficult to find child care providers, who tend to give priority to families who enroll their children full time. Despite these clear gaps, colleges offering associate’s degree and certificate programs usually do not provide child care facilities that students can easily access on site.

Figure 8 presents the share of sub-baccalaureate institutions between 2001 and 2015 that, according to the IPEDS database, had a child care facility available to students.\textsuperscript{10} The share of all institutions with campus-based child care centers declined from over 15.5 percent in 2001 to less than 11 percent in 2015. Eckerson and colleagues (2016) find similar trends for public community colleges and four-year colleges. Child care is offered at nonprofit colleges at a much higher rate than it is offered at for-profit colleges, in part because nonprofit institutions serve much larger on-site student populations than for-profit colleges, giving them the ability to leverage economies of scale. Nonprofit institutions have access to the Child Care Access Means Parents in School program, a grant program administered by the US Department of Education to subsidize the cost of providing campus-based child care. Institutions can receive up to 1 percent of their total Pell grant revenue from Child Care Access Means Parents in School. However, a recent evaluation of the program yielded mixed results, largely because funds can be used in many ways and may support activities as diverse as construction or faculty development rather than child care subsidies for low-income students (Office of Postsecondary Education 2007). Even at institutions that provide child care, openings are often taken by faculty, staff, and community members who are more likely to need full-time child care and less likely to qualify for subsidies.
One reason why so few colleges offer child care is that it is an expensive and heavily regulated service. An alternative to providing traditional child care facilities is to provide lower-cost drop-in care that parents can use during their classes. In most states, drop-in care facilities are subject to fewer regulations and licensing requirements if the parent is on the premises during the period the care is provided (as would be the case for students). Hess and colleagues (2016) find that few providers of sub-baccalaureate training currently provide drop-in care (only one of 34 training providers in the survey). Although on-campus child care may be most convenient, communities may offer other options, especially for students who are on campus only a few days each week or who enroll online.

But the greatest obstacle for low-income parents is the lack of affordable high-quality child care. The primary federal program designed to make child care affordable for low-income families, the Child Care and Development Fund, is often administered in a way that makes subsidies less accessible to parents enrolled in education and training (Adams et al. 2014). Two types of eligibility requirements are particularly challenging for parents pursuing postsecondary education, including those pursuing sub-
baccalaureate STEM education. First, states frequently require that parents be employed while they are engaged in an education or training activity to be eligible for subsidies. Employment can be an obstacle to full-time enrollment, and because STEM laboratory courses are worth fewer credits than classroom courses, a STEM or near-STEM student will spend more time on campus to earn the same number of credits as a student enrolled in a typical liberal arts or general studies program. This makes outside employment particularly difficult for STEM and near-STEM students with laboratory requirements. Second, some states have minimum education and training participation requirements, which can shut out parents who need to work and can therefore only take a limited number of classes at a time (Adams et al. 2014; Adams and Heller 2015). Removing employment and minimum participation eligibility requirements or allowing participants to meet eligibility requirements by combining the number of hours spent in school and at work would help more adult students, including those interested in pursuing sub-baccalaureate STEM education and training.

Lack of College Preparedness

Finding students who have the basic reading and math skills necessary for college success is a perennial challenge for most colleges, but even more so for the open-enrollment institutions where most sub-baccalaureate programs are offered. Students at community colleges are often underprepared for college-level work and are required to complete developmental education courses before entering their fields of study. Students requiring developmental education are less likely to complete a college certificate or degree than those who do not (Bailey, Jeong, and Cho 2010), and students with limited math skills may be excluded from admission to certain STEM programs. Even at open-admissions institutions, many STEM and near-STEM programs have entrance requirements.

One widely discussed approach to bolstering the basic skills of low-skill students and accelerating them through the necessary developmental education material is the Integrated Basic Education and Skills Training (I-BEST) model developed in Washington State. The I-BEST model integrates technical training with adult education coursework for students with low basic skill levels. Normally, adult education classes would have to be completed first, delaying or in many cases preventing students from ever enrolling in a technical class. A similar approach to integrated training for low-skilled adults was adopted in the Accelerating Opportunity (AO) initiative. By integrating technical and basic skills training in a clearly articulated career pathway, the I-BEST and AO models aim to accelerate low-skill students through technical training that leads to high-quality middle-skilled jobs.
Evaluations of the I-BEST and AO models have yielded mixed results, with more positive impacts on educational outcomes than labor market outcomes. I-BEST and AO increased the number of credentials earned by participants and accelerated their progress through their coursework (Zeidenberg, Cho, and Jenkins 2010; Ginther and Oslund 2016; and Anderson et al. 2017). Despite these positive findings for educational outcomes, there is less evidence that the I-BEST/AO approach raises the earnings or employment of participants. Zeidenberg, Cho, and Jenkins (2010) found no effect of I-BEST on the employment or earnings of participants in Washington State. Anderson and colleagues (2017) found positive employment and earnings effects in several states, but the effects were not large or persistent.

Two independent evaluations of AO in Kansas found that low-skilled students drawn from CTE courses (rather than adult education programs) saw improved educational and labor market outcomes because of AO (Anderson et al. 2017; Ginther and Oslund 2016). Although I-BEST and AO are typically considered strategies for supporting students who originate in an adult education program, the positive impacts of AO on CTE students in Kansas suggest that integrated career pathways may be well suited, and perhaps even better suited, to improving the labor market outcomes of low-skilled STEM and near-STEM technical students.

Drug Testing and Criminal Background Checks

Because many STEM and near-STEM jobs require the use or operation of large equipment, involve tasks that could result in bodily harm, or involve providing care or services to consumers in their homes, these jobs often require employees and potential employees to pass drug tests and criminal background checks. Filling vacancies is often hampered by the high number of applicants who fail mandatory drug tests (Schwartz 2017, King 2017). State efforts to decriminalize marijuana may lead young people to engage in recreational drug use, unaware that employers retain the right, and in some cases the obligation, to have strict antidrug policies. Some STEM or near-STEM jobs require employees to pass a criminal background check, which may also push potential workers out of the STEM pipeline. Health care employers are especially insistent on criminal background checks, but many IT jobs now require these checks as well, and some jobs require a national security clearance.

Drug use and criminal background checks make the hiring process particularly difficult for some workers, and they render many ineligible for STEM or near-STEM employment. A more proactive approach is required to warn young people of the impact that their personal decisions could have on their long-term employability.
STEM Apprenticeship

In the United States, registered apprenticeship has not played a significant role in preparing STEM or near-STEM workers. But under the Obama and Trump administrations, and with significant support from Congress, the US Department of Labor has been working to expand apprenticeship into STEM and near-STEM fields such as advanced manufacturing, energy technologies, health, and information technology. Although apprenticeship is associated with the building trades in the modern US, historically it has helped advance the frontier of knowledge and technology, as masters passed on techniques and innovative methods to their apprentices (Meisenzahl and Mokyr 2011; de la Croix, Doepke, and Mokyr 2016).

The most important and distinctive feature of apprenticeship is that the apprentice has a full-time (or near full-time) job from the start of training. This differs from other programs that provide training to people who hope they can find a job after the training is complete. Because apprentices are employees, they earn wages and generally receive benefits while they are learning. Although learning primarily takes place on the job using the equipment and operating procedures relevant to the employer, apprenticeships also include classroom learning, and many confer college credit and credentials. Perhaps most importantly, apprenticeship helps acculturate individuals to workplace expectations, including behavioral and attitudinal expectations. This aspect of apprenticeship may be the hardest to replicate in a traditional classroom setting.

An apprentice trains under the guidance of skilled workers who model positive workplace performance and help apprentices solve problems. Apprenticeships should have high completion rates because many are highly selective, and, unlike college, most provide free education and pay full-time wages. However, apprenticeship completion rates hover at just below 45 percent. More research is needed to understand the causes of dropping out, but some of the following factors may be important: First, those with little exposure to the workplace before the apprenticeship may realize, once on the job, that the occupation they chose is not what they thought it would be. Transportation challenges and family demands may cause some apprentices to drop out. Finally, as apprenticeship grows in popularity, due in part to greater federal policy focus, completion rates may even decline, especially if less selective programs grow in size and popularity.

The average wage earned by an apprenticeship completer today is around $60,000, but that average is heavily influenced by wages earned by workers in construction, welding, machining, and other well-paying jobs. As apprenticeship expands into entry-level health fields and child care, the
average wage will decline. This should not be construed as a shortcoming of apprenticeship training; it simply reflects that wages differ significantly from one field to another and that female-dominated occupations tend to pay the least. Policymakers could focus on eliminating the structural barriers that prevent workers from climbing the ladder to higher-paying jobs, for example, by rolling back licensure requirements that are overly restrictive or ignore the benefits of work-based learning.

Trends in STEM Apprenticeships

The penetration of registered apprenticeship into STEM occupations varies considerably by field. Outside of near-STEM technical fields, apprenticeship is relatively uncommon and it is practically non-existent in non-technician science and engineering occupations. Apprenticeship is growing in near-STEM technical fields and in health-related occupations, but growth has been minimal for science and engineering technicians and computer science and information technology fields after a period of growth in the mid-2000’s. This section describes the prevalence of STEM apprenticeships and trends over time.

The best data available on registered apprentices come from the Registered Apprenticeship Partners Information Data System (RAPIDS) database. The primary limitation of RAPIDS is that it only covers 33 states and therefore only reflects a subset of the national registered apprentice population. The numbers reported in table 3 and figures 8 and 9 therefore do not represent the full sample of registered apprentices in STEM and near-STEM occupations, but they provide a good sense of the relative prominence of and trends in these occupations for much of the US. Although RAPIDS includes data on active apprentices as well as completers, we limit our discussion to completers because the data reviewed for higher education programs included only completers.

Apprenticeship programs in RAPIDS are classified by occupational codes rather than CIP codes. Although apprentices are assigned a distinct apprenticeship occupation code, they are also assigned the more universal Standard Occupational Classification code. These occupational codes can be mapped onto the STEM and near-STEM educational fields used elsewhere in this report. Standard Occupational Classification codes corresponding to the CIP categories in box 1 are provided in box 3.
BOX 3

Standard Occupational Classification Codes for STEM Occupations

- “Science and engineering”
  - 15-2000: Mathematical Science Occupations
  - 17-2000: Engineers
  - 19-1000: Life scientists
  - 19-2000: Physical scientists

- “Science and engineering technicians”
  - 17-3000: Drafters, Engineering Technicians, and Mapping Technicians
  - 19-4000: Life, Physical, and Social Science Technicians

- “Computer science and information technology”
  - 15-1100: Computer Occupations

- “Near-STEM technical fields”
  - 49-0000: Installation, Maintenance, and Repair
  - 51-0000: Production Occupations

- “Health Professions and Related Programs”
  - 29-0000: Healthcare Practitioners and Technical Occupations
  - 31-0000: Healthcare Support Occupations

Source: Author’s categorization of Standard Occupational Classification codes, https://www.bls.gov/soc/.

Table 3 shows the total number of apprenticeship completers in each major STEM and near-STEM occupational area and the completion rate of apprentice cohorts in states that use RAPIDS. From 2003-2016, there were over 100,000 apprentice completions in STEM and near-STEM fields. STEM apprentices in near-STEM technical fields make up the majority of STEM and near-STEM apprentice completers. Near-STEM technical fields are composed of two major occupational sectors: (1) installation, maintenance, and repair; and (2) production. Two-thirds of all near-STEM apprentice completers come from installation, maintenance, and repair occupations, and one-third come from production occupations. As with college programs, it is not clear how much STEM content is included in
any given apprenticeship in a near-STEM technical field. For example, certain industrial maintenance programs are similar in content to engineering technician programs and have much STEM content. Other positions have less STEM content and may focus more on facilities than on precision equipment management or maintenance.

There were over 5,000 health program completers and over 4,300 science and engineering technician completers between 2003 and 2016. Computer science and information technology apprenticeships only accounted for about 1,200 completers between 2003 and 2016, although recent efforts focused on expanding IT apprenticeships will likely increase this number in the coming years. There were very few apprentice completers, 92 in total, in the more “academic” science or engineering occupations (i.e., non-technician occupations).

### TABLE 3

**STEM Apprenticeship Completions for Apprentices in States That Report to RAPIDS, 2003–16**

<table>
<thead>
<tr>
<th></th>
<th>Total completers in RAPIDS, 2003–2016</th>
<th>Share of all STEM and near-STEM completers in RAPIDS, 2003–16</th>
<th>Apprenticeship completion rate for apprentices registered, 2003–16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and engineering</td>
<td>92</td>
<td>0.09%</td>
<td>16.15%</td>
</tr>
<tr>
<td>Computer science and information technology</td>
<td>1,228</td>
<td>1.16%</td>
<td>68.46%</td>
</tr>
<tr>
<td>Science and engineering technicians</td>
<td>4,368</td>
<td>4.13%</td>
<td>50.76%</td>
</tr>
<tr>
<td>Near-STEM technical fields</td>
<td>95,082</td>
<td>89.88%</td>
<td>43.95%</td>
</tr>
<tr>
<td>Health professions and related programs</td>
<td>5,170</td>
<td>4.74%</td>
<td>44.46%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>105,787</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>44.52%</strong></td>
</tr>
</tbody>
</table>

*Source: Author’s calculations from RAPIDS.*

*Notes: RAPIDS = Registered Apprenticeship Partners Information Data System; STEM = science, technology, engineering, and mathematics.*

The third column of table 3 reports completion rates for each STEM and near-STEM occupation group. Completion rates are high for computer science and information technology apprentices (68 percent). This could be because only a small number of programs have rigorous admissions criteria and admit people who already have significant IT experience. Computer science and IT apprenticeship programs also tend to be shorter in length, which may make them easier to complete. Science and engineering technicians also have high apprenticeship completion rates (almost 51 percent) but, like IT programs, relatively few apprentices. Science and engineering apprenticeships have the lowest completion rates, but too few completers to compare against larger occupations. Understanding why apprentices leave their programs and where they go after departure would help employers better screen candidates or better design their programs so that apprentices complete.
Figure 9 presents the annual number of near-STEM technical field apprenticeship completers from 2003 to 2016. Between 6,000 and 8,000 near-STEM technical apprentices complete their programs each year. Completions in these occupations have increased modestly in recent years, perhaps in response to efforts by the Department of Labor to raise the profile of apprenticeship in manufacturing. One initiative that may have prompted the recent increase was a 2003 grant to the National Institute for Metalworking Skills to develop competency-based metalworking apprenticeships. In 2016, the National Institute for Metalworking Skills was awarded additional funding to serve as an industry intermediary to enlist new employers and help them develop and implement apprenticeship programs in advanced manufacturing. Although the RAPIDS data indicate that apprenticeships in these occupations began with a healthy base of almost 5,000 completers in 2003, increased completions are a positive sign. It is hard to know how many unregistered programs were also prompted by employer access to materials and support from the National Institute for Metalworking Skills.

**FIGURE 9**

Near-STEM Technical Field Apprenticeship Completers in States That Report to RAPIDS, 2003–16

![Graph showing the trend in apprenticeship completers from 2003 to 2016.](image)

**Source:** Authors’ calculations from the Registered Apprenticeship Partners Information Data System (RAPIDS).

Figure 10 presents the trends in apprenticeship completers for all STEM occupational categories except the larger near-STEM technical fields that were presented in figure 9. All these occupations
generate a limited number of apprentices a year. Because these labor markets are not currently saturated with apprentices, they could grow their apprenticeship numbers rapidly. The largest occupational groups reported in figure 10 are health and science and engineering technicians.

Science and engineering technician programs have had between 300 and 400 apprenticeship completers a year, with no persistent upward or downward trend since 2003. Health apprentices, however, experienced two periods of significant growth in completions. The first growth period occurred after 2003, when some of the initial standards for health apprenticeships were approved. The second was a sharp increase in completions between 2012 and 2013 due to a large increase in pharmacy technician apprenticeships. After 2012, health apprenticeship completions have been high (exceeding 400 completions a year) but volatile.

**FIGURE 10**

**STEM and Near-STEM Apprenticeship Completers in States That Report to RAPIDS, 2003–16**
As noted in table 3, registered apprentices in states covered by RAPIDS have produced very few scientists and engineers, an occupation which in the United States typically requires a bachelor’s degree. Computer science and information technology apprenticeship programs have shown some growth since 2005, producing about 100 apprenticeship completers a year. But computer science and information technology apprenticeships have not demonstrated the strong growth of health apprenticeships in the last decade. This may change as competency-based programs expand, or if the many nonapprenticeship information technology training programs with strong work-based learning components become integrated into the apprenticeship system (see Minic 2014 for examples).

Meeting Apprenticeship Sponsors’ Needs

The most recent comprehensive exploration of the needs of apprentice sponsors comes from a survey fielded in 2007 and reported by Lerman, Eyster, and Chambers (2009). They find that sponsors need the most help in finding and screening potential apprentices and identifying appropriate related training instruction. Sponsors also want a more expedited registration process for individual apprentices and apprenticeship programs. Although all sponsors face these challenges, the obstacles may be particularly acute for STEM occupations, which have less history with the registered apprenticeship training model. Several strategies could meet these needs, including technical assistance and better dissemination of best practices. In recent years, the Department of Labor has instead made more active investments in apprenticeship “infrastructure” to support sponsors, including funding for industry intermediaries, National Occupational Frameworks, and apprenticeship expansion grants.

The Role of Intermediaries and National Occupational Frameworks

Intermediaries are organizations that help employers (or entire industries) complete the apprenticeship registration process; develop on-the-job training plans; find an appropriate related technical instruction provider; recruit and screen potential apprentices; and identify additional sources of federal, state, and local funding that can be leveraged to advance apprenticeship. Many different organizations can serve as intermediaries, including industry associations, nonprofits, unions, and community colleges. Recognizing the importance of intermediaries in growing the scale of apprenticeship in the US, the Department of Labor awarded the 2016 ApprenticeshipUSA contracts to 14 intermediaries to expand their capability and provide direct assistance to employers. Of these 14 intermediaries, 10 are classified as industry intermediaries to work with employers in specific sectors, and four are classified as equity
intermediaries to support the larger effort of making apprenticeship more inclusive for women, minorities, disconnected youth, and people with disabilities.\textsuperscript{13}

Sponsors also struggle with designing apprenticeship programs, particularly in occupations that do not have a long history of registered apprenticeship. The Urban Institute has been contracted by the Department of Labor to help facilitate the transition to competency-based apprenticeship by developing National Occupational Frameworks for 50 "apprenticeable" occupations. These frameworks combine information derived from academic and occupational literature; functional occupational analysis; credentialing exams; and guidance from professional advisory groups to outline the critical job functions, competencies, and performance criteria associated with an occupation. Employers, sponsors, and educators can use the frameworks as a starting point in designing education and training programs, customizing where necessary to meet the unique needs of each employer. Although designed to support expansion of registered apprenticeship, these frameworks can also guide the development of traditional academic programs and other work-based learning opportunities.\textsuperscript{14}

Intermediaries and National Occupational Frameworks are particularly important for expanding apprenticeship into STEM and near-STEM occupations, even though they are intended to support a broader expansion. Outside of near-STEM technical occupations, apprenticeship has not been substantially used in STEM fields, so employers of STEM workers will need guidance on how to use the apprenticeship training model to invest in their workers’ skills.

Related Technical Instruction

Sponsors may have difficulty finding qualified related technical instruction providers that will offer the classes apprentices need at the times and locations that align with on-the-job training schedules (which may be driven by production cycles or labor-management contract requirements). Community and career colleges are important related technical instruction resources, but an employer sponsoring a small number of apprentices may not be able to convince the community college to offer the classes her apprentices need. Moreover, the theory taught in college courses may not align with the applied learning that takes place on the job, which can create frustration and reduce the effectiveness of the experience.

Some community colleges now operate as apprenticeship sponsors to serve the needs of small to medium-sized companies. As sponsors, community colleges take on the burden of paperwork, federal or state reporting requirements, and related technical instruction, and even provide student academic and
behavioral support services. But even community college leaders committed to the apprenticeship model may not be able to convince the faculty to develop or approve programs that meet apprenticeship needs. Thus, administrators may be forced to offer these programs through the noncredit or continuing-education division of the institution, which makes it difficult for apprentices to earn college credit for their work.

In the United Kingdom and Australia, government subsidizes or underwrites some or all of the cost of related technical instruction and supports experienced intermediaries who help employers recruit apprentices, deliver their programs, and issue credentials. In the US, postsecondary education funds primarily support students enrolled in traditional degree programs, but some other programs and resources help reduce the cost of apprenticeship for employers. These programs and resources include Workforce Innovation and Opportunity Act funds, GI Bill benefits for veterans, Department of Labor grants, state and local workforce and economic development grants, and, in some states, employer tax credits for apprenticeship sponsors.

Looking Ahead: The Trump Administration and Apprenticeship

The Trump administration appears prepared to make investments in expanding apprenticeship training. The administration’s March 2017 budget blueprint notes that the president’s 2018 budget “[h]elps States expand apprenticeship, an evidence-based approach to preparing workers for jobs” (Office of Management and Budget 2017). The blueprint did not clearly state whether funding for apprenticeship would increase, but this detail was included in the final budget released in May 2017. The final budget maintains funding for apprenticeship grants and Office of Apprenticeship administration at the same level as at the end of the Obama administration.

On June 15, 2017, President Trump signed an executive order on apprenticeship expansion that created a new pathway to registered apprenticeship through industry-recognized programs. Through this pathway, industry groups and organizations will be able to set their own standards for apprenticeship and still enjoy the benefits of the registered apprenticeship program, including access to federal funds. An Apprenticeship Expansion Task Force has been named to advise the Department of Labor on how best to expand and promote apprenticeship. Including industry in the apprenticeship program registration process could generate apprenticeships in new fields (such as STEM fields) where
the registration process is less familiar, or where federal and state representatives have been less attentive.

In April, 2018, the Apprenticeship Expansion Taskforce released white papers on education and credentialing; attracting business to apprenticeship; access, equity, and career awareness; and administrative and regulatory strategies to expand apprenticeship. The white papers emphasize the importance of high standards for industry-registered apprenticeship programs and the value of competency-based training models and portable, industry recognized credentials (Apprenticeship Expansion Task Force 2018).

Conclusion

Sub-baccalaureate credential programs, encompassing associate’s degree programs, certificate programs, CTE programs, and apprenticeships, are often absent from public discussion of the STEM pipeline. Attention and funding is instead directed toward K-12, bachelor’s degree programs, and graduate programs. This neglect reflects bias toward bachelor’s degrees and assumptions that science and engineering are cerebral, not hands on. Moreover, the boundaries of sub-baccalaureate STEM education are unclear, which results in overly expansive definitions that are not useful or overly narrow definitions that exclude skilled technicians. This report reviews the diverse landscape of sub-baccalaureate STEM education and highlights how policies, regulations, and public investments have shaped what institutions teach and how students learn.

Sub-baccalaureate STEM workers are produced in credit and noncredit departments of nonprofit community colleges and for-profit colleges. STEM education is usually more expensive to deliver, and it is constantly evolving relative to other fields of study, incentivizing providers to deliver it through more flexible noncredit or for-profit programs. Despite this flexibility, operating STEM programs in for-profit institutions comes with its own costs for the college and for students. Tighter federal regulations on for-profits have important unintended consequences that drive up tuition relative to community colleges.

Federal investments have also shaped the sub-baccalaureate STEM landscape. Although most federal funding for STEM education is directed toward bachelor’s and graduate degree programs, projects and programs supported by Perkins, TAACCCT, and ATE grants and education and training partnerships at the national laboratories have all shaped the STEM workforce in regional labor markets. The experiences of these federal grantees and laboratories demonstrate how sub-baccalaureate educational investments can be sustained, for example, through professional development and through the promotion of grantees that change college processes over grantees that just produce outputs.
A relative newcomer to the landscape of STEM education is registered apprenticeship, which combines structured on-the-job training with related classroom-based instruction, all while an apprentice is productively employed. Apprenticeship is a promising strategy for delivering sub-baccalaureate STEM skills because it targets hands-on technical education for working with equipment and noncognitive employability skills. There are relatively few STEM apprenticeship programs now, but they are growing. Future growth will depend on a reliable infrastructure of intermediaries and occupational frameworks for STEM occupations.
Notes

1. In his early proposal for the National Research Foundation (which would evolve into the National Science Foundation), Vannevar Bush envisioned a unified approach to scientific and medical research rather than a segregation of those activities into two separate federal institutions (Bush 1947).

2. This report primarily compares for-profit colleges and community colleges because community colleges are the largest providers of associate's degrees and certificates in the nonprofit sector. However, this comparison obscures the fact that for-profit colleges offer programs from certificates through doctoral degrees, and some institutions offer only a single academic program or programs within a single occupation, making the community college comparison less appropriate for the institution as a whole. Although many for-profit institutions, like community colleges, offer certificate and associate's degrees, the plurality of students enrolled in this sector attend large online institutions that offer degrees through the doctoral level. Even among the smaller brick-and-mortar institutions that offer certificate and associate's degrees, many are not classified as two-year institutions because they are also authorized and accredited to offer four-year programs. Cellini (2010) suggests that most two-year for-profit institutions are cosmetology and barber schools, which differ substantially from the typical community colleges. This report only includes sub-baccalaureate STEM and near-STEM for-profit college students who are in programs comparable to STEM and near-STEM community college programs.

3. This could be because proprietary institutions are a major producer of medical assistants, and changes in policies set forth by the American Association of Medical Assistants created a market for accredited postsecondary medical assisting programs in the mid-1990s. In 1994, the American Association of Medical Assistants collaborated with the Commission on the Accreditation of Allied Health Education Programs to promote the accreditation of medical assisting education programs. The American Association of Medical Assistants also set new credentialing standards in 1995 (effective 1998) requiring all future certified medical assistants to graduate from a Commission-accredited program. In other words, the credentialing organization created formal education requirements for medical assistants that limited credentialing eligibility to students who graduated from an academic program accredited by a partner organization. These requirements created a market for formal, accredited certificate programs in medical assisting; before 1995, people could qualify to sit for the credentialing exam by completing an academic program or by working in the field for a minimum number of years. In 2001, the Institute of Medicine issued a report, Improving the Quality of Long-Term Care, which recommended increasing the educational requirements for nursing assistants as part of a strategy to reduce the high turnover of nursing assistants in these facilities. Many states responded by creating nursing assistant training requirements that exceeded the federal government's requirement of 75 hours; community colleges were called upon to create certificate programs to support these requirements.

4. Louisiana and South Dakota were excluded, for a total of 48 states.

5. Although designations vary, “noncredit” typically refers to courses that do not earn academic credit. “Not-for-credit” refers to courses that do not earn academic credit and do not receive state funding.

6. The rule was originally introduced as the 85/15 rule.

7. See Cellini and Goldin (2014) for evidence that federal student aid raises tuition in for-profit institutions by about 78 percent.

8. See Federal Register Volume 79 Number 211, Part II for the final rule. The gainful employment rule assumes that sub-baccalaureate credential holders will repay their loans in 10 years, even though alternative repayment programs established by Congress allow students to take 20 or more years to do so. The rule also inflates interest rates by assuming that all loans are at the rate of an unsubsidized Stafford loan, even for students who have lower-interest subsidized loans. Both provisions yield a calculated debt load that exceeds what nearly any borrower would actually be required to pay.
9. Seventy-three grantees either did not train in a STEM or near-STEM field or did not report an occupational training area. Coding of the grantee-reported occupational training areas may not perfectly align with the CIP codes reported to the US Department of Education because of overlapping occupational titles used in engineering technology and production occupations.

10. Years before 2001 are excluded because of the higher number of institutions that did not report information on the availability of child care facilities.

11. Author’s calculation from the Registered Apprenticeship Partners Information Data System.


References


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