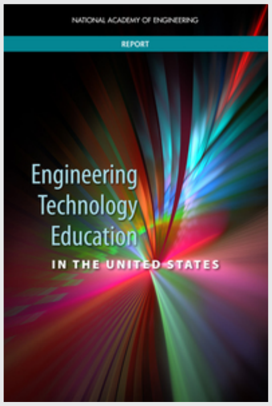

Engineering Technology Education in the United States

DETAILS

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Engineering Technology Education

IN THE UNITED STATES

Committee on Engineering Technology
Education in the United States
Katharine G. Frase, Ronald M. Latanision,
and Greg Pearson, *Editors*

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Preface

This report is the final product of a two-year study by the Committee on Engineering Technology Education in the United States, a group of experts under the auspices of the National Academy of Engineering (NAE). The committee's charge was to shed light on the status, role, and needs of engineering technology (ET) education in the United States. In fulfilling that charge, the committee commissioned a review of federal education and occupational data, fielded two surveys—one of ET educators and the other of employers of ET talent—held an information-gathering workshop, and conducted a literature review.

The ability of the United States to support innovation requires production and retention of individuals who are highly skilled in science, technology, engineering, and mathematics (STEM). These STEM professionals work in a widely disseminated global enterprise spanning government, industry, and academia. Engineers play an especially vital role as the designers of technological systems and processes. Over the past decade, policymakers, employers, researchers, and educators have focused considerable attention on the US engineering education system and the adequacy of the supply of individuals with engineering skills. Largely absent from most discussions of the future of the US technical workforce, however, has been the role that ET education plays or should play in supporting the nation's technical infrastructure and capacity for innovation. This report aims to correct that omission.

The report's primary audiences are the ET and engineering education communities, to whom the bulk of the report's recommendations are directed. Importantly, the report's data gathering, findings, and recommendation address issues relevant not only to those involved in preparing students through 4-year ET programs but also to those preparing students through 2-year and certificate programs and, to some extent, educators working in K-12 settings. The report should be of interest to small, mid-size, and large firms that hire engineering-related talent. Our survey of employers found that many firms were unaware of ET education or confused about the differences between workers with ET and engineering training. Another important audience is the federal agencies responsible for collecting and coding data about ET education and employment. Finally, state and national leaders with a role in setting STEM education policy may find the report helpful to informing future decision making.

Katharine G. Frase, *Co-Chair*
Ronald M. Latanision, *Co-Chair*

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies of Sciences, Engineering, and Medicine. The purpose of the independent review is to provide candid and critical comments to assist the National Academy of Engineering (NAE) in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Ashok Agrawal, American Society for Engineering Education
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Nick Wilson, Morrison Container Handling Solutions

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the views expressed in the report, nor did they see the final draft of the report before its release. The review of this report was overseen by NAE member Julia Phillips, Retired Vice President and Chief Technology Officer, Sandia National Laboratories. Appointed by NAE, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and NAE.

In addition to the reviewers, many other individuals assisted in the development of this report. Consultant Daniel Kuehn, Urban Institute, collected and analyzed the federal education and occupational data presented in the report and wrote substantial portions of several chapters. His willingness to answer staff and committee questions about the data throughout the project was instrumental to the study's success. Intern Marthe Folivi, Rippon College, painstakingly identified individuals associated with 2- and 4-year engineering technology (ET) education programs in the United States. Her work made possible the committee's survey of ET educators. Megan Ellinger, with the Academies Information and Technology Services unit, programmed and fielded the survey of educators and collected and analyzed the resulting data. Ed Koc, at the National Association of Colleges and Employers, programmed and fielded the project's survey of employers and analyzed the resulting data for the committee's benefit.

Credit for bringing the field of engineering technology to the attention of NAE and making the case for a study, which was ultimately funded by the National Science Foundation, goes to several ET educators, including Ken Burbank, Robert Herrick, and Michael O'Hair (ret.), Purdue Polytechnic; Ronald Land, Pennsylvania State University; and committee members Jeffrey Ray, Western Carolina University, and Walter Buchanan, Texas A&M University.

Thanks are also due to the project staff. Maribeth Keitz managed the study's logistical and administrative needs, making sure meetings and the committee workshop ran efficiently and smoothly. Christine Mirzayan Science & Technology Policy Graduate Fellow Aaron Adams conducted a background literature search for the project. Freelance editor Linda O'Doughda improved the readability of the report. Greg Pearson oversaw the project and worked with the committee to prepare the report.

Contents

APPENDIXES

Summary

The vitality of the innovation economy in the United States depends on the availability of a highly educated technical workforce. A key component of this workforce consists of engineers, engineering technicians, and engineering technologists. Much has been written about the role of engineers, their academic preparation, and their value to the nation. The purpose of this report is to shed light on the relatively underappreciated roles and contributions of engineering technicians and technologists. Very abstractly, if engineers are viewed as being responsible for designing the nation's technological systems, then engineering technicians and technologists are the ones who help build and keep those systems running.

Unlike the much better-known field of engineering, engineering technology (ET) is unfamiliar to most Americans and goes unmentioned in most policy discussions about the US technical workforce. This despite the fact that workers in this field play an important role in supporting the nation's infrastructure and capacity for innovation.

The emergence of ET as an academic discipline can be traced to the mid-1950s, when curricula in traditional engineering programs began to focus more heavily on advanced science and mathematics coursework. The resulting de-emphasis on student hands-on laboratory work was a key factor in establishment of the first 2-year (associate's degree) ET programs, which were designed to assure the engineering team included individuals skilled in application as well as theory (Henninger, 1959). Four-year (bachelor's degree) ET programs, which first appeared in the 1960s, also had a distinct focus on application.

The number of degrees awarded in engineering technology, while smaller than in engineering, is substantial. In 2014, there were 17,915 graduates with 4-year ET degrees and 34,638 graduates with 2-year ET degrees in the United States, according to the Department of Education's Integrated Postsecondary Education Data System (IPEDS). By comparison, in that same year, there were 93,950 graduates of 4-year engineering programs and 4,409 graduates with 2-year engineering degrees. In 2014, US schools, mostly community colleges, awarded 49,217 subassociate's-degree certificates in ET.

In 2013, the total stock of those with 4-year ET degrees was estimated to be about 480,000, and the stock of those with 4-year degrees in engineering was a little over 5 million. There are no data on the stock of those with 2-year degrees in either ET or engineering. Because not all those with degrees in a particular field end up working in that field, another useful metric is the number of people employed in ET, regardless of their educational background. By this measure, there were about 400,000 ET workers in the United States in 2013.

In our report, we use the term "technologist" to refer to a person with a 4-year degree in engineering technology or with a 4-year degree in another subject whom the federal government considers to be working as a technician or technologist.[1] We define a "technician" to be a person with a 2-year ET degree or someone without a 4-year degree whom the federal government classifies as working as a technician or technologist. Of the roughly 400,000 people employed in ET in 2013, we estimate the vast majority, about 80 percent, were working as engineering technicians.

The work of engineering technologists has been described by drawing comparisons to engineering. One model, developed by the American Society of Mechanical Engineering (Figure S-1), sees the jobs of engineering technologist and engineer as falling along a continuum. It is characterized at one end (engineering technology) by work involving distribution and sales; operation, service, and maintenance; and production engineering and at the other (engineering), by work emphasizing theory, analysis, and complex

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[1] The federal government does not separately collect or "code" data for those employed as engineering technicians and engineering technologists. Rather, it lumps these two groups of workers together. The committee was able to approximate the size of these two populations by analyzing differences in 2- and 4-year degree completion.

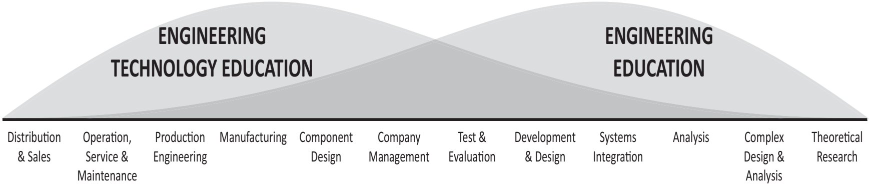

FIGURE S-1 An engineering technology—engineering continuum model. SOURCE: ASME, 2012. Used with permission.

design. In this model, a number of work-related activities can be performed by both engineers and technologists.

There is no widely accepted job description for an engineering technician. However, the International Engineering Alliance, which manages mutual accreditation recognition agreements among signatory countries for engineers, engineering technologists, and engineering technicians, offers this description:

> The roles of Engineering Technicians involve them in the implementation of proven techniques and procedures to the solution of practical problems. They carry a measure of supervisory and technical responsibility and are competent to exercise creative aptitudes and skills within defined fields of technology, initially under the guidance of engineering practitioners with appropriate experience. Engineering Technicians contribute to the design, development, manufacture, commissioning, operation and maintenance of products, equipment, processes and services. (IEA, 2014, pp. 13-14)

STATEMENT OF TASK

To shed light on the status, role, and needs of ET education in the United States, the National Academy of Engineering, with funding from the National Science Foundation, assembled a 14-member study committee to examine these issues. The committee's statement of task had the following objectives:

> ***Objective 1:*** Review the status and history of the production and employment of engineering technologists and technicians in the United States. Such a review should address not only the number and discipline-focus of graduates from engineering technology programs but also their demographic characteristics (race, gender, socio-economic status), aca-

demic preparation (e.g., participation in career and technical education programs, experience with K-12 engineering coursework), and distribution by sector, job role/category, and geographic region.

Objective 2: Gather available data and explore private- and public-sector employer perceptions regarding the adequacy of the supply of engineering technologists and technicians as well as the appropriateness of the knowledge and skills they bring to the workplace.

Objective 3: Describe the characteristics of US engineering technology education programs related to such things as curriculum and faculty professional development; outreach to/partnerships with K-12 schools, industry, and other organizations; and communication and collaboration with engineering education programs.

The committee met four times over a roughly 2-year period. Data gathering for the project included an information-gathering workshop in December 2014; a commissioned review of ET-related federal education and occupational statistics; two surveys, one of ET educators and the other of employers of engineering technicians and technologists; and a literature review. The committee's full report presents and analyzes these data in detail and includes findings and recommendations in four areas:

- the nature of engineering technology education,
- supply and demand,
- educational and employment pathways, and
- data collection and analysis.

FINDINGS AND RECOMMENDATIONS RELATED TO THE NATURE OF ET EDUCATION

From the perspectives of workforce and education policy in the United States, there appears to be little awareness of ET as a field of study or a category of employment. As just one example, 30 percent of almost 250 respondents to our employer survey had never heard of the field of ET education; this lack of awareness rose to almost 50 percent for smaller employers. Even among respondents who indicated an awareness of ET, one-third said they did not know the difference between work performed by engineers and work performed by engineering technologists. These data can be explained by a combination of factors, including ET's challenges with branding and marketing; curricula and worker skills that overlap with those of engineering; and gaps in research and data collection that make it difficult to determine how differences between the two fields affect employment opportunities and benefit employers.

Lack of awareness of ET extends into the K-12 education system, where many young people are first exposed to possible career paths. The committee found little evidence of formal outreach or communication to K-12 teachers, students, or students' parents concerning ET and its connection to postsecondary education and employment.

> **RECOMMENDATION 1:** Within academia, it is critical for leaders of 2-year and 4-year ET programs to engage more meaningfully in discussion with leaders in postsecondary engineering education about the similarities and differences between the two variants of engineering and how they might complement one another while serving the interests of a diverse student population. This engagement can be accomplished in dialog within and between individual institutions; through work by discipline-based and affinity engineering professional societies; and by leaders within the American Society for Engineering Education, such as the Engineering Technology Council, the Engineering Deans Council, and the Corporate Member Council.

> **RECOMMENDATION 2:** The ET education community should consider ways to make the field's value proposition more evident to K-12 teachers, students, and students' parents, as well as to employers. Such an effort might include new messaging developed in collaboration with a qualified public relations firm and based on data from market research on student and employer knowledge and perceptions of ET. The research might test the appeal and believability of rebranding ET as "applied engineering" or other appropriate names identified by the market research. Attention also should be paid to ways to reduce confusion associated with the term "engineering technology" and to simplifying degree nomenclature. To encourage collaboration and avoid duplication, plans for any major new outreach should be communicated with appropriate leadership within the engineering education community, such as the Engineering Deans Council and Engineering Technology Council of the American Society for Engineering Education.

FINDINGS RELATED TO SUPPLY AND DEMAND

The committee examined supply and demand within the ET workforce. This task was complicated both by the definitional confusion surrounding the field and by certain gaps in data collected by the federal government. Even with these limitations, we found no clear indication of a shortage or a surplus of engineering technicians or technologists. This does not preclude the possibility of market imbalances in certain geographic areas. Empirical data do show a significant graying of the ET workforce, which suggests to some that these skills may well be needed in greater numbers in the future. However, labor economists (e.g., Freeman, 2007) have found that an aging workforce is often an indication of business expectations of weak future demand.

FINDINGS AND RECOMMENDATIONS RELATED TO EDUCATIONAL AND EMPLOYMENT PATHWAYS

Compared with engineering, ET education programs, particularly at the 2-year level, are more attractive to older students and students currently underrepresented in science, technology, engineering, and mathematics (STEM) fields. In contrast to the situation for most college graduates, who are in their early 20s, more than one-quarter of graduates with 4-year ET degrees are older than 35. The proportion of adults enrolling in 2-year programs may be even higher. The share of students earning 4-year degrees in ET that is black is almost three times the share of students earning 4-year degrees in engineering (10.7 percent versus 3.8 percent). Blacks comprise more than 11 percent of those earning 2-year degrees and more than 17 percent of those earning certificates in ET; in engineering, the proportion earning 2-year degrees is slightly less than 6 percent. Women earn almost 20 percent of 4-year degrees in engineering but just 12 percent of 2- and 4-year ET degrees.

> **RECOMMENDATION 3:** Research is needed to understand why certain segments of the population graduate at higher frequencies from ET programs than they do from engineering programs and why women are even less engaged in ET than they are in engineering. Understanding the reasons for these preferences and trends may allow programs in both domains of engineering to better attract and retain more diverse student

populations. The National Science Foundation should consider funding research on factors affecting matriculation, retention, and graduation in ET. The research might consider, among other factors, socioeconomic issues, such as the need for some students to work while attending school; issues related to the adequacy of secondary school preparation in mathematics and science; the presence and nature of mentoring, peer and parental support, career counseling, and other mechanisms known to increase enrollment and retention of women and underrepresented groups in STEM fields; and the nature of curricular differences between 2- and 4-year ET programs and between 4-year ET and 4-year engineering programs.

The committee found that the connection between an engineering technology education and the ET workforce is fairly weak. Those with ET degrees work in a broad range of occupations, and those employed as engineering technologists have a diverse degree background. For instance, just 12 percent of technologists have a 4-year degree in ET, according to the National Survey of College Graduates (NSCG). The largest share of technologists, 39 percent according to NSCG, has degrees in engineering; smaller, but still significant, shares have degrees in business/management or the life sciences.

The relatively small salary premium for technologists, as compared with technicians, may be reducing incentives for entry into 4-year ET programs as well as tamping down overall interest in technologist jobs. Conversely, the relatively high salary potential of technician-level jobs may serve to increase interest in these jobs and educational pathways to them. Although salary growth for both types of worker has been flat over the past 40 years (remaining at an average of about $50,000 annually, in 2015 dollars), average real wages for engineers have risen 23 percent, from $70,000 to $86,000 annually.

RECOMMENDATION 4: Research is needed to better understand the reasons for the apparent loose coupling of degree attainment and employment in engineering technology. Such research might consider how factors like the salary differential between ET and engineering jobs and lack of ET wage growth may be influencing students' academic and career choices. These and related questions might be addressed in studies supported by the National Science Foundation (NSF) or by revisions in relevant survey instruments administered by NSF, the National Center for Education Statistics, and the Bureau of Labor Statistics.

FINDINGS AND RECOMMENDATION RELATED TO DATA COLLECTION AND ANALYSIS

There are significant, data-related limitations in our ability to understand differences in degree histories, specific job attributes, and educational and employment choices of those working as engineering technicians and technologists. This is particularly an issue for tracking of 2-year degrees and for the technician workforce.

For example, ET degree data reported through IPEDS currently uses a coding scheme that includes field and subfields titles that do not contain the term "engineering technology." And because of confusion about degree types within engineering-related fields, other datasets such as the American Community Survey (ACS) and NSCG, which rely on self-reports by individual survey participants, may include misclassifications. For instance, some individuals with degrees in ET may report they have a degree in engineering and are therefore counted as engineering-degree recipients.

Despite the popularity of community colleges and the large number of 2-year degrees and certificates awarded by these institutions, there are gaps in our understanding of how these types of credentials relate to further education or employment in ET. For instance, none of the four federal datasets used in our report (ACS, Current Population Survey [CPS], Occupational Employment Statistics [OES], and NSCG) that capture occupational information tally technician- and technologist-level workers separately. As noted, we estimated the number of employed technicians by pulling out those workers who have a 2-year degree but not a 4-year degree. But this approach has shortcomings, including the possibility that someone with a 2-year degree may have risen through the ranks to assume responsibilities consistent with someone with a 4-year degree in ET or engineering. Conversely, someone we counted as a technologist, because the person had a 4-year degree, may have earned that degree in a field unrelated to ET but ended up doing ET-related work after earning one or more certificates or a 2-year degree in the field, or because of relevant on-the-job training.

An underlying problem with ET employment data relates to the coding process, in this case the System of Occupational Classification (SOC). ACS, CPS, and OES all use the SOC to assign individuals to specific job types. But the SOC currently does not provide separate job descriptions for technicians and technologists, lumping them all into a category called "Engineering technicians, except drafters." An interagency work group revising the SOC is considering whether to create separate occupational categories for ET technicians and technologists.

> **RECOMMENDATION 5:** The National Center for Education Statistics should consider collecting more comprehensive survey data on individuals participating in sub-baccalaureate postsecondary education. In addition, existing nationally representative surveys, such as ACS, CPS, and NSCG, should consider collecting more detailed information from 4-year degree holders and add questions pertaining to sub-baccalaureate populations, as appropriate. ACS and NSCG, which rely on self-reported data, might consider including prompts in their survey instruments to encourage more accurate reporting of degree information from ET degree holders.

A FINAL WORD

Engineering technologists and technicians comprise an important, if overlooked, segment of the nation's STEM workforce. The field of ET has strong historical connections to traditional engineering and shares the same general sensibility toward technical problem solving. At the same time, its pedigree is rooted in application-focused and hands-on learning, perhaps to a greater extent than in engineering. We hope this report spurs greater understanding and further exploration of ET education and of the contributions of workers with ET-related skills.

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1

Introduction

Calls to expand and improve the quality of the US technical workforce have been made in one form or another for decades. Over the past 10 years, and particularly since the 2008 economic downturn, the urgency of these concerns has grown (e.g., NAS, NAE, and NRC, 2010). A key worry, expressed by both policymakers and corporate leaders, is that the nation's status as a world leader of innovation is slipping.

The ability of the United States to support innovation requires production and retention of individuals who are highly skilled in science, technology, engineering, and mathematics (STEM). These STEM professionals work in a widely disseminated global enterprise spanning government, industry, and academia. Engineers play an especially vital role as the designers of technological systems and processes that help drive economic growth, maintain and improve quality of life, and assure national security.

Policymakers, employers, researchers, and educators have focused considerable attention during the past decade on the adequacy of the US engineering education system to meet the demands of an increasingly "flat" world in which competencies that go beyond pure technical skills, including creativity, leadership, flexibility, and communication, are becoming more and more essential (NAE, 2004, 2005). Traditional engineering education is being challenged to respond to emerging fields that blur disciplinary boundaries, among them nanotechnology, synthetic biology, and biomimetics. And, although enrollments in US engineering colleges reached an all-time high in 2012, with minor declines since then (NSF, 2016a), some still are concerned that the production of engineering graduates in this country lags behind that of some notable competitor nations, such as China, a shortfall not only in absolute numbers but also in the overall percentage of college graduates who have an engineering degree.[1]

Largely absent from most discussions of the future of the United States' technical workforce, however, is the role that engineering technology (ET) education plays or should play in supporting the nation's technical infrastructure and capacity for innovation. This omission is worrisome because the number of people with this type of education, while smaller than for engineering, is nevertheless substantial. Relatively little is known, for example, about the extent to which the supply of those with ET degrees does—or does not—meet the needs of employers; what type of work those with such degrees perform; how, if at all, changes in technology are affecting the preparation and employment of those with ET degrees; and the nature and significance of the differences between the knowledge, skills, and dispositions of those with ET degrees and those with engineering degrees.

ENGINEERING TECHNOLOGY

The formal emergence of ET as an academic discipline can be traced to recommendations in the1955 Grinter report, which set the stage for engineering's swing toward "engineering science" (i.e., more focus on theory and less on hands-on practice; Harris et al., 1994). In part to meet an anticipated need for more technically trained people in industry (that would not be satisfied by the newly minted engineers coming out of science-based engineering programs) and spurred by the 1957 launch of Sputnik, some technical institutes and vocational schools created 2-year ET programs. These programs tended to emphasize development of hands-on, practical, and problem-solving skills relevant to the needs of industry.

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[1] In 2012, the latest year for which data are available, 4.6 percent of all "first university degrees" earned in the United States were in engineering. In European Union nations, the figure ranged between 3.6 percent in Denmark to 14.8 in Finland, in India it was 10 percent, and in China it was 31.7 percent. Source: NSF, 2016b. Importantly, as shown by Wadhwa et al. (2007), there are important differences in the training and employment of engineers in the United States and what occurs in China and India. These differences suggest the US-China/India "gap" in production of engineering talent may be much smaller than commonly thought.

Although there had been a handful of such institutions in the years following World War II, a dramatic growth occurred after Sputnik. By the mid-1960s, about 60 accredited programs were granting 2-year associate's degrees in the field. And in 1967, the first 4-year ET program was accredited. These 4-year programs, most housed in colleges of technology, experienced a significant growth through the mid-1980s, but their numbers have gradually fallen since then. Additional details about the origins of ET are presented in Chapter 2.

In 2014 there were 17,915 graduates of 4-year (bachelor's degree) ET programs and 34,638 graduates of 2-year (associate's degree) ET programs, according to the Department of Education's Integrated Postsecondary Education Data System (IPEDS). By comparison, in that same year 93,950 students graduated from 4-year engineering programs in the United States. Certificates in ET, which typically require fewer courses and take less time to obtain than does an associate's degree, have been awarded for decades. Since 2000, the growth rate of these certificates has surpassed that of both associate's and bachelor's degrees in ET. And for the first time, in 2010, the absolute number of sub-associate's certificates exceeded the number of associate's degrees awarded in ET. In 2014, US institutions awarded 49,217 sub-associate's ET certificates. The role of certificates in ET education is discussed in greater detail in Chapter 3.

Institutions, Programs, and Accreditation

IPEDS is the most comprehensive source of basic statistics on higher education in the United States. According to IPEDS, there were 414 public, private, or for-profit academic institutions awarding at least one 4-year ET degree in 2014. Within this group, 38 awarded 100 or more degrees that year (Table 1-1). A total of 1,192 institutions awarded at least one 2-year degree in the field in 2012. Fifty-two of these institutions awarded 100 or more degrees (Table 1-2).

In terms of the geographic distribution of ET degrees and certificates, three of the nation's largest four states—California, New York, and Texas—award the largest shares of 4- and 2-year degrees (Table 1-3). California, Texas, and Florida, the nation's third most populous state,[2] are also responsible for large shares of certificate awards, but so, too, are a number of other

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[2] According to the US Census Bureau, in 2015, New York and Florida had nearly identical populations, about 20 million.

TABLE 1-1 Institutions Awarding 100 or More 4-Year Degrees in Engineering Technology, 2014

Columbia Southern University	620
Purdue University Main Campus	342
Texas A & M University College Station	273
Southern Illinois University Carbondale	261
Rochester Institute of Technology	250
University of Houston	247
East Carolina University	222
Ferris State University	214
ECPI University	209
Wentworth Institute of Technology	207
Southern Polytechnic State University	201
Excelsior College	198
DeVry University Illinois (Chicago, IL)	189
Michigan State University	183
Farmingdale State College	167
Old Dominion University	166
Pennsylvania College of Technology	166
New Jersey Institute of Technology	160
Indiana University Purdue University Indianapolis	150
Pittsburg State University	149
University of North Carolina at Charlotte	143
Keene State College	139
University of Wisconsin Stout	139
University of Central Missouri	133
Oklahoma State University Main Campus	128
Central Connecticut State University	119
Purdue University Calumet Campus	117
Middle Tennessee State University	113
Southeast Missouri State University	113
Colorado State University Fort Collins	112
Millersville University of Pennsylvania	112

continued

TABLE 1-1 Continued

University of Toledo	111
California State Polytechnic University Pomona	108
Georgia Southern University	107
University of Wisconsin Platteville	106
Southeastern Oklahoma State University	103
Arizona State University Polytechnic	100
DeVry University California (Pomona, CA)	100

states not among the top producers of 4- and 2-year degree-earners. Table 1-4 shows the percentage of ET-degree- and certificate-granting institutions according to institutional control.

Compared with the tally of degree-granting institutions, determining the number of ET programs overseen by these institutions is more challenging. For one thing, as discussed at greater length in Chapter 3, there is no standard nomenclature for describing these programs. Also, IPEDS does not collect data on numbers of programs, only degrees. For program information, we must turn to other sources, such as the Accreditation Board for Engineering and Technology (ABET), the primary organization involved in assuring the basic soundness of educational programs in engineering and technology.[3] According to ABET, in 2014 there were 387 accredited 4-year ET programs at 153 institutions and 257 accredited 2-year ET programs at 98 institutions.[4] The most common program at both the 2- and the 4-year degree levels was electrical and electronics engineering technology, followed by mechanical engineering technology (Table 1-5). Three of the most-common ET program types at the 2-year level—in architectural, surveying and geomatics, and drafting and design engineering technology—are not among the top 10 at the 4-year level.

These ABET data, of course, capture only programs accredited by that organization. By comparing the ABET list of programs with programs listed on the websites of IPEDS schools that award degrees in ET, the committee was able to estimate the number of programs that are not ABET accredited. At the 2-year level, there were 658 such programs; at the 4-year level, there

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[3] The Association of Technology, Management, and Applied Engineering and the American Council for Construction Education accredit a very small number of ET programs.

[4] Twenty-eight institutions have both 2- and 4-year ABET-accredited programs.

TABLE 1-2 Institutions Awarding 100 or More 2-Year Degrees in Engineering Technology, 2014

Ivy Tech Community College	525
Columbia Southern University	402
Texas State Technical College Waco	351
Olympic College	261
Pittsburgh Technical Institute	254
Technical Career Institutes	254
Bismarck State College	250
Ecotech Institute	219
Mississippi Gulf Coast Community College	214
Excelsior College	203
CUNY New York City College of Technology	202
Cincinnati State Technical and Community College	186
Sowela Technical Community College	186
ECPI University	175
Oklahoma State University Institute of Technology	173
Washtenaw Community College	171
Ferris State University	168
Chattanooga State Community College	167
Ranken Technical College	164
Columbus State Community College	160
Pennsylvania College of Technology	157
Southeast Community College Area	157
ITI Technical College	150
Lee College	148
Owens Community College	143
Northeast Wisconsin Technical College	140
Stark State College	136
ITT Technical Institute National City	128
Lamar Institute of Technology	128
Hudson Valley Community College	126
Kalamazoo Valley Community College	126
Spartan College of Aeronautics and Technology	125

continued

TABLE 1-2 Continued

Thomas Edison State College	123
Nicholls State University	117
Springfield Technical Community College	117
Austin Community College District	116
Valencia College	115
University of Alaska Anchorage	114
CUNY Queensborough Community College	113
Macomb Community College	113
Instituto Tecnologico De Puerto Rico Recinto De Ponce	110
Instituto Tecnologico De Puerto Rico Recinto De Guayama	109
South Central Louisiana Technical College Young Memorial Campus	107
Northeast State Community College	106
Portland Community College	106
Tidewater Community College	106
ITT Technical Institute Houston West	104
Texas State Technical College Harlingen	103
Hennepin Technical College	102
University of Akron Main Campus	102
ITT Technical Institute San Bernardino	101
San Jacinto Community College	100

TABLE 1-3 States Awarding 5 Percent or More of ET Degrees and Certificates, 2014

4-Year Degrees (percent)	2-Year Degrees (percent)	Less than 1-Year Certificates (percent)	1- But Less than 2-Year Certificates (percent)
New York (7.6)	Texas (8.3)	California (11.7)	California (12.6)
Texas (7.1)	New York (6.6)	Washington (9.3)	Texas (12.6)
Indiana (6.1)	Ohio (6.0)	Texas (9.1)	Puerto Rico (9.3)
California (5.9)	California (5.6)	Florida (7.6)	Florida (8.3)
Michigan (5.3)		Illinois (7.0)	Louisiana (6.7)
		Louisiana (6.0)	
		Kentucky (5.9)	
		North Carolina (5.2)	

TABLE 1-4 Number of Institutions Awarding Engineering Technology Degrees and Certificates, by Institutional Control Type

Award level	Private, For Profit	Private, Not For Profit	Public	Total
Bachelor's Degrees	111	71	232	414
Associate's Degrees	275	57	860	1,192
Certificates (at least 1 but less than 2 years)	42	24	489	555
Certificates (less than 1 year)	21	11	521	553
Total	449	163	2,102	2,714

TABLE 1-5 Top 10 Most Common ABET-Accredited Engineering Technology Programs, 2- and 4-Year Degree Levels

2-Year Engineering Technology Programs		4-Year Engineering Technology Programs	
Name	Number	Name	Number
Electrical and Electronics Engineering Technology	74	Electrical and Electronics Engineering Technology	111
Mechanical Engineering Technology	48	Mechanical Engineering Technology	66
Civil Engineering Technology	34	Computer Engineering Technology	54
Computer Engineering Technology	19	Construction Engineering Technology	26
Architectural Engineering Technology	12	Civil Engineering Technology	22
Construction Engineering Technology	10	Manufacturing Engineering Technology	20
Surveying and Geomatics Engineering Technology	8	Bioengineering and Biomedical Engineering Technology	13
Drafting and Design Engineering Technology	5	Electromechanical Engineering Technology	9
Industrial Engineering Technology	5	Engineering Technology (General)	8
Manufacturing Engineering Technology	5	Industrial Engineering Technology	8

were 141. The complete universe of ET programs in the United States is presented in Table 1-6.

TERMINOLOGY

The language used by researchers, statisticians, and practitioners themselves to describe ET education sometimes muddies efforts at understanding. Often, though not universally, postsecondary educators call those with 2-year degrees in ET "technicians," while those with 4-year degrees are called "technologists." Unless noted otherwise, this is the convention we follow in our report. However, it is important to note several limitations with this nomenclature. First, federal employment data collection efforts sometimes use the term "technician" and at other times "technician or technologist" to describe work that might be done by those with either a 2- or a 4-year degree. Second, we have learned through our research that many of those with 4-year ET degrees do not identify themselves as technologists. If asked in surveys, for instance, they may call themselves engineers or managers. Third, the term "technologist" also does not seem to have much currency within industry, where the focus tends to be on the function an employee fulfills rather than the degree earned (e.g., Land, 2012). Finally, within the ET education community there is a long-simmering debate about the potential value of adopting the "applied engineering" label for bachelor's of science (BS) ET programs (Chandler et al., 2006; Rezak and McHenry, 1997). The Association of Technology, Management, and Applied Engineering (ATMAE), which accredits a small number of 2- and 4-year ET programs, also accredits BS and associate of applied science (AAS) degree programs in "applied engineering" and "applied engineering technology." The possibility of accrediting some ET programs as "applied engineering" through ABET's Engineering Accreditation Commission or its Engineering Technology

TABLE 1-6 Estimated Universe of Engineering Technology Programs in the United States

	2-Year Programs	4-Year Programs
ABET Accredited	257	387
Non-ABET Accredited	658	141
Total	915	528

Accreditation Commission is something that leadership at the organization has recently begun to consider (J. Ray, Western Carolina University, personal communication, Aug. 30, 2015).

A second area of potential confusion relates to the large number of distinct ET education programs at both the 2- and the 4-year levels. Although there is a relatively small set of such program types in engineering (e.g., civil, electrical, mechanical, environment, industrial, bioengineering), there are many more in ET (see Box 3-1 in Chapter 3), and there does not appear to be a consistent naming convention across academic institutions. This sometimes results in one-of-a-kind program titles. Finally, education data collection by the federal government also does not consistently use the term "engineering technology" in the descriptions of programs it counts as producing graduates in this field (see the discussion of CIP codes in Chapter 3's section on "Degree Fields.")

Overall, there is considerable variation in how different groups characterize ET, particularly in comparison to engineering (Box 1-1).

LICENSING, CERTIFICATION, AND EQUIVALENCY

In the United States, engineers must be licensed to perform certain tasks such as certifying the safety-related specifications of design drawings. Individuals who have earned a 4-year engineering degree from an ABET-accredited program who wish to be licensed must first pass the Fundamentals in Engineering (FE) exam, a test of broad knowledge in mathematics, science, and engineering. After gaining work experience (the amount of experience required varies by state), those with the FE designation and requisite experience can take the Principles and Practice in Engineering (PE) exam. Licensing is done by the states, and 30 states allow those with an ET degree from an ABET-accredited program to take the FE and PE exams. According to the National Council of Examiners for Engineering and Surveying, which administers the exams, 2,600 of 45,600 candidates taking the 2010 FE exam, or 5.7 percent, indicated they had a 4-year degree in ET. Of the 26,600 candidates taking the PE exam that year, 900, or 3.4 percent, had a 4-year ET degree.

The National Institute for Certification in Engineering Technologies, a semiautonomous division of the National Society of Professional Engineers, offers certification for 4-year ET degree holders. Since 1977, 1,775 people with 4-year ET degrees have opted to get this certification (M. Clark,

BOX 1-1
A Perspective on Engineering Technology Education

Engineering technology is not very well understood. To a substantial extent this is true for those in academia and in industry. Hence, when engineering technology issues are discussed, the exchange of opinions may be dominated by oft-repeated stereotypical images. Such stereotypes, which while true to some extent, are indeed only partially true. For example, the lesser emphasis on theory and mathematical rigor causes engineering technology to be viewed as inferior to engineering, that is, as engineering-light. This is perhaps the most damaging stereotype. Even engineering is understood in the context of a range of activities: engineering as applied science and math, engineering as problem-solving, and engineering as producing things.

The situation is actually more complicated because a myriad of various descriptors exist: engineering, engineering technology, applied science, engineering science, applied mathematics, technology, industrial technology, and others. The overlap between the descriptors is compounded by the numerous degree variations between programs that provide a spectrum of skills and student educational outcomes that match the wide range of needs required by industry. Forcing a distinct delineation between engineering and engineering technology is simplistic at best and generally inaccurate.

SOURCE: Kelnhofer et al., 2010.

NICET, personal communication, Aug. 19, 2015). ATMAE offers a variety of certifications, one of which, Certified Technical Professional, is available to graduates of both 2- and 4-year ET programs.

The United States, through ABET, is a signatory to three international "equivalency" agreements: one for engineers (the "Washington Accord"), one for engineering technologists (the "Sydney Accord"), and one for engineering technicians (the "Dublin Accord"; IEA, 2014). Sixteen countries, including the United States, have signed the Washington Accord. Australia, Canada, Chinese Taipei, Hong Kong, China, Ireland, Korea, New Zealand, South Africa, the United Kingdom, and the United States have signed the Sydney Accord. And Australia, Canada, Ireland, Korea, New Zealand, South Africa, the United Kingdom, and the United States have signed the Dublin Accord.

A further illustration of the inconsistency surrounding terminology within and for ET may be seen in the variety of names used by the seven initial signatory countries[5] to the Sydney Accord to identify those with similar educational backgrounds in ET (Table 1-7).

Engineering Technology and Engineering

As noted, the work of engineering technologists is often described by drawing comparisons to engineering. One model (Figure 1-1), developed by the American Society of Mechanical Engineering (ASME), sees the jobs of engineering technologist and engineer as falling along a continuum. It is characterized at one end (engineering technology) by work involving distribution and sales; operation, service, and maintenance; and production engineering and at the other (engineering), by work emphasizes theory, analysis, and complex design. As shown in the area where the two jobs overlap, a number of work-related activities can be performed by both engineers and technologists, including component design, management, and testing and evaluation.

An earlier version of the ASME model included a similar spread of occupational functions but also suggested that jobs at the engineering end of the spectrum involve more mathematical work while those at the ET end involve less.

There is no widely accepted job description for an engineering technician. However, the International Engineering Alliance, which manages mutual accreditation recognition agreements among signatory countries for engineers, engineering technologists, and engineering technicians, offers this description:

> The roles of Engineering Technicians involve them in the implementation of proven techniques and procedures to the solution of practical problems. They carry a measure of supervisory and technical responsibility and are competent to exercise creative aptitudes and skills within defined fields of technology, initially under the guidance of engineering practitioners with appropriate experience. Engineering Technicians contribute to the design, development, manufacture, commissioning, operation and maintenance of products, equipment, processes and services. (IEA, 2014, pp. 13-14)

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[5] The United States was not among the original signatories to the Sydney Accord, and the International Engineering Alliance, which oversees the accord process, does not provide terminology used by later signatories.

TABLE 1-7 Sydney Signatories' Titles for "Engineering Technologist"

Country	Title
Australia	Engineering Technologist
Canada	Certified Engineering or Applied Science Technologist
Hong Kong, China	Associate Member of HKIE
Ireland	Associate Engineer
New Zealand	Engineering Technologist
South Africa	Professional Technologist (Engineering)
United Kingdom	Incorporated Engineer

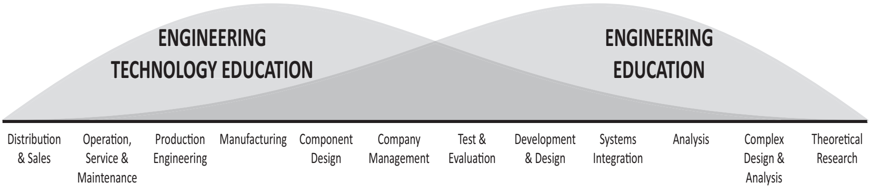

FIGURE 1-1 An engineering technology—engineering continuum model. SOURCE: ASME, 2012. Used with permission.

Compared with engineering, the history of ET education (Chapter 2) suggests a greater emphasis on hands-on laboratory experiences and less emphasis on advanced mathematics. To get a sense of how valid this characterization is today, the committee examined required coursework for engineering and 4-year ET majors at three institutions housing both programs (Table 1-8). Though qualitative and involving a very small sample, the review nonetheless suggests that some of the historical differences between the two fields remain.

Another illustration of the differences between ET and engineering is reflected in the student outcomes criteria used by ABET for the two types of programs (Table 1-9). Overall, the criteria are very similar. However, ET's historical roots in application can clearly be seen in ABET's Engineering Technology Accreditation Commission's criteria b and c. The greater hands-on emphasis of ET also can be seen in ABET's curriculum criteria for the field, which call on these programs to "Develop student competency in the use of equipment and tools common to the discipline." No such guidance is provided to engineering programs.

TABLE 1-8 Required Science, Mathematics, and Laboratory Courses in Engineering and Engineering Technology BS Programs at the University of Cincinnati, University of North Carolina, Charlotte, and Purdue University

University of Cincinnati[a]
Electrical Engineering and Electrical Engineering Technology

SCIENCE	
Engineering	***Engineering Technology***
General Chemistry I	General Physics I (algebra based)
College Physics I (calculus based)	General Physics II (algebra based)
Semiconductor Physics for Engineers	
Science Elective	
MATHEMATICS	
Calculus I	Calculus I
Calculus II	Calculus II
Multivariate Calculus	Engineering Statistics
Linear Algebra	Mathematic Applications in Engineering Technology
Probability and Statistics I	
LABORATORIES	
General Chemistry Laboratory I	General Physics Laboratory I (algebra based)
College Physics Laboratory I (calculus based)	Digital Systems Laboratory
Electronics Laboratory I	Circuit Analysis II Laboratory
Electronics Laboratory II	General Physics Laboratory II (algebra based)
	Electronics Laboratory
	Electronic Communication Laboratory
	Flexible Automation Laboratory
	Electric Machinery Laboratory
	Feedback Control Laboratory
	Computer Networks Laboratory

continued

TABLE 1-8 Continued

University of North Carolina, Charlotte[b] Mechanical Engineering and Mechanical Engineering Technology	
SCIENCE	
Engineering	***Engineering Technology***
Chemistry I	Introductory Physics I
Physics I	Introductory Physics II
Physics II	Principles of Chemistry
Science Elective	
MATHEMATICS	
Calculus I	Pre-Calculus Math for Science & Engineering
Calculus II	ET Calculus or Engineering Analysis I
Differential Equations	Elements of Statistics
Calculus III	Engineering Analysis II
Computational Methods for Engineers	Engineering Analysis III or IV
Mathematics Elective	
LABORATORIES	
Chemistry I Laboratory	Introductory Physics I Laboratory
Physics I Laboratory	Engineering Technology Computer Applications Laboratory
Physics II Laboratory	Introductory Physics II Laboratory
Design Projects Laboratory I	Sophomore Design Practicum Laboratory
Instrumentation Laboratory	Stress Analysis Laboratory
Design Projects Laboratory II	Junior Design Practicum Laboratory
Mechanics and Materials Laboratory	Fluid Mechanics Laboratory
Thermal Fluids Laboratory	Thermodynamics and Heat Transfer Laboratory
	Instrumentation Laboratory

continued

TABLE 1-8 Continued

Purdue University[c] Electrical Engineering and Electrical Engineering Technology	
SCIENCE	
Engineering	***Engineering Technology***
General Chemistry	General Physics I
Modern Mechanics	General Physics II
Electric and Magnetic Interactions	
Electric and Magnetic Fields	
MATHEMATICS	
Analytic Geometry and Calculus I	Applied Calculus I
Analytic Geometry and Calculus II	Applied Calculus II with Differential Equations
Multivariate Calculus	Introduction to Probability Models (or Elementary Statistical Models)
Ordinary Differential Equations	Monetary Analysis for Industrial Decisions (or Production Cost Analysis)
Probabilistic Methods	
Linear Algebra	
LABORATORIES	
None listed by name	None listed by name

[a] At the University of Cincinnati, both the electrical engineering and the electrical engineering technology programs are housed within the College of Engineering and Applied Science. Both programs are 5 years long. The "curriculum guide" for electrical engineering can be viewed here: https://webapps.uc.edu/DegreePrograms/CurriculumGuideView.aspx?Program=1232&Pasla=20BSEE-EE&CurriculumGuideID=1326. The curriculum guide for electrical engineering technology can be seen here: https://webapps.uc.edu/DegreePrograms/CurriculumGuideView.aspx?Program=1003&Pasla=20BSEET-ET&CurriculumGuideID=901.

[b] At UNC, Charlotte, both the mechanical engineering and the mechanical engineering technology programs are housed within the William States Lee College of Engineering. The September 2014 "suggested plan of study" for mechanical engineering can be viewed here: http://academics.uncc.edu/sites/academics.uncc.edu/files/media/Mechanical-Engineering-APS-Sept-2014.pdf. The April 2014 suggested plan of study for mechanical engineering technology can be seen here: http://academics.uncc.edu/sites/academics.uncc.edu/files/media/Mechanical-Engineering-Technology-APS-Apr-2014.pdf.

[c] At Purdue, the electrical engineering program is housed within the College of Engineering, and the electrical engineering technology program is housed within the School of Engineering Technology, part of the Purdue Polytechnic Institute. The 2015 "plan of study" for electrical engineering can be viewed here: https://polytechnic.purdue.edu/sites/default/files/EET-fall-2015.pdf. The 2015 plan of study for electrical engineering technology is here: https://engineering.purdue.edu/Engr/Academics/Undergraduate/PlansOfStudy/schools/ece/bsee/fall-2015/Electrical%20Engineering%20-%20Fall%202015.pdf.

TABLE 1-9 Comparison of ABET Student Outcomes Criteria A-K for Engineering and Engineering Technology

Engineering Accreditation Commission	Engineering Technology Accreditation Commission
(a) an ability to apply knowledge of mathematics, science, and engineering;	(b) an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
(b) an ability to design and conduct experiments, as well as to analyze and interpret data;	(c) an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;	(d) an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;
(d) an ability to function on multidisciplinary teams;	(e) an ability to function effectively as a member or leader on a technical team;
(e) an ability to identify, formulate, and solve engineering problems;	(f) an ability to identify, analyze, and solve broadly-defined engineering technology problems;
(f) an understanding of professional and ethical responsibility;	(i) an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
(g) an ability to communicate effectively;	(g) an ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature;
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;	(j) a knowledge of the impact of engineering technology solutions in a societal and global context;

continued

TABLE 1-9 Continued

Engineering Accreditation Commission	Engineering Technology Accreditation Commission
(i) a recognition of the need for, and an ability to engage in, life-long learning.	(h) an understanding of the need for and an ability to engage in self-directed continuing professional development;
(nothing comparable)	(k) a commitment to quality, timeliness, and continuous improvement.
(j) a knowledge of contemporary issues	(nothing comparable)
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	(a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;

SOURCE: EAC, 2015; ETAC, 2014.

The hiring practices of the federal government also reflect perceived differences between ET and engineering. The federal Office of Personnel Management (OPM) places ET under the same broad category, "All Professional Engineering Positions," that includes those with 4-year engineering degrees (OPM, 2012). Technically, this means that some with 4-year ET degrees from institutions accredited by ABET can be hired by the federal government, but the OPM rules restrict hiring to entry-level jobs (GS-5, pay range $27k-$36k; those with "superior academic performance" may enter at GS-7). Some within the ET field believe that this OPM provision reflects a bias against the field and poses an unfair barrier to federal employment for engineering technologists. The National Engineering Technology Forum, an initiative of the Engineering Technology Council of the American Society for Engineering Education, has been lobbying for the creation of a separate federal job category, or the equivalent, for engineering technologists. In 2014 OPM drafted and circulated to other agencies for comment a proposal that would have reclassified engineering technologists. Subsequently, the agency decided not to move forward with the proposal.

Separately, the Department of Labor classifies engineering technologists and technicians among the occupations that are subject to minimum-wage and overtime-pay rules under the Fair Labor Standards Act (USDOL, 2008). In contrast, engineers are exempt from these rules, because they are considered part of a "learned profession." By DOL definition, a learned profession involves "work requiring advanced knowledge," which is "customarily acquired by a prolonged course of specialized intellectual instruction."

Issues related to the employment of engineering technologists and technicians are considered in detail in Chapter 4. However, it is worth noting here the personal experiences of one of our workshop participants, Verna Fitzsimmons, CEO of Kansas State University at Salina. Her institution awards both 4-year engineering and 4-year ET degrees. Dr. Fitzsimmons reported that she has been working closely with employers in the Salina community to help them understand the value of students with a BS in ET. Although many local employers hire her graduates and wish the university could provide more of them, she said most thought the graduates they were hiring were all engineers. Our own survey of employers, also described in Chapter 4, found that roughly one-third had never heard of the academic field called "engineering technology education."

Pathways

Although the committee's statement of task, described below, does not specifically require us to examine educational and career pathways in ET, it was our hope that this project would provide insights into this issue. Figure 1-2 provides a notional view of some of the major connections between and among various parts of the ET education system and the workforce. We were not able in this project to characterize all of the pathways pictured, or to provide definitive information about many of the specific pathways, but we were able to elucidate patterns in certain of these flows as well as to identify potentially intriguing connections (and gaps) that suggest the need for more research. A number of facets of this pathways diagram are addressed in data presented in Chapters 3 and 4.

THE NAE PROJECT

This National Science Foundation (NSF)-funded project took place over a roughly 2-year period, culminating in publication of this report in summer 2016. To oversee the project, the NAE appointed a committee of 14 individuals with expertise across a range of areas relevant to the study topic, including engineering and engineering technology (ET) education; labor economics; STEM workforce policy and research; career and technical education; K-12 teaching; and industry. (Committee bios appear at Appendix A.)

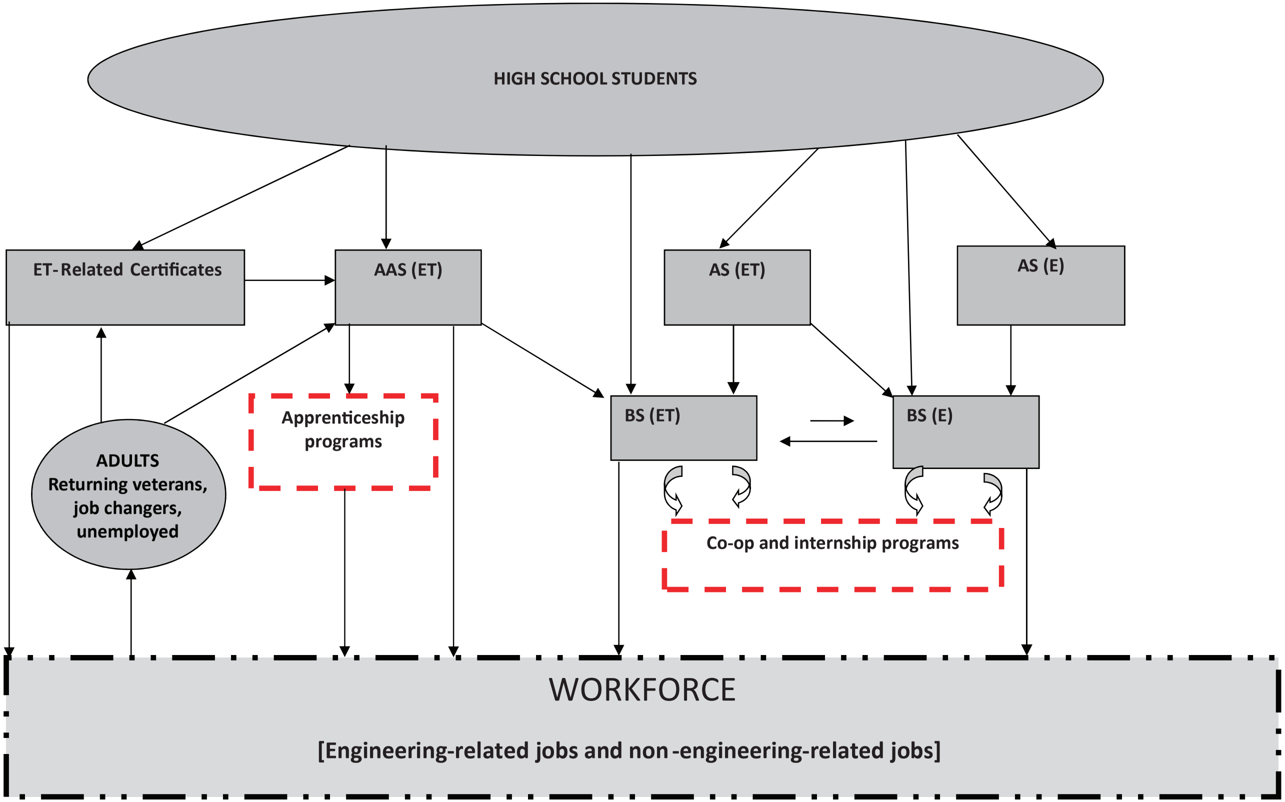

FIGURE 1-2 Notional outline of educational and career pathways in engineering technology.

The committee met four times and held a 1-day workshop in December 2014 in Washington, DC.

The project had the following statement of task:

> An ad hoc committee will conduct a study and prepare a report to shed light on the status, role, and needs of engineering technology education in the United States. The project will address the following objectives and questions and include a public workshop as a primary data-gathering event.
>
> ***Objective 1:*** Review the status and history of the production and employment of engineering technologists and technicians in the United States. Such a review should address not only the number and discipline-focus of graduates from engineering technology programs but also their demographic characteristics (race, gender, socio-economic status), academic preparation (e.g., participation in career and technical education programs, experience with K-12 engineering coursework), and distribution by sector, job role/category, and geographic region.
>
>> QUESTION: What are the significant trends and patterns in the production and employment of engineering technologists and technicians?
>
> ***Objective 2:*** Gather available data and explore private- and public-sector employer perceptions regarding the adequacy of the supply of engineering technologists and technicians as well as the appropriateness of the knowledge and skills they bring to the workplace.
>
>> QUESTION: What aspects of engineering technologist/technician performance in the workplace are most valued by employers and where are such workers seen to fall short of expectations or needs?
>>
>> QUESTION: Is there evidence for shortages or oversupply of engineering technologists/technicians regionally or within particular employment sectors or job categories?
>>
>> QUESTION: How is increasing automation, and technological developments more generally, changing the nature of work for engineering technicians and technologists?
>
> ***Objective 3:*** Describe the characteristics of US engineering technology education programs related to such things as curriculum and faculty professional development; outreach to/partnerships with K-12 schools, industry, and other organizations; and communication and collaboration with engineering education programs.
>
>> QUESTION: To what degree are curricula, professional development, and institutional policies supporting or hindering efforts to meet employer needs and expectations?

> QUESTION: In what ways and to what effects are engineering technology programs connected to other parts of the K-16 education system, including engineering education?
>
> QUESTION: How transferable (e.g., to different technology types, regions, or career paths) are the knowledge and skills learned in engineering technology programs?
>
> QUESTION: What is the extent and nature of articulation between and among 2- and 4-year engineering technology programs and between these programs and engineering programs?

Data Gathering

Data gathering for the project consisted of (1) collection and analysis of the relevant published literature; (2) review of relevant federal education and employment datasets; (3) a survey of ET education programs and a survey of a sample of companies that hire graduates from these programs; and (4) a stakeholder workshop.

To conduct the review of federal datasets, the project hired a consultant, Daniel Kuehn, a research associate at the Urban Institute with considerable knowledge of the STEM workforce. Educational data assembled by Kuehn provided information on the rate of production and the demographic composition of new engineering technicians and technologists. Enrollment and graduation trends offer a great deal of insight into the supply of engineering technicians and technologists, although a full picture of their supply and demand requires analysis of labor market data. Movements in labor supply and demand have predictable impacts on earnings and employment reported in the large surveys of workers and firms conducted by the Census Bureau, the Department of Labor, and (in the case of the STEM labor market) the NSF. The educational datasets used in this study were IPEDS, the Baccalaureate and Beyond 2008/2009 (B&B), and the Career/Technical Education (CTE) Statistics. Each of these datasets is produced and distributed by the Department of Education's National Center for Education Statistics.

The labor market datasets used in the study were the American Community Survey (ACS), the Current Population Survey (CPS), the Occupational Employment Statistics (OES) database, and the National Survey of College Graduates (NSCG). These data are made available by a variety of government agencies and present the STEM workforce generally and engineering technicians and technologists in particular in varying degrees of detail.

TABLE 1-10 Summary of Data Sources

	Education Data	Employment Data
ACS	Yes for bachelor's degree	Yes
B&B	Yes	Yes
CPS	Degree level, not field	Yes
CTE Statistics	Yes	No
IPEDS	Yes	No
NSCG	Yes for bachelor's degree	Yes
OES	No	Yes

These datasets are summarized in Table 1-10, and an additional description of each dataset is provided in Appendix B.

The survey of educational programs was conducted by the NAE. The survey of employers was conducted by the National Association of Colleges and Employers under contract to NAE.

Data Gaps

At various points in the project, we encountered gaps in the available data, which limited our ability to address aspects of the statement of task. One key gap relates to the availability of data regarding the work experiences of students with 2-year ET degrees. This gap and several others are discussed at greater length in other sections of the report, and in some cases, they are addressed in our recommendations.

THE REPORT

The committee's report is organized into five chapters. Chapter 2 contains a brief history of ET education. Chapter 3 discusses the production of ET talent, and Chapter 4 considers the employment of ET talent. Chapter 5 contains the committee's findings and recommendations.

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2

The Origins of Engineering Technology Education[1]

The emergence and expansion of engineering technology (ET) degree programs is a convergence of several key aspects of the United States' technological development. These include (1) the nation's desire to remain the preeminent leader in technology and innovation; (2) a series of engineering education reports; (3) the development of technical institutes; (4) the expansion of the junior and community college programs in technical education; and (5) the consistent movement of US engineering education toward curricula containing more emphasis on science knowledge/theory and advanced mathematics. The convergence of the first three factors provided impetus for the creation of the 2-year ET programs and what amounted to a three-tiered structure in the engineering workforce. The convergence of the last two factors contributed to the creation of 4-year ET education programs.

According to Henninger (1959), the engineering workforce can be thought of as comprising three distinct but related components: engineers, engineering technologists, and laborer-technicians. Access to each tier is granted based on things such as degree completion, licensing, accreditation standards, and discipline choice. The idea of a three-tiered structure emerged

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[1] This chapter is based on research done by Ron Dempsey, School of History, Technology, and Society, Ivan Allen College, Georgia Institute of Technology, as part of a dissertation proposal. Used with permission.

from the formation of the US technical institutions. Noted Henninger (1959:27-28):

> [T]o produce efficiently an adequate supply of qualified manpower for the three-part engineering-scientific team, we shall require a three part educational program: 1) The university-collegiate program for engineers and scientists, 2) The technical institute program for the engineering and scientific technicians, and 3) The vocational-trade programs for the craftsmen and apprenticeship.

In their *Report of the Investigation of Engineering Education: 1923-1929*, W.E. Wickenden and H.P. Hammond (1930) included a supplemental report on technical institutes, in which they recommended a split between the professional engineer and the practical engineering technician. Technical institutes were postsecondary institutions with courses of study lasting between 1 and 3 years whose focus was the application of scientific principles more than development of manual skills (Smith and Lipsett, 1956).

Two precursors to the technical institute were industrial technology programs and the mechanics institutes. The industrial technology programs provided postsecondary education and training. Most focused on business management, production operations, and labor relations (Barnhart, 1963), while a few emphasized technological knowledge and expertise. Existing in parallel with the industrial technology program were the mechanic institutes (Defore, 1966). These institutes were geared toward "the maturing technology of the time, laying emphasis upon application with intensive instruction during short periods of less than four years" (Graney, 1965:9). Prominent engineering schools such as Rochester Institute of Technology, Milwaukee School of Engineering, and the Wentworth Institute of Technology began as mechanic institutes (Smith and Lipsett, 1956).

A key component of technical institutes was the provision of education and training for the "area between the skilled crafts and the highly scientific professions" (Smith and Lipsett, 1956:4). Wickenden and Hammond (1930) suggested that these technical institutes should become the locus for a more practical form of engineering education. Hammond repeated the recommendation in the 1940 *Hammond Report* on engineering education and in the 1944 report *Engineering Education after the War*. For Hammond, the two world wars had highlighted the need for scientific knowledge creation, technological innovation and development, and increased engineering expertise in order to maintain global leadership and military dominance. "It is a matter of vital concern to the nation in relation both to security and economic welfare that the highest levels of scientific and engineering excellence be maintained at all times" (1944:592).

The *Hammond Report* argued that technological education must be offered on a broader, not a narrower, basis and that scientific and engineering knowledge must be diffused "among the industrial classes rather than . . . canalize[d] . . . in strictly professional channels. In view of their broad function and their complex relationships, we consider it neither feasible nor socially desirable for the present group of engineering colleges to limit their aim to the preparation of young men for professional registration and practice" (Hammond, 1940:560).

This more practical form of training encouraged development of an "industrial group" track of technical education that "gives major attention to matters relating to production and operations" (Hammond, 1944:592). The 1944 report noted the lack of a systemic technological education at the "intermediate and sub-professional" level (605). One reason for the underdevelopment of this form of technological education was the lack of recognition afforded to these degree programs and their graduates from "industry, the engineering profession, and the public at large" (605, 607).

These reports, along with the motivation provided by World War II, led to the establishment of ET programs within the technical institutes. Their emphasis on scientific principles versus manual skills helped distinguish the technical institutes from junior colleges and vocational training institutions. By 1945 the first 2-year ET programs were accredited by the Engineers' Council for Professional Development (ECPD, 1954; Smith and Lipsett, 1956), predecessor to the Accreditation Board for Engineering and Technology (ABET). The Council also established a separate accreditation board for ET programs (Smith and Lipsett, 1956). Later, as junior colleges and vocational training institutions began offering technical degrees, confusion arose about the differences between these programs and those offered by the technical institutes, and, as discussed below, this would contribute to the establishment of 4-year ET programs.

Critically, the technical institutes provided education and training for the "area between the skilled crafts and the highly scientific professions" (Smith and Lipsett, 1956:4). Such stratified thinking contributed to the idea of a three-tiered structure in engineering. "The basic objective of the technical institute idea in higher education is the development of qualified engineering technicians proficient in a selected field of technology" (Henninger, 1959:16). The ET programs housed in the technical institutes were not intended as a feeder into university/college engineering programs but were to stand on their own as an independent degree program. The clear expectation for this degree program was to have its graduates become a vital part of the engineering-scientific team (1959:20-21). Henninger clearly placed the engineering technician in this structure of engineering:

> The first fact is that some adequate and integrated provision must be made to continue the supply [of] the technically competent manpower required for this engineering application and operation, and required also to augment and to supplement the professional engineer and the scientists in research, design, development, and supervision. This manpower is part of the over-all engineering manpower spectrum. In general effect, it is taking the place of the engineer as we have known him, as the engineer of today and of tomorrow increasingly takes his place and becomes more and more devoted to the scientific problems and opportunities of the expanding technological universe. This manpower area is the professional area of the "engineering technician" (1959:20).

The Technical Institute Division of the American Society for Engineering Education (ASEE) provided oversight for the emerging ET programs from 1946 to 1962. Just as ET evolved, so did the nomenclature of this oversight group. It was renamed the Technical Institute Administrative Council in 1965, the Technical College Council in 1971, the Engineering Technology College Council in 1981, and, finally, in 1987, the Engineering Technology Council (O'Hair, 1995).

Between 1945 and 1955, ET was introduced as a new academic program at existing technical institutes located at institutions such as Purdue University and the University of Houston. During this period, the number of technical institutes increased from 44 to 69 (Smith and Lipsett, 1956) in order to house the growing number of new engineering technology programs. The technical institutes and ET programs followed a series of boom and bust enrollment cycles (Harris and Grede, 1977). For example, from 1946 to 1954 the engineering technology programs surged in enrollment with the influx of war veterans and passage of the GI Bill. But from 1954 to 1957, enrollment stabilized or decreased due to the movement toward humanities and the arts by entering college students (Carr, 1979). Two-year ET programs now produce about 37,000 graduates annually (see Table 3-1).

The launch of the Soviet satellite Sputnik in 1957 played a key role in the next phase of development of ET education, the move to 4-year baccalaureate degree programs. Sputnik caused many to believe traditional engineering programs needed to be refocused in order for the United States to compete in the space race. This shift was achieved "at the expense of design and application-based laboratory courses," according to Holloway (1991:94). As a debate over the engineering curriculum grew, S.C. Hollister, president of ASEE, commissioned a review of engineering education, which would become known as the Grinter Report. A primary recommendation of the Grinter Report was for engineering programs to increase the mathematics, physics, and engineering sciences content of the curriculum (Grinter, 1955). A draft of the report also recommended that engineering be bifurcated (Seely, 1995). One form would focus more on the scientific and theoretical aspects of engineering and educate engineers working in research and design for the government. The other would focus on the more general, practical, and technical aspects of engineering and educate engineers for industry. However, the committee reviewing the report, led by Hollister, did not approve this recommendation, and it was removed from the final report.

In an ASEE oral-history project on ET education, Winston Purvine, founder of the Oregon Institute of Technology, recounted a post-Sputnik talk by the dean of the College of Engineering at Michigan State in which the dean noted his institution "has literally plowed under acres" of laboratory space as the school reworked its engineering curriculum (O'Hair, 1995:263). The curricular shift by engineering programs and the decision not to create two branches in the field created room for expansion of ET into the arena of 4-year baccalaureate degree programs. Noted Ungrodt:

> Some of the changes in engineering technology education have resulted from the changes in engineering education. The development of science oriented engineering curricula and the trend toward advanced level programs in engineering, as well as the rapid growth and development of associate degree programs in engineering technology, have stimulated the development of baccalaureate programs in engineering technology (1975:787).

Dean Michael Mazzola of the Franklin Institute in Boston put it more bluntly: "[T]he technical institute group, engineering technology, jumped into the gap. And this is why the four-year program was started, because engineering colleges were not doing engineering; they were putting too much emphasis on science" (O'Hair, 1995:216).

The other factor contributing to the birth of 4-year ET programs was the increasing number of junior and community colleges offering associate's degrees in "engineering technology." At the 1958 mid-year meeting of ASEE's Technical Institute Division, Curriculum Development Chair H.H. Kerr voiced concern over the "inroads" that the vocational education system was making into technical education. Kerr noted that this set of institutions was much larger and more politically connected than the technical institutes and could pose a significant threat to engineering technology. It was during these discussions that the term "technologist" was coined to described graduates of 4-year ET programs (O'Hair, 1995:118).

Historically, the technical institute programs had been confused with the vocational technical school programs, because of their similar 2-year duration. The addition of ET programs at the vocational schools and junior colleges only added to the confusion. Therefore, the "expansion of the long standing engineering technology programs from two to four years is at least one way of maintaining the differential in level and standard which has existed between the technology programs and the vocational programs" (Foecke, 1964:12).

ABET-accredited bachelor's degree programs in ET soared from 2 in 1967 to 155 a decade later (ECPD, 1978). Some of the first institutions to establish 4-year baccalaureate degrees in engineering technology included Virginia Tech, Texas A&M, Purdue University, Southern College of Technology (the technical institute of Georgia Tech), and the New Jersey Institute of Technology. Enrollment growth in these programs followed. By the late 1980s, there were about 20,000 annual graduates of these 4-year programs. The number of graduates has fluctuated over the intervening years between about 15,000 and 18,000 per year. Much more information about the production of ET degrees, at both the 2- and 4-year levels, is provided in Chapter 3.

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3

The Production of Engineering Technology Talent

This chapter presents information about the size and composition of the cohort of students with degrees in engineering technology (ET) education at the 2- and 4-year levels and, to the extent possible, the academic pathways available to those who wish to pursue this type of education. Because the definition of the term "engineering technology" is difficult to establish, particularly as an occupational category, the committee compared basic information across multiple datasets to help ensure that subsequent analyses consider the same population. Table 3-1 provides such an overview, presenting the total stock and annual awards of ET bachelor's degrees and the annual awards for associate's degrees in 2013.

The committee used the Integrated Postsecondary Educational Data System (IPEDS) as its source of federal data on new bachelor's and associate's degrees in ET. IPEDS is effectively a census of postsecondary institutions that does not directly interview any students (Box 3-1). The IPEDS data indicate that more than 18,000 new bachelor's degrees in ET were awarded in 2013. IPEDS reports the production of nearly 37,5000 associate's degrees in 2013.

The American Community Survey (ACS) and the National Survey of College Graduates (NSCG), both surveys of individuals, can be used to estimate the total stock of those with 4-year degrees in ET. ACS and NSCG suggest that this stock of graduates stands at more than 480,000 and 435,000, respectively. These surveys revealed that there are roughly 10 times as many

TABLE 3-1 Comparison of Estimates of Stock of and New Awards in Engineering Technology and Engineering in 2013,[a] Various Sources

Degree Holders	IPEDS	ACS	NSCG
Stock of bachelor's degrees in engineering technology	—	480,925	435,716
Newly awarded bachelor's degrees in engineering technology	18,322	—	—
Newly awarded associate's degrees in engineering technology[b]	37,475	—	—
Stock of bachelor's degrees in engineering	—	5,098,403	3,879,754
Newly awarded bachelor's degrees in engineering	87,812	—	—

[a] Although the most recent IPEDS data are from 2014, Table 3-1 uses 2013 data for comparability with NSCG, which has data only through 2013.

[b] The federal government does not collect data that allow estimates to be made of the stock of 2-year engineering technology degrees.

SOURCE: Calculations from noted datasets.

BOX 3-1
The "Universe" of IPEDS Institutions

Any postsecondary institution that is eligible for financial aid under Title IV of the Higher Education Act is required by law to participate in IPEDS. To be eligible for Title IV funds, an institution must meet four criteria: (1) be accredited by an agency or organization recognized by the Secretary of the US Department of Education, (2) have a program of more than 300 clock hours or 8 credit hours, (3) have been in business for at least 2 years, and (4) have a signed Program Participation Agreement with the Office of Postsecondary Education, US Department of Education. For the 2013-14 data collection period, the universe of IPEDS institutions totaled 7,477 (NCES, 2014).

As noted later in this chapter, a number of 2-year engineering programs (and a much smaller number of 4-year programs) are not accredited. However, eligibility for Title IV and the related requirement to participate in IPEDS depends on institutional-level accreditation, not program-level accreditation. Therefore, data related to any engineering technology program in any accredited higher-education institution should be reported in IPEDS.

individuals with 4-year degrees in engineering as there are with 4-year degrees in ET. Because these data are self-reported and because of confusion about degree types within engineering-related fields, it is possible that some individuals with degrees in ET are reporting they have a degree in engineering (and are therefore being counted as engineering-degree recipients). In addition, although data on the number of degrees awarded in any one year include only those graduating from US institutions, estimates of stocks include those who have earned degrees outside the United States. Through the Accreditation Board on Engineering and Technology (ABET), the United States is signatory to two international "equivalency" agreements that provide recognition for 2-year (Dublin Accord) and 4-year (Sydney Accord) ET degrees earned in several other countries. (See "Licensing, Certification, and Equivalency" in Chapter 1.)

TRENDS IN DEGREE PRODUCTION

The principal dataset for analysis of the production of 2- and 4-year ET degrees is the IPEDS. Figure 3-1 presents the number of ET degrees awarded

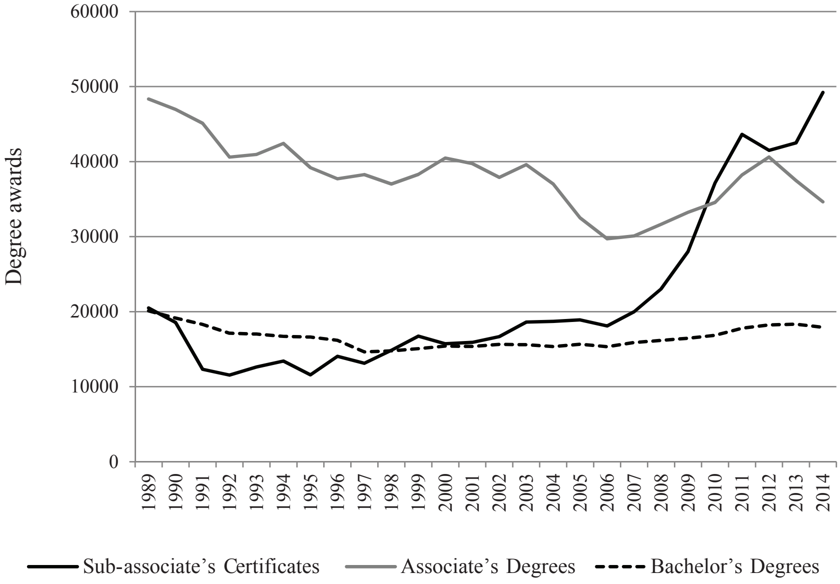

FIGURE 3-1 Engineering technician and technology degree production, 1989-2014. SOURCES: Calculations from IPEDS data; population of institutions from NCES.

between 1989 and 2014, by degree level, with separate types of sub-associate's degree certificates aggregated into a single "certificate" category and the (relatively rare) certificates that take between 2 and 4 years to earn and with master's degrees omitted.

For the entire period, most ET degrees were associate's degrees, although these declined from almost 50,000 a year in 1989 to approximately 30,000 in the mid-2000s, and then they rose to a peak of just over 40,000 in 2012 before declining again to just over 37,000 in 2014. Sub-associate's degree certificates played the smallest role in ET education for most of this 23-year period, although growth in these certificates has been rapid for the past 5 years.[1] By 2010, more certificates than associate's degrees were awarded and have continued to exceed associate's degrees since that time. Relative to the large declines in associate's degree awards and increases in certificates, bachelor's awards in ET held fairly steady over the period at between 15,000 and 20,000.

Figure 3-2 presents nondegree certificate awards in more detail, differentiating between certificates awarded within a year, certificates that take between 1 and 2 years to earn, and certificates that take between 2 and 4 years to earn. The latter category is relatively rare (these were not included in Figure 3-1), particularly in recent years. As recently as the early 1990s, however, 2- to 4-year certificates were almost as common as certificates that take less than 1 year to earn. Most of the engineering technician certificates are therefore sub-associate's degree certificates. Between 1990 and 2002, most of these certificate awards required between 1 and 2 years to earn. After 2005, however, the number of engineering technician certificates that took less than a year to earn surpassed the number of 1- to 2-year certificates awarded. Much of the growth in sub-associate's certificates over this period is therefore attributable to the strong growth in certificates that took less than a year to earn, although growth in 1- to 2-year certificates also was a contributor.

A clearer illustration of the rates of change of these degrees is presented in Figure 3-3, which charts indices for each of the degree categories in Figure 3-1 (with 1989 as the base year). Although the absolute number of bachelor's degrees in ET did not decline by a substantial amount between 1989 and 2014, the bachelor's index declined at a rate that is almost identical to the associate's index between 1989 and 2004. By 2004, almost 25 percent fewer associate's and bachelor's degrees were awarded compared to 1989 levels.

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[1] Some of this growth may be related to the Trade Adjustment Assistance Community College and Career Training grant program (TAACCCT). TAACCT provided nearly $2 billion in grants from 2011 to 2014 to expand targeted training programs for unemployed workers, especially those impacted by foreign trade (USDOL, 2014).

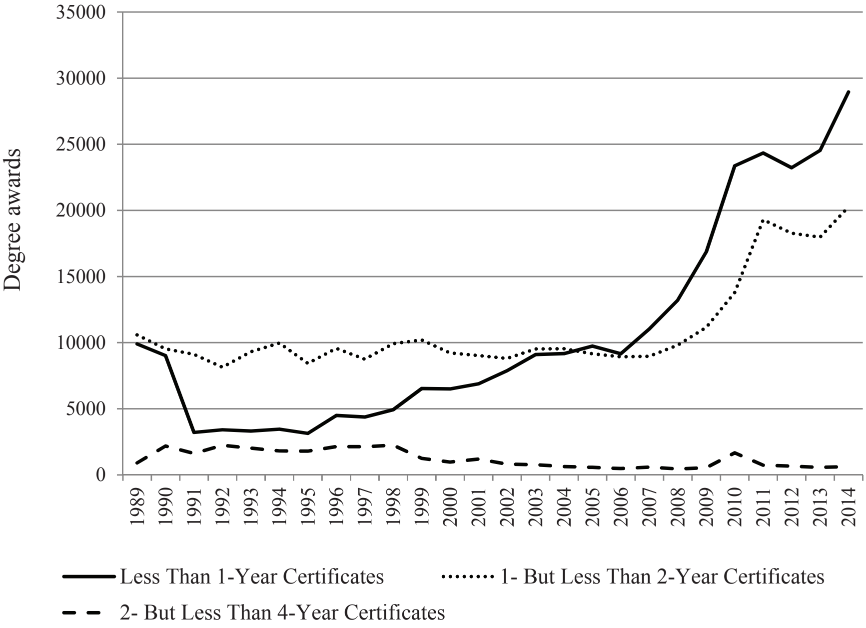

FIGURE 3-2 Engineering technician detailed certificate production, 1989-2014. SOURCES: Calculations from IPEDS data; population of institutions from NCES; and labels from IPEDS.

After 2004, however, some of the losses in bachelor's awards were recovered, while associate's awards continued to decline until 2006. The large growth of sub-associate's certificates is clear in Figure 3-3 as well. Hard economic times can be an impetus for retraining, which may explain some of the rapid growth in the 5 years spanning 2007-2014. However, neither the 1990-1991 nor the 2001 recession seems to have had this influence on certificate awards.

EDUCATIONAL COMPOSITION OF THE ET WORKFORCE

Chapter 4 provides an in-depth discussion of the employment of ET talent. Here, we touch briefly on the educational composition of those employed as engineering technologists and technicians. Over the past 40 years the educational background of those in the ET workforce has undergone substantial change (Figure 3-4). In the early 1970s, more than half held a high school degree or less, presumably gaining requisite skills through

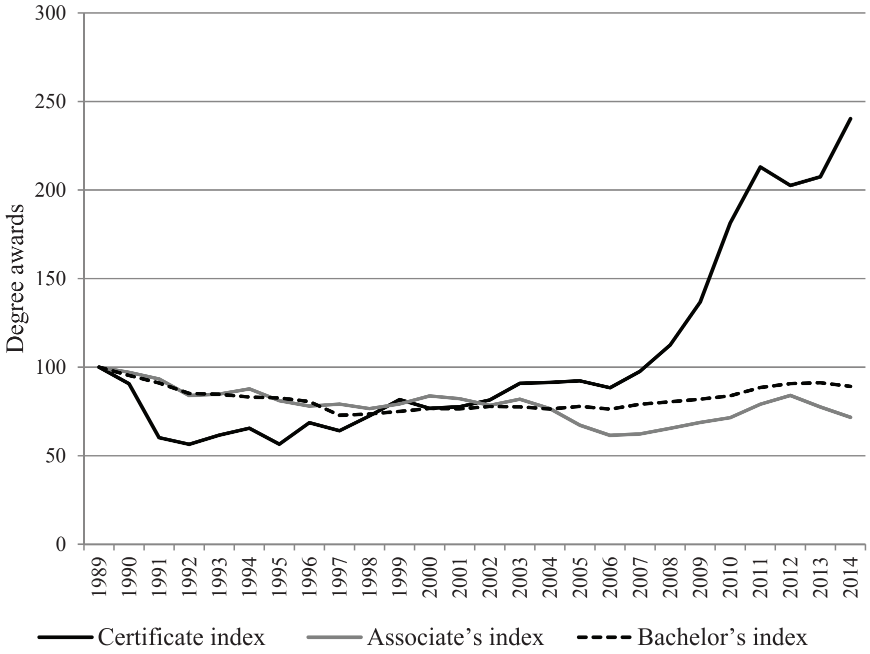

FIGURE 3-3 Index of engineering technician and technologist degree production, 1989-2014 (Base year: 1989). SOURCES: Calculations from IPEDS data; population of institutions from NCES.

high school vocational education, on-the-job training, and apprenticeships. This population steadily declined to less than 30 percent by the early 1990s, remaining at that level for the remainder of the period. Most of this decline consisted of an increase in the share of sub-baccalaureate's degree holders, which grew from approximately one-third of the workforce in the early 1970s to greater than 50 percent in the 2000s. With only slight increases in the share of bachelor's and graduate degree holders, most of the change in educational attainment comes from realignments in the sub-baccalaureate's degree population (see also Figure 3-2).

Degree Fields

Table 3-2 provides greater detail on the distribution of awards across ET subfields using data from the 2014 IPEDS. The field names listed in Table 3-2

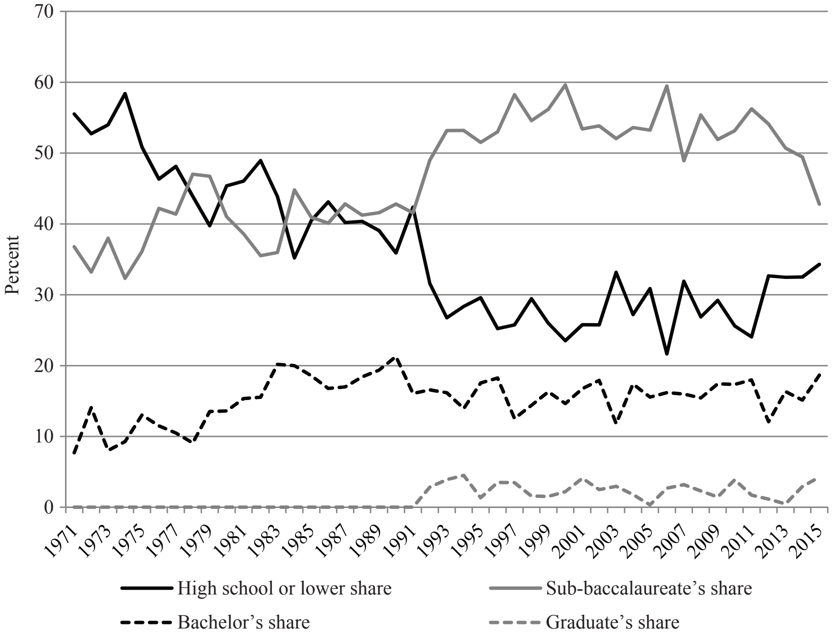

FIGURE 3-4 Educational attainment of engineering technicians and technologists, 1971-2015. SOURCE: Calculations from the 1971-2015 March Current Population Survey.

are taken from the Classification of Instructional Programs (CIP), the educational coding system developed by the National Center for Education Statistics (NCES), part of the US Department of Education. Unlike IPEDS, many federal datasets do not include this more detailed CIP breakdown but instead aggregate the data at a higher level. The result is that information about individual fields within ET often cannot be analyzed separately. Drafting/design engineering technology, for example, is often not categorized with ET in occupational codes used by the US Department of Labor, although it is nested within the broader ET category in standard educational field codes.

The astute reader may notice that the totals of 2- and 4-year ET degrees awarded in 2014 presented in Table 3-2 do not match those in Figure 3-1. The former shows that nearly 2,500 fewer 4-year and about 2,100 fewer 2-year degrees were handed out that year. This difference relates to the way NCES has standardized its coding of degrees across different years. Because CIP codes are revised occasionally, the standardization allows researchers and

TABLE 3-2 Postsecondary Awards by Engineering Technology Field and Degree Level, 2014

	Bachelor's Degree	Associate's Degree	2-4 yr. Cert.	1-2 yr. Cert.	< 1 yr. Cert.
Electrical and electronic engineering technology	2,661	8,182	9	1,411	1,445
Industrial production technology	2,563	3,469	12	1,987	2,523
Mechanical engineering related technology	2,104	2,009	208	572	729
Engineering technology, other	1,936	1,702	548	173	1,198
Construction engineering technology	1,680	576	0	148	173
Quality control and safety technology	1,445	846	149	113	522
Computer engineering technology	832	1,971	1	913	891
Civil engineering technology	532	825	5	28	75
Architectural engineering technology	386	686	0	62	208
Environmental control technology	321	2,709	0	3,288	2,437
Electromechanical and instrumentation technology	313	3,132	109	1,369	1,671
Engineering related technology	202	315	24	76	198
Drafting/design engineering technology	200	5,495	31	1,879	3,426
Nuclear engineering technology	169	137	0	49	0
Mining and petroleum technology	22	431	0	270	162
Nanotechnology	4	43	0	2	5
Total	15,370	32,528	548	12,340	15,663

SOURCE: Calculations from the 2014 IPEDS.

others to make consistent comparisons over time, and we present these time-series data for ET degrees graphically in Figures 3-1, 3-2, and 3-3. A downside of the standardized system, however, is that it includes several fields of degrees that the committee does not believe should be considered part of ET education (Box 3-2), and standardized coding is not available at the detailed level of Table 3-2. Thus, although the CIP codes are not as useful as the standardized ones for analyzing trends over time, they do have the advantage of enabling analysis that excludes certain portions of the underlying data. The data in Table 3-2 exclude the degree fields noted in Box 3-2.

The CIP System

Although a useful tool, the CIP system raises an important issue related to the definitional confusion surrounding ET. Specifically, some of the fields listed in Table 3-2 may not be recognized as ET by all stakeholders. Five of the field names, for example, do not include the term "engineering technology" and for this reason were not included in the committee's survey of academic programs. As noted, CIP is organized hierarchically, with more detailed subfields aggregated into larger fields. Thus, to understand what kind of education is being counted as ET, it helps to look at the more detailed subfields. The field Environmental Control Technologies/Technicians, for example, which does not contain the term "engineering technology," includes the following subfields, two of which do include the term "engineering technology" (NCES, 2010a):

- Energy Management and Systems Technology/Technician
- Environmental Control Technologies/Technicians, Other

BOX 3-2
Fields Excluded from the Count of
Engineering Technology Degrees in Table 3-2

- Audiovisual Communications Technologies/Technicians, Other
- Communications Technology/Technician
- Photographic and Film/Video Technology/Technician and Assistant
- Radio and Television Broadcasting Technology/Technician
- Recording Arts Technology/Technician
- Welding Technology/Welder

- Environmental Engineering Technology/Environmental Technology
- Hazardous Materials Management and Waste Technology/Technician
- Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician
- Solar Energy Technology/Technician
- Water Quality and Wastewater Treatment Management and Recycling Technology/Technician

An additional complication is that not all field or subfield names correspond to the title of the degree awarded to students or to the program names recognized by accrediting bodies, such as ABET. NCES acknowledges this general limitation:

> CIP codes, for the most part, are not intended to correspond exclusively to any specific degree or program level. In most cases, any given instructional program may be offered at various levels, and CIP codes are intended to capture all such data. (NCES, 2010b, p. 1)

In the case of the IPEDS survey, the job of reconciling specific degree and program names with the CIP coding system rests with the institution. IPEDS requires institutions to assign a single "keyholder," the person ultimately responsible for all data submitted (NCES, 2014). The keyholder may invite as many as seven other individuals to help input data. In the end, whether a specific degree or program is included in the IPEDS tally—and which specific CIP code it is listed under—depends on decisions made by these institutional representatives.

As noted, the lack of a one-to-one correspondence between degree and program names and the CIP field and subfield descriptors had to be taken into account in the committee's survey of ET programs. (The survey methodology is described in Appendix 3A, and a copy of the survey instrument appears in Appendix 3B.) To avoid confusion and to simplify the survey task, the committee decided to survey only those individuals associated with programs that included the words "engineering" and "technology" in the title. The resulting list of 55 programs (Box 3-3) was generated by combining the names of 2- and 4-year programs accredited by ABET with names of programs contained in the IPEDS database that do not have ABET accreditation.

Survey respondents were asked to select from the list the names of all of the ET programs offered at their institution. At the 2-year level (an associate of applied science or an associate of science degree), 86 respondents

BOX 3-3
Engineering Technology Program Names Included in NAE Survey of Educational Institutions

Aeronautical Engineering Technology
Agricultural Engineering Technology
Air Conditioning Engineering Technology
Applied Engineering Technology
Architectural Engineering Technology
Audio Engineering Technology
Automotive Engineering Technology
Bioengineering and Biomedical Engineering Technology
Chemical Engineering Technology
Civil Engineering Technology
Composites Engineering Technology
Computer Engineering Technology
Construction Engineering Technology
Drafting and Design Engineering Technology
Electrical and Electronics Engineering Technology
Electromechanical Engineering Technology
Embedded Systems Engineering Technology
Energy Systems Engineering Technology
Engineering Design Technology
Engineering Graphics and Design Technology
Engineering Graphics Technology
Engineering Management Technology
Engineering Technology (General)
Engineering Technology Management
Environmental Engineering Technology
Facilities Engineering Technology
Fire Protection Engineering Technology
Food and Process Engineering Technology
Geospatial Engineering Technology
Healthcare Engineering Technology Management
Highway Engineering Technology
Industrial Engineering Technology
Information Engineering Technology
Instrumentation and Control Systems Engineering Technology
Manufacturing Engineering Technology
Materials Engineering Technology
Mechanical Engineering Technology
Mechatronics Engineering Technology
Motorsports Engineering Technology

continued

BOX 3-3 Continued

Nano Engineering Technology
Naval Architecture and Marine Engineering Technology
Nuclear and Radiological Engineering Technology
Oil and Gas Engineering Technology
Packaging Engineering Technology
Plastics and Polymer Engineering Technology
Plastics Engineering Technology
Power Engineering Technology
Power Systems Engineering Technology
Product Design Engineering Technology
Robotics and Communication Systems Engineering Technology
Software Engineering Technology
Structural Analysis/Design Engineering Technology
Surveying and Geomatics Engineering Technology
Telecommunications Engineering Technology
Welding Engineering Technology

were responsible for 37 program types.[2] Of these, Electrical and Electronics Engineering Technology was the most prevalent, identified by 51 respondents, followed by Mechanical, Civil, Drafting and Design, Manufacturing, Architectural, Computer, Mechatronics, and Construction Engineering Technology, and Engineering Technology (General). At the 4-year level, 70 respondents identified 30 programs from the same list. Of these, Electrical and Electronics Engineering Technology was again the most prevalent, identified by 44 respondents, followed by Mechanical, Computer, Manufacturing, and Construction.

The NAE survey also found that the 4-year programs are much more likely to be accredited, particularly through ABET, than are the 2-year programs. About one-third of 2-year programs were ABET accredited; another one-third reported no accreditation; and about one-quarter indicated they

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[2] The survey item that asked about 2-year program names did not distinguish between associate of applied science (AAS) and associate of science (AS) degrees, so it is not possible to know the program names for the two degree types independently.

TABLE 3-3 Detailed Engineering Technology Degree Populations

Survey and Field of Bachelor's Degree	Population Estimate
2013 NSCG	
"Electrical and electronic technologies"	112,634
"Industrial and production technologies"	133,419
"Mechanical engineering-related technologies"	69,660
"Other engineering-related technologies"	120,003
2013 ACS	
"Engineering technologies" (general)	49,375
"Engineering and industrial management"	67,120
"Electrical engineering technology"	132,332
"Industrial production technologies"	106,428
"Mechanical engineering related technologies"	37,426
"Miscellaneous engineering technologies"	88,244

SOURCE: Calculations from the 2013 NSCG and the 2013 ACS.

were accredited by another entity.[3] Eighty-four percent of respondents representing 4-year programs indicated those programs were ABET accredited; 10 percent reported no accreditation; and about 6 percent indicated accreditation by another entity.

Beyond the aggregate total stock of degrees shown in Table 3-1, ACS and NSCG also can provide general information about degree fields. Table 3-3 presents the distribution of what Table 3-1 called the "stock" of bachelor's degrees in ET. Electrical engineering technologies and industrial and production technologies are among the most popular fields in both datasets. Reflecting the issues of nomenclature and categorization described earlier, it is worth noting that "Industrial and Production Technologies," per se, is not among the program names included in our survey of educational institutions. However, consistent with the federal data, our survey found that electrical and electronics engineering technology and mechanical engineering technology were the first and second most common program types, respectively, at both the 2- and the 4-year degree levels.

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[3] In addition to ABET, the survey asked about accreditation by two other organizations known to accredit some engineering technology programs: the Association of Technology, Management, and Applied Engineering and the American Council for Construction Education. However, only one 2-year program was accredited by each organization. The remaining 27 percent of respondents indicated accreditation by "Other." The survey did not ask respondents to explain "Other," but it may be in some cases that accreditation is conducted by the state in which the program resides.

Prevalence of Award Types

To get a sense of the prevalence of 2- and 4-year ET degree and ET certificate programs within institutions, the committee survey asked respondents to indicate the types of academic credit they grant (Table 3-4). Roughly equal numbers of respondents were responsible for 4-year and 2-year associate of applied science (AAS) degree programs. In our sample, certificate programs were much less common, and 2-year associate of science (AS) programs less common still. The relatively small number of AS programs in the survey sample may reflect the relative newness of these so-called transfer degrees (Box 3-4).

TABLE 3-4 Types of Academic Credit Granted by Engineering Technology Programs, Committee Survey

	Number of Programs
Bachelor of Engineering Technology, 4-year degree	70
Associate of Applied Science (AAS) in engineering technology, 2-year degree	72
Associate of Science (AS) in engineering technology, 2-year degree	22
Certificates in engineering technology, less than a 2-year degree	45

BOX 3-4
Two-year AS and AAS Degrees

Community colleges, technical schools, and some 4-year institutions offer 2-year associate of science (AS) degrees in engineering technology. These programs are often referred to as transfer programs because the coursework is intended to allow students to transfer credits to finish the last 2 years of a 4-year degree program. Community colleges and technical schools, but very few 4-year institutions, offer 2-year associate of applied science (AAS) degrees in engineering technology. These programs, which typically contain more practical, hands-on work but less advanced mathematics and science, are often intended to prepare graduates for jobs at graduation rather than of continued higher education. However, results from the committee's survey of ET programs, discussed later in this chapter, suggest transfer to 4-year programs is happening with considerable frequency for those with both AS and AAS degrees in engineering technology.

TABLE 3-5 Number and Types of Engineering Technology Programs Overseen by Respondents to Committee Survey

	Number of Programs Overseen by Respondents		
Program Type	1 (n=83)	2 (n=42)	3 (n=14)
BS	51	10	9
AAS	27	34	9
AS	4	8	12
Certificate	1	32	12

A number of people responding to the survey had responsibility for more than one type of degree program (Table 3-5).

DEMOGRAPHICS: DIVERSITY AND AGE

IPEDS data are ideal for generating a comprehensive understanding of engineering technician and technologist production, but other data can contribute to in-depth analysis of the characteristics of these graduates. In addition to the IPEDS, the ACS, the Baccalaureate and Beyond Longitudinal Study (B&B), and NSCG offer detailed cross-sectional information on student demographic, educational, and labor market characteristics.

IPEDS data on recent graduates (Table 3-6) show that racial and ethnic groups traditionally underrepresented in STEM fields are better represented in ET than in engineering. Most striking, ET degree earners are almost three times as likely to be black as those who receive a 4-year degree in engineering (almost 11 percent vs. almost 4 percent); the percentage of graduates who are Hispanic is equivalent between the two degree types, at about 10 percent. The share of sub-baccalaureate ET awards going to blacks and Hispanics in ET is even higher than is the share of 4-year ET degrees. And, compared to their representation in engineering, the proportion of ET graduates who are American Indian or Alaska Native is more than three times higher. However, degree earning by all groups remains significantly below their shares of the overall population. Compared with engineering, smaller shares of graduates with degrees in ET are Asian or Pacific Islander, a group not underrepresented in science, technology, engineering, and mathematics (STEM) fields.

In terms of gender, women were about 60 percent more likely to earn a 4-year degree in engineering than a 4-year degree in ET (almost 20 versus 12 percent). Both percentages are much lower than are the female share

TABLE 3-6 Gender and Race of Engineering Technology and Engineering Graduates, 2014 IPEDS

		Engineering Technology			Engineering
	Total Population	Less Than 1-Year Certificates	Associate's Degrees	Bachelor's Degrees	Bachelor's Degrees
Race and ethnicity					
White, Non-Hispanic	62.1%	62.5%	63.1%	63.6%	61.5%
Black, Non-Hispanic	12.4%	14.8%	11.4%	10.7%	3.8%
Hispanic	17.4%	12.3%	13.0%	10.0%	9.6%
Asian or Pacific Islander	5.4%	2.7%	3.1%	3.9%	10.9%
American Indian or Alaska Native	0.7%	1.1%	1.0%	0.8%	0.3%
Other/Unknown Races & Ethnicities[a]	2.0%	5.8%	7.4%	7.2%	5.8%
Student visa	—	0.8%	0.9%	3.7%	8.0%
All Females	50.8%	10.1%	12.4%	12.0%	19.8%
Females, by race and ethnicity					
White, Non-Hispanic	31.5%	5.5%	7.2%	6.5%	11.2%
Black, Non-Hispanic	6.5%	1.5%	1.7%	2.1%	1.0%
Hispanic	8.6%	1.4%	1.7%	1.5%	2.1%
Asian or Pacific Islander	2.8%	0.6%	0.5%	0.5%	2.6%
American Indian or Alaska Native	0.4%	0.1%	0.2%	0.1%	0.1%
Other/Unknown Races & Ethnicities	1.0%	0.8%	0.9%	0.9%	1.2%
Student visa	—	0.2%	0.2%	0.5%	1.7%

[a] The committee is unaware of any federal data that estimate the stock of those with student visas, so the "Total Population" cell for men and women with visas is left blank in this table.

SOURCES: Calculations from the 2014 IPEDS; population of institutions from NCES. Total population shares are from the US Census Bureau, with population-level race and ethnicity shares used for the female race and ethnicity shares.

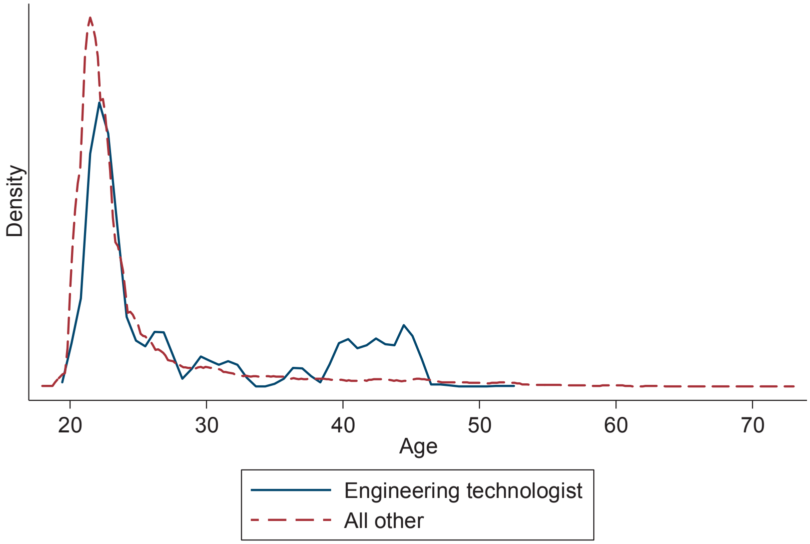

FIGURE 3-5 Age distribution of college graduates at time of B&B 2008/2009 survey interview. SOURCE: Calculations from the Baccalaureate and Beyond (B&B) Longitudinal Study 2008/2009.

of bachelor's degree earners overall (57.3 percent; IPEDS) and the share of women in the population (51 percent; US Census Bureau, 2016). The one female subgroup where ET fared better than engineering was African American females, where the (admittedly small) share graduating with 2- and 4-year awards was 70 percent and 100 percent greater, respectively, than was the share earning 4-year degrees in engineering.

The age distribution of 4-year ET graduates and all other 4-year graduates at their interview date for the first wave of the B&B (2008/2009) survey[4] (administered 1 to 2 years after graduation) is presented in Figure 3-5. Of course, the large majority of 4-year college graduates are in their early 20s, and ET graduates are no exception. What is more notable is the nontrivial share of ET graduates in their early 40s. In stark contrast to the general popu-

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[4] The unweighted sample of ET bachelor's program graduates in the B&B is relatively small, about 220 respondents. Because the full B&B sample is not stratified by academic major, population sizes for ET graduates in the 2008-09 school year cannot be produced with certainty from these data (and other estimates should be interpreted with caution). Still, the unweighted sample size is large enough to generate basic descriptive statistics on 4-year ET graduates.

lation of bachelor's degree holders, one-quarter of ET graduates were older than 35 at the time of their interview in their early postbaccalaureate careers.

WORK-BASED EDUCATION AND TRAINING

Work-based education and training plays an important role in the development of engineering technologists and technicians. In this section, we consider four types of such experiences: internships, cooperative education (co-ops), apprenticeships, and on-the-job training. Relative to what is known about classroom-based education, comprehensive data on work-based education and training are illusive and pose many empirical difficulties, particularly when examining a specific field such as ET.

Work-based education and training can have advantages over traditional classroom education. By design, trainees form strong connections to the labor market, either as employees (apprenticeship and on-the-job training) or as potential employees (internship and co-op). These connections help to ease the school-to-work transition, which can be especially difficult for individuals coming from disadvantaged backgrounds or for any worker in a depressed labor market. Work-based education and training also is valuable because the content of provided instruction is directly relevant to tasks performed on the job. Although classroom education can be highly practical and make close connections to work, it cannot replicate the specific collection of tasks on the job, need for problem solving, interactions with coworkers, or the pace of a standard workday. Finally, work-based education and training almost always come with financial compensation, so that trainees can "learn and earn." This model can make education and training more affordable, accessible, and rewarding. In addition, there is some evidence (e.g., Schuurman et al., 2008) that work-based learning experience in engineering can raise starting salaries even after controlling for academic performance.

Internships and Co-Ops

Our survey of educators finds that compared with apprenticeships, either internships or co-op experiences are a fundamental component of many engineering and ET programs (Table 3-7).[5] Both are work-based learning

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[5] This is in contrast to the situation with apprenticeships, which are much less prevalent. Apprenticeships are discussed later in this section.

TABLE 3-7 Estimated Prevalence of Work-Based Experiences for Students at 2- and 4-Year Engineering Technology Programs, Percent

	Apprenticeship	Internship	Co-op	Summer	Other	Don't Know
Two-Year Programs (N=84)	20.2	66.7	32.1	46.4	6.0	8.3
Four-Year Programs (N=70)	5.7	71.4	51.4	68.6	12.9	4.3

NOTE: In the committee survey, apprenticeships were described as "paid vocational programs for certification" and may not be formally identified as an apprenticeship by the educational institution, the employer, or the Department of Labor; internships as "paid or unpaid, at an employer, coordinated with the academic curriculum"; cooperative work experience (Co-op) as "semester- or quarter-based work experience as an alternative to campus-based learning"; and summer industrial work experiences (Summer) as "paid or unpaid and independent of the college/university."

experiences that occur while a student is enrolled in a degree program. Internships are shorter (often only a semester or during the summer) and less intensive than co-ops. They may or may not be paid or full-time. In contrast, co-ops are intensive, full-time, and paid experiences that typically require several alternating semesters with the employer. Training is often provided in both cases, although to varying degrees depending on the employer. Students are typically evaluated by the employer and report on their experiences to their academic department. This reporting process is often used to reinforce professional skills. For example, students in the computer ET program at Rochester Institute of Technology have to make a formal presentation on their co-op to their department in order to improve their presentation and communication skills (Eastman et al., 2005).

The primary values of the internship to the student (besides the pay) are the on-the-job experience and the potential for converting to an employee after graduation. Academic departments can benefit from internships and co-ops that provide stronger connections to local businesses. Vidalis and Cecere (2008) discuss the use of feedback from employers involved in internships to keep their construction ET curriculum up to date. The benefits of ties to local businesses can flow in both directions; the authors also discuss the recruitment of internship hosts through their industry advisory board.

Data from our survey of employers (Table 3-8) are consistent with what we learned from educational programs (Table 3-7): internships and co-ops

TABLE 3-8 Types of Experiential Education Provided to Students by Employers, Percent (N=225)

Internship	92.4
Cooperative work experience	65.3
Summer technical work experiences	36.4
Apprenticeship	8.4
Don't Know	0.4
Other	1.8

are a very popular mechanism for providing ET students with work-based experiences, while apprenticeship opportunities are much less prevalent.

According to the National Association of Colleges and Employers (NACE), employers operating internships and co-ops primarily offer this training in order to recruit entry-level hires. In a 2014 NACE survey, three-quarters of employers reported this as a reason for operating internships, and better than 60 percent reported the same for co-ops.[6] As noted, one measure of the value of co-ops and internships, for students, is the likelihood of converting their part-time experience into a full-time job. Table 3-9 presents the job offer, acceptance, and conversion rates for all (not just those enrolled in ET programs) intern and co-op students working for the employers surveyed by NACE. Interns and co-op students of all education levels consistently convert to employees at a rate of about 45 percent. Co-op students are more likely to accept an offer than are interns, so a lower offer rate is able to achieve the same conversion rate. This is not surprising, because students in co-ops have the opportunity to build deeper relationships with employers than do interns, with the result that their job skills may be more closely aligned with that employer. Interns have more generalizable job experience that may free them to reject job offers and pursue opportunities elsewhere.

To gain some insight into the nature of internship and co-op programs specific to ET, the committee used information compiled by *U.S. News and World Report* for its rankings of American colleges and universities. As part of its ranking process, the magazine asked chief academic officers, deans of

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[6] These data represent survey responses from 264 out of 1,116 NACE employer members. This is a relatively low response rate and may introduce bias into the reported results if respondents differ systematically from nonrespondents. Additionally, the NACE corporate membership is weighted toward large and midsize companies. As a result, the NACE data should be understood as coming from a "convenience sample," providing useful but not necessarily nationally representative information.

TABLE 3-9 Job Offer, Acceptance, and Conversion Rates of Intern and Co-op Students, NACE Employer Members, 2014

	Offer Rate	Acceptance Rate	Conversion Rate
Interns			
Associate's	69.40%	66.70%	46.30%
Bachelor's	60.50%	77.40%	46.80%
Co-ops			
Associate's	—	—	—
Bachelor's	53.70%	82.20%	44.10%

NOTES: Data are from the NACE 2014 Intern and Co-op Survey. Although the NACE survey reports co-op rates for associate's degree holders, the sample is sufficiently small that these figures are not reported here.

students, and deans of admissions from more than 1,500 schools to nominate up to 10 institutions with stellar examples of internship and co-op programs. Of the 13 top schools, 5 had ET programs, and 3 of these (Rochester Institute of Technology [RIT], the University of Cincinnati, and Purdue University) reported salary data. RIT and Cincinnati report minimum, average, and maximum hourly wages for all co-ops (Table 3-10). Purdue reported average monthly earnings (Table 3-11). Because all three institutions also have engineering programs, co-op earnings also are presented for engineers in comparable fields (when a comparable field is available). As shown in Table 3-10, patterns of average hourly wages vary across fields and schools. Typically, engineering students earn more than do ET students, although this is not the case for all fields at the University of Cincinnati. Architectural and civil ET students earn lower average hourly wages, but students in all other fields have relatively comparable average wages.

In the case of Purdue[7] (Table 3-11), engineering students typically earn more than do their ET counterparts in these co-ops, although this is not always the case (e.g., fifth period earnings for electrical and computer engineering technology co-ops).

Valentine and Richardson (2010) have studied the long-term performance of RIT ET students, all of whom are required to have at least 50 weeks of co-op experience before graduating. They find that RIT graduates' earn-

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[7] Because Purdue presents data from one academic year, a different group of students will be represented in each period. These data do not report the wages of the same cohort of students as they move through their co-op.

TABLE 3-10 Hourly Wages of Engineering Technology and Engineering Co-op Students at Rochester Institute of Technology and the University of Cincinnati

	Engineering Technology			Engineering		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Rochester Institute of Technology						
Civil	$8.00	$12.89	$24.00	—	—	—
Computer	$8.50	$16.01	$25.00	$7.50	$19.89	$46.25
Electrical	$10.00	$15.98	$22.00	$14.00	$17.00	$28.00
Manufacturing	$10.00	$15.36	$22.38	—	—	—
Mechanical	$8.00	$16.65	$30.00	$10.00	$17.02	$35.00
Telecommunications	$10.00	$17.54	$31.25	—	—	—
The University of Cincinnati						
Architectural	$11.50	$13.87	$18.00	$9.00	$13.65	$17.00
Computer	$13.00	$16.90	$22.00	$10.00	$16.94	$30.00
Electrical	$11.50	$15.99	$22.00	$10.00	$17.51	$33.00
Mechanical	$10.00	$16.12	$22.72	$7.25	$17.49	$40.96

NOTES: RIT data are from www.rit.edu/emcs/oce/employer/salary, downloaded October 2014. The University of Cincinnati data for the 2013-14 academic year are from www.uc.edu/propractice/salary-information.html. The salaries listed with RIT's Electrical Engineering Technology program actually pertain to its "Electrical/Mechanical Engineering Technology" program. No such degree exists for engineering, so these are compared to Electrical Engineering wages.

ings grew during the 2000s at approximately the same rate as engineering technologists generally. Graduates tend to work in more "applied" engineering jobs, and among these ET graduates an increasing share have identified their occupation as "engineer" over time. Satisfaction with the education provided by RIT also has increased. Dave and Dong (2010) note that the University of Cincinnati's work-based learning opportunities in ET extend beyond traditional co-ops to include service learning and study abroad programs.

Despite the shorter duration of associate's programs in ET, many 2-year institutions also run internships, often during the summer between students' first and second year of study. These programs are more difficult to assess, given their diversity and the tendency of 2-year degree programs to either feed local labor markets or provide transfers to 4-year degree programs. No data comparable to those provided by *U.S. News and World Report* are available for this cohort.

TABLE 3-11 Monthly Earnings of Engineering Technology and Engineering Co-op Students at Purdue University, by Period

Five Period Co-ops	First	Second	Third	Fourth	Fifth
Elect. & Comp. Engineering Technology	$1,860	$3,040	$3,451	$3,812	—
Computer Engineering	$3,110	$32293	$3,406	$3,553	$3,683
Electrical Engineering	$3,218	$3,541	$3,615	$3,715	$4,357
Mechanical Engineering Technology	$2,800	$2,880	$3,025	$3,360	—
Mechanical Engineering	$3,036	$3,160	$3,410	$3,533	$3,857
Three Period Co-ops					
Elect. & Comp. Engineering Technology	$2,700	$3,200	$3,360	—	—
Computer Engineering	$3,402	$3,692	—	—	—
Electrical Engineering	$3,209	$3,491	—	—	—
Mechanical Engineering Technology	$3,040	$3,280	—	—	—
Mechanical Engineering	$2,934	$3,404	$3.702	—	—

NOTE: Data downloaded in October 2016 from https://opp.purdue.edu/files/Average-Salaries-Guidelines.pdf.

ET departments and employers have experimented with variations on the traditional internship and co-op experience to fit their needs. For example, the electronics and telecommunications ET program at Texas A&M University operates an “Engineering Entrepreneurship Educational Experience” (E4) program, where local employers work with students in the classroom to move their product ideas to the prototype stage. Because these employers are locally based, interested students also can work on further commercialization of the product if they wish to. Porter and Morgan (2006) argue that this strategy is better suited to teaching entrepreneurship to students than is either standard classroom instruction or an internship or co-op that the department has less control over. It can even help serve as a professional development opportunity for faculty involved in the project.

Montana State University’s (MSU’s) mechanical engineering technology program has designed an internship that addresses the unique challenges faced by rural universities. In a rural setting, it is often difficult to identify employers for internships and co-ops. At MSU, instead of pairing with external employers, mechanical engineering technology students have the opportunity to work at the Center for Biofilm Engineering, a National

Science Foundation–funded engineering research center. Interns are tasked with designing, building, and testing a biofilm test system for use at the center (Cook et al., 2010). Although the internship program at MSU looks to intramural employers as an alternative to a traditional internship, the manufacturing engineering technology program at Brigham Young University offers paid internships at small manufacturing enterprises in Cambodia as an option for its students. This internship gives students a global perspective and emphasizes the role that these enterprises play in developing economies (Hawks and Miles, 2006).

Apprenticeships

The principal components of the apprenticeship training model are paid, productive employment that occurs concurrently with both on-the-job and classroom training in order to gain mastery over a specified set of skills. Apprenticeships are often integrated into career ladders or certifications, but these are not necessarily elements of all apprenticeships. In this sense, the model inverts the internship or co-op model, insofar as the apprentices are first and foremost paid, productive employees rather than students enrolled at a college or university. In the United States, apprenticeship programs are heavily concentrated in the construction industry, and in many cases, they are administrated by unions. Union sponsorship is less common for ET apprenticeships, which primarily serve the manufacturing sector.

Apprenticeship in the United States has received new attention with President Obama's pledge in the 2014 State of the Union address to reprogram $500 million in federal funds to promote "job-driven training." As part of this effort, the administration announced the availability of $100 million from H-1B visa fees to fund grants to apprenticeship partnerships (White House, 2014).

Apprenticeship programs in the United States fall into three broad (and in some cases overlapping) categories: (1) registered apprenticeships, (2) unregistered apprenticeships, and (3) youth apprenticeships. Registered apprenticeships meet certain federal and state program requirements in order to register with the Employment and Training Administration (ETA) of the US Department of Labor (DOL) or a State Apprenticeship Agency (SAA). Registered apprenticeship programs can be time based (requiring a minimum of 2,000 training hours), competency based (requiring demonstration of proficiency in essential job skills), or a hybrid of time- and competency-based training.

Unregistered apprenticeships follow the same training model, but they do not have a formal relationship with the DOL-ETA or an SAA. As a result, training intensity and quality may vary more substantially across unregistered apprenticeship programs. Youth apprenticeships target high school students in order to smooth the transition from school to work. These programs are well developed in Wisconsin and Georgia but are less common in other states. Our analysis will focus on registered ET apprenticeship programs, with a brief discussion of two cases of unregistered programs.

Registered Apprenticeships

Information on registered apprentices comes from the DOL's Registered Apprenticeship Partners Information Management Data System (RAPIDS). The system provides a complete record of individual registered apprentice experiences, but it critically covers only the states where programs register with DOL or register with SSAs but use the RAPIDS system.[8] Therefore, the analyses presented below provide valuable information on many (ET registered apprenticeships but they may not be representative of all programs.

The available RAPIDS data cover all apprenticeship programs registered with DOL-ETA from 1999 to 2014. Over this period, almost 5,000 apprentices were identified as engineering technicians or technologists,[9,10] less than half of 1 percent of the total of more than 1.2 million such apprenticeships. These ET apprentices were employed by 398 different sponsors (typically employers), although many reported sponsors represent different divisions of the same company. Several major manufacturers sponsor engineering technician and technologist apprenticeship programs covered in the RAPIDS data, including Alcoa, BP, Cummins, DuPont, ExxonMobil, Ford, John Deere, and Raytheon. Other large employers include local utilities. Federal agencies and labs do not

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[8] The states not included in the RAPIDS dataset are Connecticut, Delaware, Hawaii, Maine, Maryland, Massachusetts, Minnesota, Montana, Nebraska, New York, North Carolina, Oregon, Rhode Island, Vermont, Virginia, Washington, and Wisconsin.

[9] Some of the job titles entered by sponsors in RAPIDS can be cryptic, so apprentices were counted as engineering technicians or technologists if they (1) had an O*NET-SOC occupational code associated with engineering technology or (2) the job title provided explicitly used the phrase "engineering technologist" or "engineering technician."

[10] States not part of RAPIDS provide yearly estimates to the DOL on the total number of active apprenticeships within the state, so it is possible to get a rough sense of the magnitude of the apprenticeship population not captured in RAPIDS. In 2014, roughly one-third of apprentices nationally were not in the RAPIDS database.

employ a large number of these apprentices, but they also are represented, including NASA and Sandia National Laboratory. Table 3-12 presents the distribution of apprentices across employer industries.

Most employers with registered apprenticeship programs involving engineering technologists and technicians are engaged in manufacturing or in the public sector, with a lower share in construction than is typical of the full population of apprentices. Just over 20 percent of ET apprentices receive job training as prison inmates (Table 3-13). Because this population may be quite different from the typical engineering technician or technologist population, the characteristics of apprentices provided in Table 3-13 are presented separately for inmates.

A little more than one-third of non-inmate engineering technician and technologist apprentices are unionized (36.7 percent). Unions often play an instrumental role in apprenticeship programs operating at union shops. Only 7.9 percent of these apprentices are female, a lower share than for female recipients of ET certificates, associate's degrees, or bachelor's degrees (Table 3-6). And compared with those in certificate- and degree-granting programs, a greater proportion of engineering technician and technologist inmate apprentices are black. This is not surprising, given well-known racial disparities in incarceration rates in the United States (e.g., NRC, 2014). Non-inmate apprentices also are older than apprentices overall, with an average

TABLE 3-12 Industrial Distribution of Engineering Technician and Technologist Apprentices, 1999–2014

Industry	Percent
Manufacturing	46.69
Public Administration and National Security	30.29
Utilities	9.84
Construction	3.24
Unknown Industry	3.16
Professional and Technical Services	2.11
Information	1.40
Wholesale Trade	1.28
Mining, Quarrying, and Oil and Gas Extraction	0.89
Educational Services	0.55
Other Services (except Public Administration)	0.43
Administrative and Waste Services	0.10
Health Care and Social Assistance	0.04

NOTE: Committee's calculations are based on the RAPIDS database from 1999 to 2014.

TABLE 3-13 Characteristics of Engineering Technologist and Technician Registered Apprentices in the RAPIDS Database, 1999–2014

	Total Engineering Technologists and Technicians	Non-inmate Engineering Technologists and Technicians	Inmate Engineering Technologists and Technicians	All Apprentices
Apprentices in the RAPIDS database	4,939	3,872	1,067	1,222,046
Unionized				
Union	28.79%	36.73%	0.00%	60.44%
Nonunion	68.05%	59.25%	100.00%	39.33%
Unknown	3.16%	4.03%	0.00%	0.24%
Gender				
Female	7.85%	7.85%	3.84%	6.80%
Male	92.15%	91.12%	96.16%	91.66%
Unknown	0.00%	1.03%	0.00%	1.54%
Race/ethnicity				
White	71.39%	78.23%	46.58%	64.77%
Black	14.56%	8.37%	37.02%	11.63%
Hispanic	7.25%	6.02%	11.72%	16.11%
Asian	2.15%	2.53%	0.75%	1.20%
Hawaiian/Pacific Islander	1.19%	1.42%	0.37%	0.76%
Native American	1.58%	1.39%	2.25%	1.44%
Unknown	1.88%	2.04%	1.31%	4.08%
Age at registration				
16-20	4.66%	5.81%	0.47%	14.46%
21-25	11.93%	14.10%	4.03%	27.26%
26-30	16.00%	17.20%	11.62%	20.28%
31-35	16.70%	16.14%	18.75%	13.40%
36-40	15.75%	14.82%	19.12%	9.08%
41-45	14.09%	13.69%	15.56%	6.19%
46-50	11.30%	10.38%	14.62%	3.78%
51-55	5.73%	5.04%	8.25%	1.94%
55+	3.77%	2.76%	7.40%	1.11%
Unknown	0.07%	0.06%	0.18%	2.50%
Mean age	36.4	35.2	40.3	29.4
Educational attainment				
≤ 8th grade	0.18%	0.15%	0.28%	1.01%
9th-12th grade	4.13%	4.36%	3.28%	10.35%
GED	14.38%	6.04%	44.61%	12.03%

continued

TABLE 3-13 Continued

	Total Engineering Technologists and Technicians	Non-inmate Engineering Technologists and Technicians	Inmate Engineering Technologists and Technicians	All Apprentices
≥ High school	66.75%	74.04%	40.30%	68.57%
Postsecondary or technical training	12.43%	12.91%	10.68%	4.39%
Education unknown	2.12%	2.48%	0.84%	3.66%

NOTES: Committee's calculations are based on the RAPIDS database from 1999 to 2014. Apprentices in states that do not use the RAPIDS data system are not included.

age of 35.2, and more than 30 percent are over age 40. Although apprentices in the United States tend to be older than their counterparts in Europe and elsewhere (where apprenticeship primarily functions as a form of entry-level training for youth), the age differential is even starker for engineering technicians and technologists.

Almost three-quarters of non-inmate apprentices report attaining a high school diploma or higher, including nearly 13 percent who report having a postsecondary degree or some form of technical training. Unfortunately, the RAPIDS system does not provide consistent or detailed information about educational attainment above the high school level. It is clear, however, that ET apprenticeships are being filled by workers who are at least as well educated as the population of apprentices as a whole.

Unregistered Apprenticeships: Two Case Studies

Many apprenticeship programs are not covered in the RAPIDS database either because they are registered with an SSA that does not use RAPIDS or because they are unregistered. This includes several prominent ET apprenticeship programs. Two such programs are operated at BMW's South Carolina plant and at the Apprentice School in Newport News, Virginia. The BMW program is unregistered, while the Apprentice School program is registered with the state of Virginia but does not appear in the federal database. BMW cites confidence and flexibility in its capacity to provide widely recognized, high-quality training without public assistance and unnecessary bureaucracy as a reason for being unregistered. It reproduces the same training regime in its South Carolina plant that the company implements with great success in Germany. The Apprentice School started operating its school long before the modern growth in registered apprenticeship programs, and its quality is highly regarded in the shipbuilding industry.

BMW is one of a number of German companies that have brought the apprenticeship training model to the United States.[11] Others include Volkswagen (Chattanooga, Tennessee) and Siemens (Charlotte, North Carolina). BMW established its only American plant near Spartanburg and Greenville, South Carolina. Its apprenticeship program is called the "BMW Scholars Program," and it accepts more than 50 students into the program each year for a 2-year period that combines education with on-the-job training. The more traditional educational components of the apprenticeship are provided by Spartanburg Community College, Tri-County Tech, and Greenville Technical College. As a requirement of the program, apprentices complete an AS or AAS degree in relevant fields, such as automotive technology, mechatronics, industrial maintenance, mechanical engineering, electrical engineering, or production technology. The on-the-job BMW-specific training is provided by BMW in its facility over the 2-year period. BMW also supports intern and co-op assignments for apprenticeship completers who choose to pursue a bachelor's degree in engineering. The certifications earned by the BMW Scholars are internationally recognized in the BMW Group, and completers can work productively in any BMW plant and for other employers as well.

Apprentice pay in the BMW program is somewhat lower than in some ET intern and co-op programs (e.g., Tables 3-10 and 3-11, although these data reflect students pursuing bachelor's degrees) and at the more comparable Apprentice School, discussed below. Aring's (2014) study of German companies operating apprenticeship programs in the United States found that BMW Scholars are paid $10-12 an hour as apprentices and are offered jobs paying $20-25 an hour upon completion, a rate comparable to completion wages at the Apprentice School. According to BMW (Werner Eikenbusch, BMW Manufacturing Co., LLC, 10/21/2015),[12] the pay for apprentices at BMW reflects the prevalent apprenticeship rate paid in the region and takes into consideration the cost of living in the region. In addition, BMW provides generous tuition assistance and benefits for its apprentices, which for most of the apprentices cover the full cost of tuition.

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[11] The following discussion of the BMW Scholars Program draws heavily on Monika Aring's (2014) report on apprenticeships at BMW, Volkswagen, and Siemens plants in the United States.

[12] Werner Eikenbusch was a member of the study committee for this project.

South Carolina is attractive to BMW in part because of its policy environment, which is characterized by heavy promotion of apprenticeship training through the Apprenticeship Carolina initiative (www.apprenticeshipcarolina.com), a robust technical college system, a work-ready labor pool, generally low taxes, and business-friendly regulations. BMW has avoided external regulation of its on-the-job training curriculum, while the AS/AAS college degree curricula are regulated by the state of South Carolina. BMW operates the BMW Scholars Program successfully without coordinating curriculum or training across other programs in the same occupation group, which is distinct from the functioning of federally registered apprenticeships, which have to have their training approved by either DOL-ETA or a federally recognized SSA. The approach of leveraging the existing AS/AAS technical degree infrastructure and keeping the on-the-job training content flexible to quickly address changes in business requirements has been satisfying for both BMW and its apprentices. BMW has worked successfully with Apprenticeship Carolina to establish certification of the BWM Scholars Program at the state level. BMW believes that this sort of apprenticeship training is conducive to scaling in the United States (for ET specifically or more generally).

The Apprentice School was established in 1919 and is operated by Huntington Ingalls Industries in Newport News, Virginia. It is not registered with DOL-ETA and does not appear in the RAPIDS database, but it is registered with the state. The school is a highly regarded apprenticeship program that produces engineering technicians in collaboration with Thomas Nelson Community College, where apprentices may matriculate if they elect to pursue an advanced curriculum after their introductory shipbuilding and trade-related curriculum.[13] The school also partners with Tidewater Community College and Old Dominion University (Fain, 2015).

Apprentices first go through four academic terms of shipbuilding and trade courses, with trade options ranging from dimensional control technician and electrician to pipefitting and welding. Shipbuilding courses include a foundation in technical math, technical communication, physical science, and ship construction. Apprentices who elect to go on to pursue ET are first required to take “pre-advanced” college preparatory and higher math courses. These courses, along with the ET courses, together take an additional nine semesters. Apprentices have the option of pursuing an associate’s degree in either mechanical or electrical ET. Apprentice School apprentices are full-time paid employees as they advance through their coursework, and

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[13] The advanced curriculum also has business administration and engineering options provided by Tidewater Community College.

they receive on-the-job training and mentorship from a team of 70 craft instructors. These instructors monitor and evaluate the development of the apprentices' job skills and provide training.

A wage progression is an important part of the Apprentice School program, as it is for many apprenticeship programs, and is contingent on progress through the curriculum. Table 3-14 presents the wage schedule effective in 2014. The beginning and ending wages for these apprentices match or exceed the co-op earnings for those enrolled in 4-year ET programs (Table 3-11).

The Apprentice School also recognizes differences in conditions across occupational labor markets by providing alternative wage schedules for dimensional control technicians, patternmakers, marine designers, and production planners. The wage schedule provides apprentices with steady pay increases from term to term. In total, apprentices that remain in the program will experience at least a 57 percent pay increase, according to this schedule.

On-the-Job Training

On-the-job training (OJT) is an essential source of human capital investment, particularly in fields that are rapidly changing due to technological development. However, OJT can be difficult to assess empirically. It lacks the standardized definitions of classroom training (or even internships, co-ops, and apprenticeships) and is often delivered in an informal way, so that

TABLE 3-14 Apprentice School Wage Progression, 2014

Pay Rate Effective	Hourly Wage
Beginning of 1st Term	$15.95
Mid-Term of 1st Term	$16.64
Beginning of 2nd Term	$17.36
Mid-Term of 2nd Term	$18.18
Beginning of 3rd Term	$19.00
Mid-Term of 3rd Term	$19.70
Beginning of 4th Term	$20.68
Beginning of 5th Term	$22.12
Beginning of 6th Term	$22.77
Beginning of 7th Term	$23.56
Beginning of 8th Term	$24.18
Completion	$25.12

NOTE: Data are from www.as.edu/wages.html.

reporting, if it even occurs, may be unreliable. Barron and colleagues (1997) find that although employers and workers report similar incidence of OJT, employers report 25 percent more hours of training than do workers. This measurement error is not inconsequential; it results in an underestimation of the effect of training on wages in studies that do not take this problem into account (Barron et al., 1997, pg. 525). Lerman and colleagues (2004) compile evidence from previous studies of OJT with more recent survey data in order to make broader claims about training despite the inherent measurement problems. They find that OJT has increased over time and that bachelor's degree holders tend to receive more OJT than less-educated workers receive.

Prior studies of OJT have used datasets such as the National Household Education Survey or the Survey of Income and Program Participation. These are valuable data sources for studying training for the entire national workforce, but they are not as well suited to studying detailed subpopulations such as the engineering technician and technologist workforce, because too few technicians and technologists appear in these datasets. As an alternative, we use data from the 2010 NSCG, which oversamples STEM graduates and provides a sufficiently large sample of engineering technologists. NSCG is not a perfect data source because it only collects information about bachelor's degree holders and is therefore not useful for understanding the OJT experiences of engineering technicians. In addition, the survey also seems to identify more engineering technologists than do other labor market surveys, suggesting that some engineers or related technician occupations may be classified mistakenly as engineering technologists. If this is the case, then the findings below may imperfectly reflect the actual OJT experience of engineering technologists.

Respondents to NSCG are asked whether they received training in the past 12 months, although they are not asked about the intensity, formality, or duration of the training. Table 3-15 presents the training rates for all engineering technologists and by age group. Training rates are higher for younger workers, although a substantial amount of training occurs for all

TABLE 3-15 Percentage of Engineering Technologists and Bachelor's Degree Holders Receiving OJT in the Last 12 Months, 2013

All engineering technologists	48.8
Early career (ages 25-35)	65.6
Mid- and late career (age 35+)	47.0
All bachelor's degree holders	51.5

SOURCE: Committee's calculations based on the 2013 NSCG.

TABLE 3-16 Most Important Reason for OJT for Engineering Technologists, 2013

Reason	All Engineering Technologists	Mid- And Late Career (Age 35+)	Early Career (Ages 25-35)
1. To improve skills or knowledge in current occupation	56.6%	56.3%	61.5%
2. To increase opportunities for promotion or advancement in current occupation	9.2%	8.4%	12.5%
3. For licensure/certification in your current occupation	9.1%	8.6%	4.1%
4. To facilitate change to a different occupation	0.5%	0.6%	0.3%
5. Required or expected by employer	22.2%	23.6%	18.9%
6. For leisure or personal interest	0.8%	0.4%	2.2%
7. Other	1.7%	2.2%	0.4%

SOURCE: Committee's calculations based on the 2013 NSCG.

engineering technologists. These training rates are much higher than are estimates of OJT for all Americans but are comparable to some estimates of the incidence of training for bachelor's degree holders.[14] Lerman and colleagues (2004) note that higher levels of training for bachelor's degree holders may indicate that a worker's existing stock of human capital raises the benefits of subsequent training. This interpretation suggests that ET education not only imparts important technical skills and competencies, but also helps graduates become better learners and critical thinkers.

NSCG also asks respondents to identify the most important reason for their training (Table 3-16). Early career engineering technologists (ages 25 to 35) were more likely than were mid- and late career engineering technologists (35 years or older) to cite improving skills or knowledge as a driving motivation. They were less likely than were mid- and late career engineering technologists to report having taken training to please their employer. These data may not only reflect objective differences in reasons for training but also indicate changing attitudes toward and enthusiasm for training as workers age.

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[14] These estimates vary widely, typically depending on what the question asked on the survey implies about the intensity of training.

COMMUNITY COLLEGE EXPERIENCES

A substantial share of recent ET graduates has prior experience in the community college system (Table 3-17). In the B&B survey, graduates are asked if (1) they have ever enrolled at a community college and (2) they have ever taken a course at a community college. That a larger share of survey-takers responds affirmatively to the latter question than the former may reflect confusion about what it means to be enrolled in a program of study. Regardless of this possible confusion, these data indicate a high prevalence of community college attendance among ET graduates. Greater than 44 percent of graduates in the B&B sample claimed that they had enrolled in a community college before attending a 4-year degree program. This compares to 27 percent of all engineering graduates and almost 35 percent of all graduates. However, given the small size of the B&B sample of ET graduates, these comparisons must be interpreted cautiously.

Because of their accessibility and relatively low cost compared with 4-year institutions, community colleges are potentially important institutions not only for educating 2-year ET technicians but also for providing a jump start to students who intend to earn a 4-year ET degree. The role of community colleges in the ET education pathway is evident in some of the project's survey results, discussed later in this chapter.

CONNECTIONS TO PreK-12 EDUCATION

The IPEDS data cover only the postsecondary education system and do not provide insight into pre-college educational experiences related to ET. Such experiences may provide an important introduction and inspiration for related postsecondary and OJT. Data on high school coursework in engineering-related subjects is not readily available in standard educational

TABLE 3-17 Community College Experience of Engineering Technologist Graduates

	Weighted Number	Weighted Percentage
Ever enrolled at a community college	6,714	44.34
Ever took a course at a community college	7,698	50.84
Ever enrolled or took a course at a community college	8,592	56.74

NOTE: Committee's calculations are based on the B&B 2008/2009 survey.

TABLE 3-18 Percentage of Public High School Graduates Earning Various Numbers of Credits in CTE Fields, Year

	Engineering Technology	Any Occupational Education CTE Field	All CTE Fields
Any credits	11.1	84.9	94.16
At least 1 credit	8.3	76.1	88.46
At least 2 credits	2.2	53.2	70.86
At least 3 credits	0.9	36.2	54.56
At least 4 credits	0.4	23.8	40.26
At least 5 credits	0.2	15.5	28.6

SOURCE: Adapted from NCES, 2009a.

and workforce surveys, which tend to focus on postsecondary education. However, it is available in the NCES' series of Career/Technical Education (CTE) tables.

Table 3-18 shows the share of public high school graduates earning various minimum numbers of credits in ET, in any occupational education CTE field, and in all CTE fields (occupational and nonoccupational training combined). About two-thirds of US high school students attend or have access to CTE schools (NCES, 2009a). Only 11 percent of graduating students take any credits in ET, with the majority of those (8 percent of all students) taking at least one credit.[15] However, the incidence of ET education at the high school level declines quickly, with only 2.2 percent of all graduates earning at least two credits and even fewer earning three or more. This decline in credit taking is not as steep for broader measures of CTE course taking, suggesting that many students (including those enrolled in ET classes) have the opportunity to mix many different CTE courses.

Although more than a tenth of students get some exposure to ET in high school, the average number of credits earned by all students is quite low due to the already low number of credits earned by students taking any ET credits. In selected years between 1990 and 2009, no more than 0.2 ET credits were earned by high school graduates on average (Table 3-19). Moreover, the average number of credits declined over this period, in line with the number of any CTE credits earned. Average ET credits and CTE credits declined not only in absolute terms but also as a percentage of all credits earned by high school graduates. Thus, although in the realm of postsecondary education

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[15] A credit in this context is the equivalent of a 1-year (two-semester) course, also known as a Carnegie Unit.

TABLE 3-19 CTE Credits Earned by Public High School Graduates

	Engineering Technology	Any Occupational Education CTE Field	All CTE Fields
Average number of credits earned			
1990	0.2	2.7	4.2
2000	0.2	2.9	4.2
2005	0.2	2.6	4
2009	0.1	2.5	3.6
Percentage of total credits earned			
1990	0.7	11.5	18
2000	0.7	10.9	16.1
2005	0.6	9.8	14.9
2009	0.5	9	13.1

SOURCE: Adapted from NCES, 2009b.

the center of gravity of ET has shifted to lower institutional levels (certificates rather than 2- or 4-year degrees), this shift is not mirrored in high schools, which are graduating students with fewer ET credits over time.

Prior to 2007, NCES did not have a grouping of CTE coursework called ET. However, a revision that year in the taxonomy the agency uses to analyze CTE offerings established ET as a new category (NCES, 2008). (Data in Table 3-19 reflect the fact that NCES reanalyzed CTE data collected prior to 2007 using categories from the new taxonomy.) Thirty-three of the courses in the new category were moved from the “other technology” area within what had been called “Technology and Communications.” Nine courses were taken from the “drafting/graphics/printing” area within the former “Precision Production” category. Four courses were moved from “computer technology” and two from “other precision production.”

In crafting the taxonomy, NCES says it attempted to align the secondary school categorizations with codes used in the CIP, the coding scheme for postsecondary instructional programs. In the case of ET, NCES aligned the 48 CTE courses with CIP code 15, engineering technologies/technicians. It is worth noting that relatively few of the CTE courses in the ET category include the term “engineering technology” in their titles, hinting again at the confusion surrounding terminology in the field.

Engineering Education in Other Parts of the PreK-12 Curriculum

The CTE statistics do not tell the whole story with respect to the engineering-related experiences of precollege students in the United States. For one thing, the CTE taxonomy excludes programs in technology education/industrial arts. Although much smaller than the teaching force in PreK-12 mathematics and science, the approximately 30,000 teachers certified in technology education (Moye, 2009) have played an important role over the past 15 years in exposing students to engineering ideas and practices. Many of these teachers have been encouraged by the *Standards for Technological Literacy: Content for the Study of Technology* (ITEEA, 2007) and instructional materials based on the standards, which devote major attention to ideas in engineering and engineering design. The history of technology education/industrial arts echoes some of the same themes that underlie development of ET: that is, the desire of educators to assure students' learning of theory is complemented with development of practical skills.

> The advent of formal engineering education with its emphasis on theoretical mathematics and science was accompanied by a growing recognition that aspiring engineers also needed manual skills. As early as 1870, Calvin M. Woodward, dean of the engineering department at Washington University, instituted shop training for his engineering students after he found that they were unable to produce satisfactory wooden models to demonstrate mechanical principles. John D. Runkle, president of the Massachusetts Institute of Technology, introduced a similar program after seeing demonstrations of Russian manual arts training at the 1876 Centennial Exposition in Philadelphia. Both men believed that shop skills were essential for engineers (Sanders, 2008).
>
> In the 1880s, under the leadership of Woodward and Runkle, Washington University and MIT established schools for intermediate and secondary students that provided a combined program of liberal arts and manual training. . . . By the early twentieth century, there had been a conceptual shift from "manual training" to "industrial arts." Contrary to what many people assume, industrial arts represented a shift away from vocational training toward general education for all (Herschbach, 2009). Students studied how industry created value from raw materials in the context of the developing industrial society in America. The curriculum required the ability to use industrial tools, equipment, and materials in a laboratory setting, but the "shop experience" was a means to an end, not an end in itself. [Excerpted from NAE and NRC, 2009, pp. 31-32.]

Dozens of curricula at the elementary, middle, and high school levels include an emphasis on engineering (NAE and NRC, 2009). Several of these have reached national scale, such as Project Lead the Way (www.pltw.org), Engineering is Elementary® (www.eie.org), and Engineering by Design™ (www.iteea.org/EbD/ebd.htm) (Box 3-5). Educators delivering these curricula include not only technology teachers but also science teachers, mathematics teachers, and elementary school generalists. PreK-12 students also are being exposed to engineering through a host of after- and out-of-school experiences, such as those organized by the Girl and Boy Scouts, provided

BOX 3-5

Examples of Established K-12 Engineering Curricula

Project Lead the Way

Project Lead the Way (PLTW; www.pltw.org) was started in the late 1980s by a New York high school technology education teacher. In the late 1990s, with support from a private foundation, PLTW created a high school curriculum that was adopted by a number of New York high schools. PLTW offers engineering-focused coursework at the high school and middle school levels, and it recently launched a new elementary program. PLTW teachers take part in a 2-week summer training program to be certified to deliver the curriculum. PLTW claims a presence in more than 6,000 schools across all 50 states.

Engineering is Elementary®

Engineering is Elementary® (EiE; www.eie.org) is a 13-year-old project of the National Center for Technological Literacy® at the Museum of Science, Boston. EiE consists of 20 units, each of which has a hands-on engineering design challenge combined with a thematic storybook, teacher guide, and a materials kit. The EiE project conducts workshops and other teacher professional development activities to support use of the curriculum. As of November 2014, EiE says more than 72,000 teachers and 6.6 million students across the country have used EiE in all 50 states plus Washington, DC.

Engineering by Design™

Engineering by Design™ (EbD; www.iteea.org/ebd) is a K-12 curriculum project developed by the International Technology and Engineering Educators Association (ITEEA). The units address topics across the spectrum of technology and engineering, and they are used primarily by technology education programs in a 20-state consortium. Through its STEM Center for Teaching and Learning, ITEEA provides professional development for teachers planning to use the EbD curriculum.

through robotics competitions such as US FIRST, and programs and exhibits hosted in museums and science and technology centers.

Beyond specific curricula, a number of factors recently have combined to increase the visibility and potential importance of engineering in PreK-12 education. Most notable is the *Next Generation Science Standards* (NGSS), developed by a consortium of 26 states and coordinated by Achieve, Inc. (NGSS Lead States, 2013). NGSS, which is based on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), weaves engineering design and a few key engineering concepts into science content and practices, providing an important lever for connecting learning in engineering and science. So far, 16 states and the District of Columbia have adopted the new standards, and nearly twice that many are expected to eventually adopt them. The idea that engineering can provide application opportunities for concepts in science and mathematics is not new, and research suggests that under the right circumstances more integrated forms of education can improve student learning and interest in the STEM subjects (e.g., NAE and NRC, 2014).

In summer 2014, the College Board made public its plans to develop curriculum and associated exams for an AP engineering course. And in spring 2016, the National Assessment Governing Board (NAGB), which oversees the so-called Nation's Report Card, released results of the first-ever assessment of engineering and technology literacy among a large sample of American 8th graders (NAGB, 2016). Overall, 43 percent of those taking the assessment were rated "proficient" in skills and knowledge related to engineering and technology. However, proficiency rates were much lower for black and Hispanic students than they were for white students. And students in the national school lunch program scored much lower than those receiving free-and-reduced-priced meals. Slightly more than one-half of students reported taking at least one class in school related to the topics covered in the assessment.

Precise, reliable data about the number of US PreK-12 students exposed to meaningful engineering education opportunities are hard to come by. However, the size and growth of the several engineering curriculum projects noted here; the likely need for new engineering-related instructional materials to meet the needs of states implementing NGSS; and the likely advent of an AP engineering course suggest that the trend line slopes upward. The committee is aware that the mere presence of opportunity does not mean PreK-12 students exposed to engineering—through CTE courses, other types of courses, or after-/out-of-school programs—will pursue college coursework or careers in ET. Nevertheless, these precollege experiences are a potentially important part of the pathway into ET.

EDUCATIONAL PATHWAYS

In an effort to better understand the educational choices made by those who pursue degrees in ET, the committee included questions probing this issue in its survey of educational institutions. We also learned something about this choice-making directly from several students and former students who participated in our December 2014 workshop (the agenda appears in Appendix 3C). Combined with the federal data on the prevalence of degree- and certificate-earning described earlier in the chapter, this information provides insights into ET educational pathways.

We asked respondents to our survey to reflect on their incoming student populations and to tell us, in rank order, the top three sources of students for their programs. The responses were weighted (with top rank having more weight than second, and second more than third). The weighted summaries indicate that 2-year programs (N=86) draw primarily from two populations—high school students and adults who are changing careers or adding to their skills—but returning veterans also are a significant source of students for these programs (Figure 3-6). Transfer students from other 2-year, 4-year, or certificate programs are much less prevalent sources. The 4-year programs

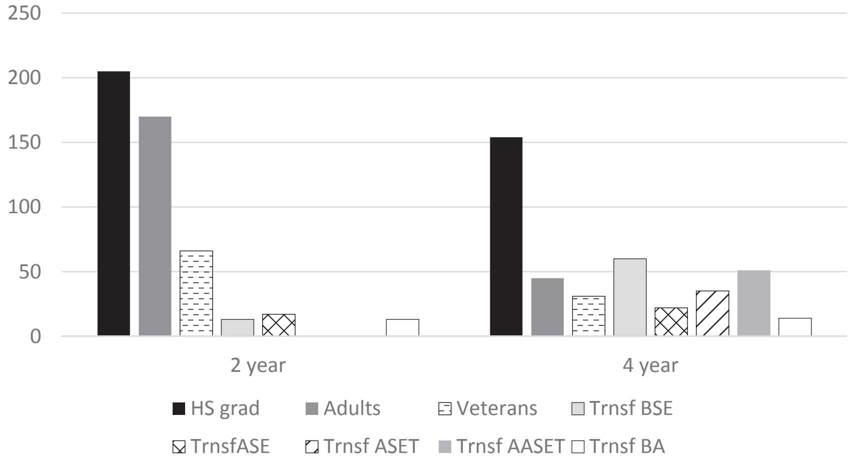

FIGURE 3-6 Prevalence of sources of students for 2- and 4-year ET programs, weighted scores

NOTES: Respondents' first choices were given a score of 3, second choices a score of 2, and third choices a score of 1. Unselected choices received a score of 0. The final reported "score" is the sum of all of these weighted values.

(N=70) draw most heavily on recent high school graduates, with modest contributions from five other categories of students.

To get a sense of the flow of students within and between educational institutions, we also asked respondents for information about transfer options and their views on student mobility. A key enabler of inter-institutional student transfers is the articulation agreement, which establishes rules about such things as the equivalence of course credits. More than 60 percent of respondents indicated they had agreements that allow students to transfer with a 2-year AAS degree in ET to a 4-year BS ET program at another school (Table 3-20). Slightly greater than 40 percent said they had agreements allowing students to transfer to a 4-year ET program with a 2-year AS degree in ET. Smaller percentages of respondents, 28 and 21 percent, respectively, had agreements allowing 2-year AAS and 2-year AS degree recipients to transfer to 4-year engineering programs.

Between 32 and 56 percent of survey respondents indicated that less than 10 percent of their 2-year ET graduates (both AS and AAS) transfer to a 4-year ET or engineering degree program (Figure 3-7). Consistent with the number of programs that allow transfer (Table 3-20), the most prevalent transfer path appears to be between 2-year AAS degree programs and 4-year ET and engineering degree programs. However, the small number of respondents to this item reduces our confidence in the generalizability of the data.

In order to successfully transfer to a 4-year program, a student must have earned enough credits in certain required subjects in the 2-year program. Our survey attempted to ascertain whether and to what degree the earning

TABLE 3-20 Percentage of ET Programs with Articulation Agreements Allowing Students with 2-Year ET Degrees to Transfer to a 4-Year ET or Engineering Program at Another Institution

	Yes	No	N/A
Transfer with an AAS in Engineering Technology to a BS program in Engineering (N=121)	28.1	53.7	18.2
Transfer with an AAS in Engineering Technology to BS program in Engineering Technology (N=134)	61.9	31.3	6.7
Transfer with an AS in Engineering Technology to a BS program in Engineering (N=111)	21.6	47.7	30.6
Transfer with an AS in Engineering Technology to a BS program in Engineering Technology (N=112)	40.2	40.2	196

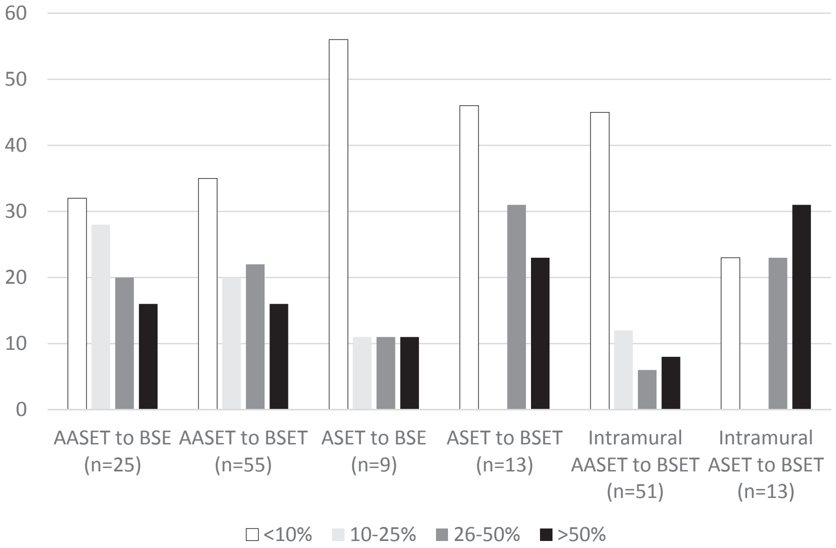

FIGURE 3-7 Prevalence, in percentage ranges, of student transfers between 2-year ET programs and 4-year programs in ET and engineering, including transfers within the same institution ("intramural")

of credits at the 2-year level was hindering transfers. Based on input from committee members with direct experience in ET education, we expected that the credit readiness of AAS degree earners might be less than that of AS degree recipients, because coursework for the former is often not designed to prepare students to continue to a 4-year program.[16] For this reason, the survey asked only about the credit readiness of AAS ET graduates. Overall, lack of credits was not a major concern (only 8 of the 50 respondents who answered this item believed credit readiness to be an issue for more than one-quarter of the students desiring to transfer). The primary areas where credits were likely to be insufficient were in mathematics (cited by 23 of 37 respondents) and science (cited by 5).

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[16] In hindsight, based on data from the survey (i.e., Figure 3-7), this assumption may not have been correct.

Student Impressions

The committee's December 2014 workshop included a panel of one current and three former ET students. Two were women, and two were men. Two were white, and two were African American. The current student was completing a 2-year electrical engineering technology program at Camden County College. The two 4-year graduates both received their degrees from Southern Polytechnic State University, now Kennesaw State University (one in electrical engineering technology and the other in mechanical engineering technology), and were early in their work careers. The fourth panelist had a 2-year degree in computer integrated manufacturing engineering technology from Camden County College and had been in the workforce better than 10 years. Although what we heard from these young people can best be thought of as personal stories, not data, we believe their comments are helpful to understanding ET education.

Each of the students came to major in ET from different motivations and encountered different challenges along the way. Common across their stories were ideas of inclusion (being first-generation college or from an underprivileged background), flexibility (ability to work and support their families while going to school), a preference for hands-on learning and practical experiences, and the presence of mentors. The three graduates said that having a strong hands-on component in their college experience enabled them to contribute meaningfully in their jobs very soon after being hired, an idea echoed in some of the data from our survey of employers (discussed in Chapter 4). All agreed that the ET education community could do a better job of publicizing the field to PreK-12 students, to their parents, and to high school guidance counselors.

Connections to Employers

To meet the needs of employers, educational institutions need to have communication channels with them. Our survey respondents use a number of mechanisms, particularly industry advisory boards, to receive input from employers (Figure 3-8). Other popular ways institutions stay connected to employers include interactions resulting from student internships and the relationships between career services personnel on campus and employer representatives. These interactions have led to changes in curricula, in pedagogy, and, to a lesser extent, in institutional policy (Figure 3-9).

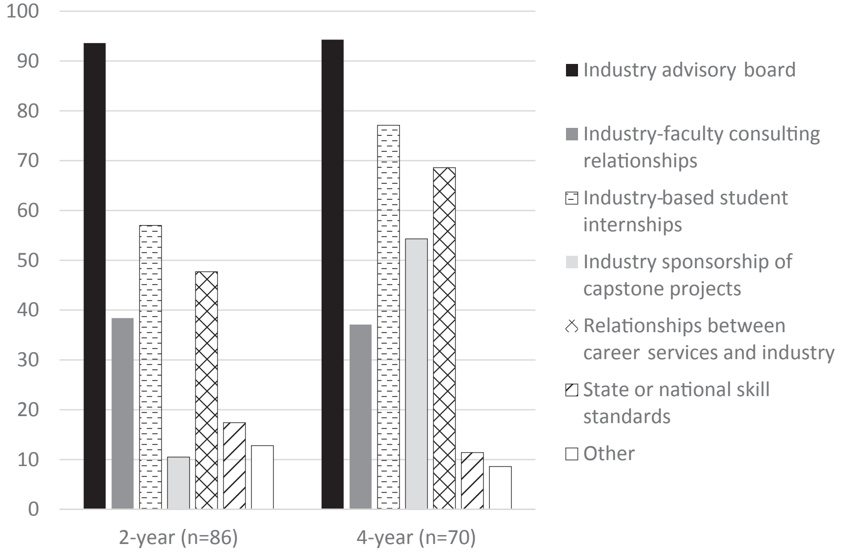
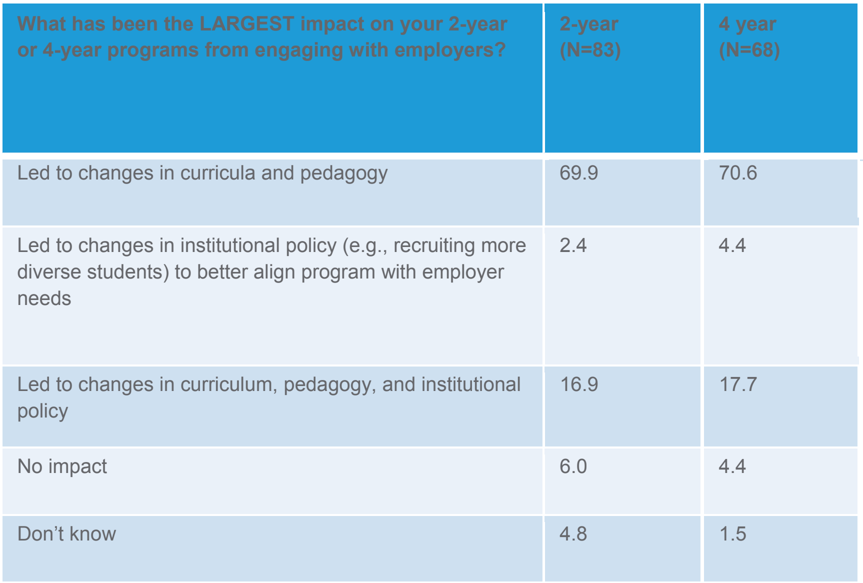


FIGURE 3-8 Percentage of 2- and 4-year ET programs using different modes of communication with employers.



What has been the LARGEST impact on your 2-year or 4-year programs from engaging with employers?	2-year (N=83)	4 year (N=68)
Led to changes in curricula and pedagogy	69.9	70.6
Led to changes in institutional policy (e.g., recruiting more diverse students) to better align program with employer needs	2.4	4.4
Led to changes in curriculum, pedagogy, and institutional policy	16.9	17.7
No impact	6.0	4.4
Don't know	4.8	1.5

FIGURE 3-9 Impacts of engagement with employers on 2- and 4-year ET programs, by percent.

APPENDIX 3A

Methodology for Survey of Engineering Technology Education Programs

The project's survey of educational programs was fielded in November 2014 by staff within the National Academies Information Technology Services unit using SurveyGizmo software. A link to the survey was sent via email to a list of roughly 650 people whom NAE identified as being in charge of one or more 2-year engineering technology (ET) programs, one or more 4-year programs, or some number of both types of programs. Two follow-up email reminders were sent to encourage participation by nonrespondents.

The list of emails was developed by an NAE college intern, Marthe Folivi, Rippon College, through a multistep process. Ms. Folivi first collected the names of institutions with ET programs accredited by the Accreditation Board for Engineering and Technology (ABET), available on the ABET website. She then compared this list to a longer list of institutions known to award ET degrees (through accredited and nonaccredited programs) derived from the 2012 federal Integrated Postsecondary Education Data System, and she eliminated duplicate institutions. She next went online to each school and attempted to find contact information for the institution's ET program(s). Programs that had no Internet presence were dropped from the list. So, too, were programs, even if accredited, that did not include the words "engineering" and "technology" in the title. This last step eliminated from consideration nearly 530 institutions from the IPEDS dataset. Once she identified someone who appeared to be in charge of an ET program, Ms. Folivi attempted contact by email (or by phone if no email was available) to confirm involvement with the program (and to get an email contact if none was provided on the website). This step identified a number of programs that were no longer active as well as some for which no contact information could be identified.

In the end, the list of email contacts used in the survey included individuals responsible for 527 4-year and 909 2-year ET programs (Table 3A-1). Because of the committee's decision to limit participation in the survey to people overseeing programs with the words "engineering" and "technology" in the title, the survey population cannot be considered inclusive of all programs in the United States that award ET degrees (as determined by the Department of Education's CIP coding system), and so the results may not be generalizable to the entire population of ET programs.

TABLE 3A-1 Number of Schools and Programs Represented by Those Asked to Participate in NAE's Survey of Engineering Technology Education

	4-Year ABET	4-Year Non-ABET	4-Year Total	2-Year ABET	2-Year Non-ABET	2-Year Total
Schools	153[a]	82[b]	235	98	372	470
Programs	387	140	527	255[c]	654	909

[a] Of these ABET-accredited 4-year schools, 27 award both 4- and 2-year engineering technology degrees.

[b] Of these non-ABET-accredited 4-year schools, 28 award both 4- and 2-year engineering technology degrees.

[c] Some of these 2-year engineering technology programs are offered by 4-year institutions.

Respondent Demographics

Respondents to the survey on ET education came from institutions located in 38 states and Puerto Rico. The largest numbers of responses were received from people representing institutions in Pennsylvania (12), Michigan (9), and Indiana, New York, and North Carolina (8 each). Eighty-seven percent (121) of survey participants indicated they worked for public institutions, 9 percent (12) for private schools, and 4 percent (6) for for-profit education enterprises.

APPENDIX 3B

NAE Survey Instrument for Engineering Technology Educators

The National Academy of Engineering (NAE) is conducting an online survey of 2- and 4-year engineering technology programs to learn more about the education of workers with engineering-related skills.

The results from this survey will inform an ongoing NAE study funded by the National Science Foundation. Your participation is critically important to the success of the NAE project.

The survey will take approximately 15 minutes to complete, and your participation is entirely voluntary. Your specific responses will be completely confidential, and any information that could be used to identify you will not be shared with NAE staff or the committee that is involved in overseeing the study. In addition, any information that could be used to identify you will be destroyed within one year of the conclusion of the NAE study. Finally, you will not be personally identified in any public reports or presentations of survey results.

By clicking the "I AGREE" button below, you are declaring that you have read and understood the information above and agree to take part in this survey. If you so choose, you may end participation in the survey at any time.

1. What is the name of your institution? [text field]

2. In what state is your institution located? [drop-down menu]

3. Which of the following best characterizes your institution?
   a. Public (state- or local-government supported)
   b. Private
   c. For profit

4. Which of the following types of academic credit is granted by the engineering technology program(s) you are responsible for? Check all that apply. [respondents who oversee both 2-year and 4-year programs will hereafter answer some questions twice, once for the 2- and once for the 4-year programs]
   a. Bachelor of Engineering Technology, 4-year degree
   b. Associate of Applied Science (AAS) in engineering technology, 2-year degree

  c. Associate of Science (AS) in engineering technology, 2-year degree
  d. Certificates in engineering technology, less than a 2-year degree

5. From the list below, please select the name(s) that best describes the [2-year and/or 4-year] engineering technology program(s) you are responsible for. Check all that apply. [list is at Appendix]

6. What type of accreditation, if any, does/do the [2-year and/or 4-year] program(s) you are responsible for currently have?
   a. ABET (Accreditation Board of Engineering and Technology)
   b. ATMAE (Association of Technology, Management, and Applied Engineering)
   c. ACCE (American Council for Construction Education)
   d. Other
   e. Not accredited
   f. Don't know

7. From the list below, please indicate the FIRST, SECOND, AND THIRD LARGEST category of students entering your [2-year and/or 4-year] program
   a. Recent high school graduates
   b. Returning military/veterans
   c. Adults changing careers or "up skilling" to increase earnings
   d. [This choice only for those with 4-year programs]Recent graduates of a 2-year AAS engineering technology degree program
   e. [This choice only for those with 4-year programs]Recent graduates of a 2-year AS engineering technology degree program
   f. Recent recipients of one or more certificates in an engineering technology field
   g. students from 4-year (BS) engineering programs
   h. Transfer students from 2-year (AS) engineering programs
   i. Transfers students from non-engineering 4-year degree programs
   j. Other

8. Does your school have arrangements (e.g., articulation agreements) with other academic institutions that allow students any of the following transfer options (check all that apply) [answer choices a-d have yes/no options]:

a. Transfer with an AAS in Engineering Technology to a BS program in Engineering
b. Transfer with an AAS in Engineering Technology to BS program in Engineering Technology
c. Transfer with an AS in Engineering Technology to a BS program in Engineering
d. Transfer with an AS in Engineering Technology to a BS program in Engineering Technology
e. Other

9. For students who graduate with a [degree type from item chosen in Q8], what percentage do you estimate *transfer to another institution* to obtain a [degree type from item chosen in Q8]? [NOTE: This question will need to be asked more than once for respondents who select more than one "yes" in Q8; someone who answers "no" to all choices in Q8 will skip Q9.]
   a. Less than 10%
   b. Between 10% and 25%
   c. Between 26% and 50%
   d. More than 50%
   e. Don't know

10. [only for survey respondents who check 4b or 4c] For students who graduate with an [AS or AAS] degree in engineering technology, what percentage do you estimate *transfer within your institution* to obtain a 4-year degree in engineering technology?
   a. Less than 10%
   b. Between 10% and 25%
   c. Between 26% and 50%
   d. More than 50%
   e. Transfer is not an option
   f. Don't know

11. [only for respondents who check 4b; goes to Q12 except if answers "Transfer is not an option" or "Don't know," then goes to Q13] For your students who graduate with an AAS degree in engineering technology, what percentage do you estimate would like to transfer within your institution *or* to another institution to obtain a 4-year

degree in engineering technology but lack course credits in one or more areas to do so?

a. Less than 10%
b. Between 10% and 25%
c. Between 25% and 50%
d. More than 50%
e. Transfer is not an option
f. Don't know

12. For students who graduate with an AAS degree in engineering technology but who lack course credits to transfer within your institution or to another institution to obtain a 4-year degree in engineering technology, which of the following is the most common academic area where credits are lacking?
    a. Mathematics
    b. Science
    c. Social Sciences
    d. Humanities
    e. English
    f. Other

13. What do you estimate the rate of employment (full and part time combined) for graduates of your [2-year/4-year] program WITHIN 3 MONTHS OF EARNING A DEGREE? [open response field and "don't know"]

14. Understanding that this will probably be a "best guess," in which of the following occupational areas do the MAJORITY of graduates from your [2-year and/or 4-year] program(s) work upon leaving your institution?
    a. Engineering technology or engineering
    b. Computer and information technology
    c. Management
    d. Sales
    e. Other
    f. No job (unemployed)
    g. Don't know

15. Thinking about the supply of those with [2-year and/or 4-year] engineering technology degrees in the areas served by your institution, which of the following characterizes your situation?
    a. There are more graduates with these degrees than the job market can support
    b. The number of those with these degrees matches the availability of jobs
    c. There are not enough graduates with these degrees to fill available jobs
    d. Don't know

16. To what degree do you believe the skills and knowledge of graduates of your [2-year and/or 4-year] engineering technology program(s) are meeting the needs of employers?
    1-Extremely well, 2-Well, 3-OK but could be better, 4-Not so well, 5-Not at all

17. Through which of the following mechanisms, if any, does your [2- and/or 4-year] program(s) learn about the needs of employers? Check all that apply.
    a. Industry advisory board
    b. Industry-faculty consulting partnerships
    c. Industry-based student internships
    d. Industry sponsorship of capstone projects
    e. Relationships between university career services personnel and industry representatives
    f. State or national skills standards
    g. Other
    h. We have no such mechanisms [goes to Q19]
    i. Don't know [goes to Q19]

18. What has been the LARGEST impact on your [2-year and/or 4-year] program(s) from engaging with employers?
    a. Led to changes in curricula and pedagogy
    b. Led to changes in institutional policy (e.g., recruiting more diverse students) to better align program with employer needs
    c. Led to changes in curriculum, pedagogy, and institutional policy
    d. No impact
    e. Other
    f. Don't know

19. Which, if any, of the following types of work-related experiences are available to students in your [2- and/or 4-year] program(s)? Check all that apply.
    a. Apprenticeship (paid vocational programs for certification)
    b. Internship (paid or unpaid, at an employer, coordinated with the academic curriculum)
    c. Cooperative work experience (semester- or quarter-based work experience as an alternative to campus-based learning)
    d. Summer industrial work experiences (paid or unpaid) independent of the college/university
    e. Other
    f. Don't know

20. How much, if at all, is the increasing integration of new technologies (e.g., additive manufacturing, advanced digital manufacturing, complex control systems) into the workplace changing the skills/knowledge your students need to acquire in your [2- and/or 4-year] program(s)?
    a. Substantially
    b. A fair amount
    c. Very little
    d. Not at all
    e. Don't know

21. In what ways, if at all, is the integration of new technologies in the workplace affecting the employability of graduates from your [2-year and/or 4-year] program(s)?
    a. Making it much harder for graduates to find work
    b. Making it much easier for graduates to find work
    c. No difference in employability
    d. Don't know

22. Does your institution offer 4-year degrees in engineering? [Y/N; if yes, to Q23; if no, to Q24]

23. Do faculty in engineering technology and in engineering ever teach courses in the other program area (i.e., an engineering faculty member teaches a course to engineering technology students or an engi-

neering technology faculty member teaches a course to engineering students)? [Y/N]

24. In your opinion, which of the following statements best characterizes the difference between the skills/knowledge of graduates with 4-year degrees in *engineering technology* and 4-year degrees in *engineering*?
    a. Engineering technology graduates are better prepared to do applied work, while engineering graduates have more preparation in higher-level science and mathematics.
    b. Engineering technology graduates are better prepared to do applied work, while engineering graduates are better prepared to do engineering design.
    c. Engineering technology and engineering graduates are essentially the same.
    d. There is too much variability among engineering technology and engineering programs to answer this question.
    e. Don't know

25. What challenges and opportunities does your institution face with respect to your [2-year/4-year] engineering technology program? (200 words maximum)

26. What information, if any, would you like the committee overseeing this project to have that was not covered in the previous survey questions? (200 words maximum)

APPENDIX 3C

National Academy of Engineering
Workshop on Engineering Technology Education

December 2, 2014
National Academy of Science Building
Washington, DC

8:00 a.m. **Registration and Continental Breakfast**

8:30 a.m. **Welcome and Comments from the Sponsor**
Ron Latanision, Exponent, Inc., and Katharine Frase, IBM, NAE Committee on Engineering Technology Education
Susan Singer, Division of Undergraduate Education, Directorate for Education and Human Resources, National Science Foundation

8:45 a.m. **Keynote Address:**
Paul Tonko (D-NY), US House of Representatives

9:30 a.m. **Break**

9:45 a.m. **Employment and Education of Engineering Technology Students**
Daniel Kuehn, American University

10:15 a.m. **Panel: Student Reflections on Engineering Technology Education**
Chris Cutter, Novellis, Kennesaw, GA
Raven Poux, Camden Community College
Brandi Rearden, Georgia Power
Jason Bauer, Brenner Aero

11:15 a.m. **Lunch**

12:00 p.m. **Guest Speaker: Matthew B. Crawford, author of *Shop Class as Soulcraft: An Inquiry into the Value of Work*, University of Virginia**

12:45 p.m. **The Value Proposition for ET Education: Highlights of an NAE Survey**
Werner Eikenbusch, BMW (committee); Jeffrey Ray, Western Carolina University (committee)

1:30 p.m. **Panel: Opportunities and Challenges Facing Employers and Educators**
George Parker, Associate Technical Fellow, Boeing
Nick Wilson, President, Morrison Container Handling Solutions
Verna Fitzsimmons, Kansas State University
Douglas H. Handy, Coordinator, Office of Career & Technology Education, Baltimore County Public Schools

2:30 p.m. **Break**

2:45 p.m. **Table Discussions**

3:30 p.m. **Plenary Reporting**

4:15 p.m. **Final Remarks**
Ron Latanision and Katharine Frase, Co-Chairs

4:30 p.m. **Adjourn**

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Chapter 4

The Employment of Engineering Technology Talent

This chapter presents information about the size and the composition of the engineering technology (ET) workforce as well as the earnings, job roles, skills, hiring patterns, and other characteristics of those employed in this sector. To the extent possible, we also discuss the employment pathways of these workers.

The federal government has produced large and detailed standardized labor market surveys for many years, and these datasets, along with information from our survey of employers, form the basis of our analysis. (Details of the methodology used in the committee's survey of employers and the demographics of respondents appear in Appendix 4A. The survey instrument is in Appendix 4B.) The federal datasets used for the employment analysis are the American Community Survey (ACS), the March supplement to the Current Population Survey (CPS), the National Survey of College Graduates (NSCG), and the Occupational Employment Statistics (OES). As with the educational surveys described in Chapter 3, each of these datasets has strengths and weaknesses. The March CPS provides data on this workforce going back to the early 1970s (the occupational categories of earlier versions of the CPS do not sufficiently match later categories to ensure that the identification of engineering technicians and technologists is reliable). Although CPS will be used for most analyses in this section, data from ACS, NSCG, and OES are used to report detailed occupational subfields.

SIZE AND COMPOSITION OF THE ENGINEERING TECHNOLOGY WORKFORCE

Occupational data from the relatively small CPS and the much larger ACS (both household surveys) as well as the large OES (an employer survey) all indicate that approximately 400,000 workers were employed as engineering technicians and technologists in 2013 (Table 4-1).

All of these surveys ask respondents—whether the workers themselves (CPS, ACS, NSCG) or their employers (OES)—to describe the nature of the job done by the worker. For all but NSCG, these descriptions are then analyzed by staff at the US Census Bureau and assigned to a specific code within the Bureau of Labor Statistics' Standard Occupational Classification (SOC) system. The SOC system does not distinguish between the job duties of engineering technicians and technologists; instead, it lumps them together under a category called "Engineering Technicians, Except Drafters,"[1] which includes eight detailed occupations (Table 4-2).

NSCG uses employment codes from the Scientists and Engineers Statistical Data System, which collapses the eight detailed SOC jobs into two broad classifications: "Electric, electronic, industrial, and mechanical technicians" and "OTHER engineering technologists and technicians."

In an effort to get a sense of how many of these approximately 400,000 workers might be working as technicians rather than as technologists, the committee looked at survey respondents' degree attainment. Using this approach, CPS and ACS both agree that around 80 percent of these workers have 2-year degrees or lower educational attainment, while the remaining 20 percent have at least a 4-year degree. In Table 4-1, the former are labeled technicians and the latter technologists. NSCG only surveys graduates of 4-year degree programs, and it uses a different coding system to determine job type. Because OES does not collect educational attainment information it is not possible to separate those who might be technicians from those who might be technologists. Thus, for this dataset, the two job types are combined in Table 4-1.

This presentation of the data needs to be interpreted with caution. For one thing, it assumes those with 2-year degrees cannot be working as higher-skilled technologists. For someone with many years of on-the-job experience, or with additional technical certificates beyond a 2-year degree

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[1] An ongoing revision of the SOC system, due to be complete in 2018, is considering whether to create separate coding for engineering technicians and technologists (N. Kannankutty, National Science Foundation, personal communication, January 21, 2015).

TABLE 4-1 Comparison of Estimates of Engineering Technician and Technologist Employment in 2013 from Various Datasets.

	CPS	ACS	NSCG	OES
Engineering technicians & technologists	360,400	434,854	—	435,650
Engineering technicians	302,402	355,861	—	—
Engineering technologists	57,998	78,993	404,465	—
Technician share of total	0.839	0.818	—	—

SOURCE: Calculations from noted datasets.

earned at a community college, this may not be true. For example, one of the former 2-year ET graduates who spoke at our December 2014 workshop, Jason Bauer, worked for 10 years at Ocean Spray Cranberries, Inc., beginning as an electro-mechanical maintenance technician and rising through the company in various positions, eventually becoming an operations manager.

A further complication is that someone with a 4-year degree may have earned that degree in a field unrelated to ET but ended up doing work related to ET after earning one or more certificates or a 2-year degree in the field (e.g., someone changing careers). Such a person might more appropriately be classified as an engineering technician. In other words, our assumption that someone with a 4-year degree is working as a technologist may not be correct either. Unfortunately, none of these databases captures information about field for those with 2-year degrees, and only ACS and NSCG collect information about field for those with 4-year degrees. (The latter informa-

TABLE 4-2 Engineering Technology Subfield Estimates, OES, 2013

	Population Estimates
Aerospace engineering and operations technicians & technologists	10,540
Civil engineering technicians & technologists	69,830
Electrical and electronics engineering technicians & technologists	141,150
Electro-mechanical technicians & technologists	15,540
Environmental engineering technicians & technologists	18,020
Industrial engineering technicians & technologists	68,520
Mechanical engineering technicians & technologists	46,090
Engineering technicians & technologists, except drafters, all others	65,960
Total	435,650

SOURCE: 2013 OES.

tion is presented in Table 4-12 in the section "Career Pathways and Hiring Patterns.")

The most significant outlier among the datasets is the National Science Foundation's (NSF's) NSCG. This survey suggests that there are slightly more than 400,000 technologists, which is significantly more technologists than are identified in either CPS or ACS, which put the figure at about 58,000 and 79,000, respectively. One possible explanation for this discrepancy is that those coding occupations for the NSF include a large number of engineers and perhaps other types of technicians into the "engineering technician" category—people who the Census Bureau would not have identified as engineering technicians.

Of the various federal datasets, only OES provides employment estimates of distinct subfields within ET (Table 4-2). The OES data suggest that these workers are heavily concentrated in electrical and electronics engineering technology occupations, to an even greater extent than were degrees concentrated in this subfield (see Table 3-3, Chapter 3). Civil, industrial, and mechanical engineering technicians and technologists also are well represented in the OES, while all other categories employ fewer than 20,000 workers.

TRENDS IN EMPLOYMENT, INCOME, AND AGE

Figure 4-1 presents employment trends from 1971 to 2015 for engineering technicians and technologists and (for comparison purposes) for engineers using data from CPS. The combined engineering technician and technologist population grew steadily over this period from almost 447,000 in 1971 to almost 666,000 in 2002 (following a peak of more than 821,000 in 2000). The engineering workforce grew even faster over the same time span, from almost 1.2 million in 1971 to 2.16 million in 2002. The abrupt decline in the employment of engineers (and more modest decline in the employment of engineering technicians and technologists) around 1994 may be due to a major redesign of the CPS survey instrument in that year (see Polivka and Miller, 1998, for details).

Official occupational categories changed occasionally over this period. Typically these changes are extremely minor and are used to account for the emergence of specific new types of jobs. A more notable reassessment of occupational codes was implemented after 2002, with important implications for the information technology (IT) workforce. These new categories

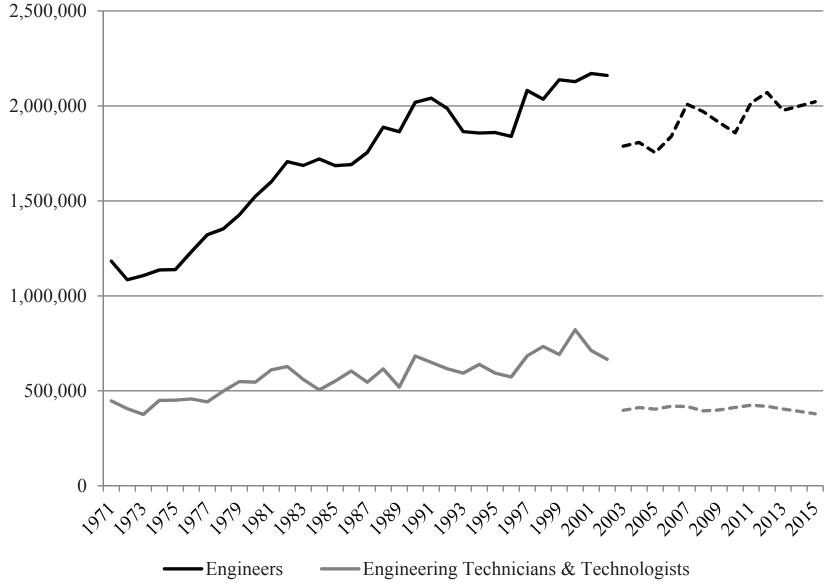

FIGURE 4-1 Employment of engineers and engineering technicians and technologists, 1971-2015. SOURCE: Calculation from the 1971-2015 March CPS.

reassigned some workers previously categorized as engineers and engineering technicians and technologists to other fields, resulting in an abrupt decline in employment after 2002. One of the most common reassignments was to a computer or IT occupation.[2] Because this decline is a statistical artifact, resulting from the reorganization rather than any changes in the workforce itself, the post-2002 data are distinguished by a dashed line in Figure 4-1. Under the new occupational definitions, approximately 2,000,000 engineers and 379,000 engineering technicians and technologists were employed in 2015.

The federal surveys peg the average engineering technician and technologist annual earnings at between $48,000 and $57,000 (2015 dollars) in 2013, with CPS providing a figure somewhat lower and OES a figure somewhat higher than that central tendency (Table 4-3). CPS data suggest that technologists enjoy a greater premium than do technicians relative to ACS.

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[2] Detailed occupational transfers are found in "Conversion factors for the 1990 and 2002 Census occupational and industry classifications," Tables 5 and 6, available at www.bls.gov/cps/cpsoccind.htm.

TABLE 4-3 Average Annual Earnings for Engineering Technicians, Engineering Technologists, and Engineers in 2013 (2015 Dollars)

	CPS	ACS	NSCG	OES
Engineering technicians & technologists (combined)	$48,345	$54,050	—	$57,202
Engineering technicians	$45,785	$53,227	—	—
Engineering technologists	$57,496	$57,757	$80,670	—
Engineers	$86,792	$101,967	$94,933	$94,013

SOURCE: Calculations from noted datasets.

Engineers on average earn considerably more than both in all surveys. As was true for employment data (Table 4-2), NSCG earnings data are much higher than are those from the other federal data sources.

Table 4-3 suggests an earnings premium for technologists (compared with technicians) of 25 percent (CPS) or 9 percent (ACS). Looking at a single year's data can be misleading, however. CPS is a longer-running survey than is ACS, which makes it ideal for understanding long-term trends in the ET workforce. But the sample size in any given year in CPS is much smaller, which means that estimated earnings differentials in a given year have a much higher variance. A comparison of technician to technologist earnings in CPS over a longer time period, from 2006 to 2015, shows a much narrower gap in earnings. During that period, the average annual earnings differential was just 1.5 percent ($52,670 for technicians vs. $53,448 for technologists), with some individual years having high differentials and some having much lower differentials.

Inferences about earnings need to be drawn carefully. Because no adjustments or controls have been made to these data, the similarity in salary between technicians and technologists could reflect differing characteristics between these populations. For example, if the technician population tended to be older or more experienced than was the technologist population due to fewer promotional opportunities and lower educational requirements in prior decades, their age (i.e., seniority) and experience may enable them to have earnings that are comparable to a younger cohort of technologists. It also is important to remember that these data show only occupation, and we know that the majority of individuals with an ET degree are not working as technologists (see Table 4-14 in the section Career Pathways and Hiring Patterns). For instance, if the most productive technologists are employed as engineers then we would expect to observe relatively lower earnings for technologists, because the data would be capturing the lower-wage portion of the stock of ET degree holders who are occupationally classified as technologists, not engineers.

The real annual income of engineering technicians and technologists has remained remarkably stable over the past 40 years, with a consistent average of approximately $50,000 (2015 dollars) (Figure 4-2). This contrasts with the steady growth in real annual earnings for engineers, which grew from an average of slightly more than $70,000 in the early 1980s to about $86,000 in 2015 (both 2015 dollars). Although weak real wage growth over the past several decades is a widely cited phenomenon, it is typically not considered to be as substantial a problem in skilled occupations.

Given recent interest in income inequality and wide variation in the educational attainment of the engineering technician and technologist workforce, changes in the income distribution are as important to consider as variations in the average income level are. Figures 4-3 and 4-4 present the distribution of real (2015 dollar) incomes for technicians and technologists separately for the 4 decades between 1974 and 2015. Figure 4-2 and Table 4-3 suggest that technicians and technologist have comparable earnings, so it is

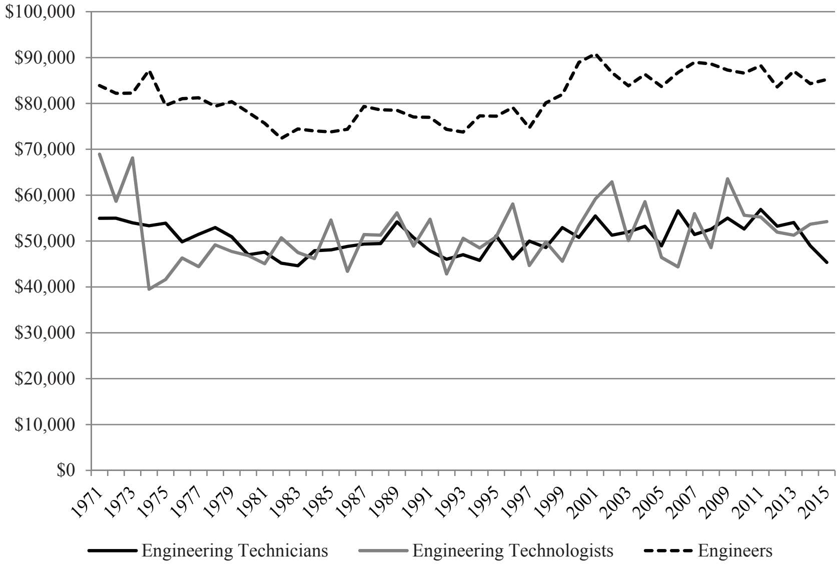

FIGURE 4-2 Annual earnings (2015 dollars) of engineering technicians, engineering technologists, and engineers, 1971-2015. SOURCE: Calculated from the 1971-2015 March CPS.

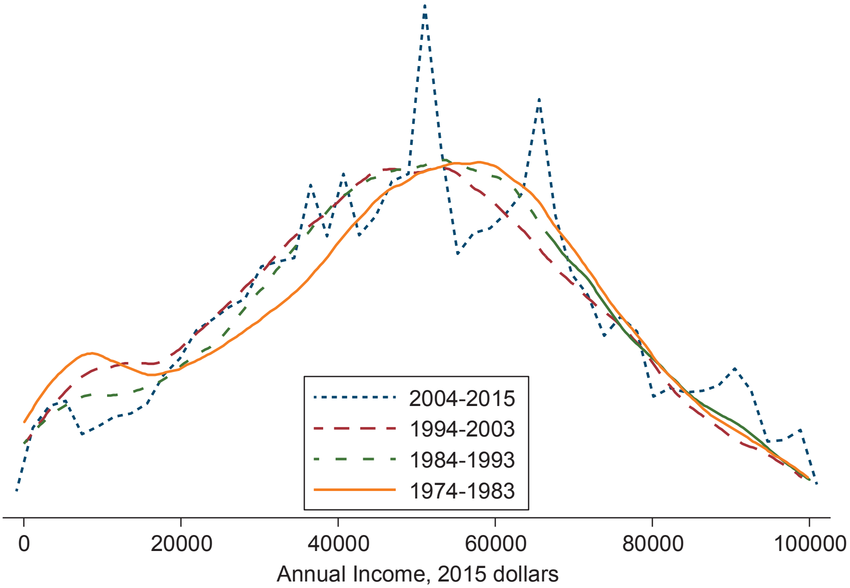

FIGURE 4-3 Income distribution for engineering technicians for the period 1974-2015 (2015 dollars). SOURCE: Calculations from 1974-2015 March CPS.

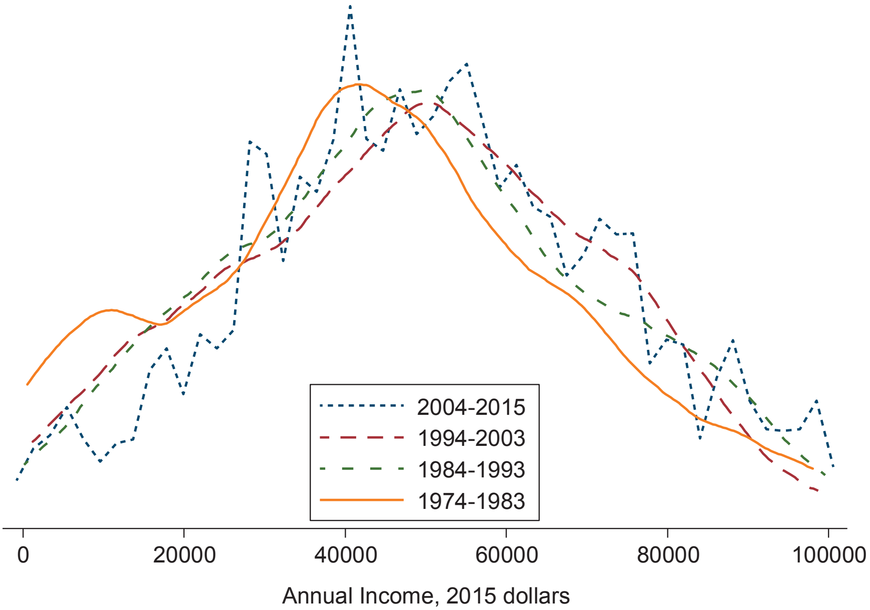

FIGURE 4-4 Income distribution for engineering technologists for the period 1974-2015 (2015 dollars). SOURCE: Calculations from 1974-2015 March CPS.

no surprise that the distribution of those earnings looks similar as well (Figures 4-3 and 4-4). The distribution of the 2004-2015 period is not as smooth as earlier years, however, for either technicians or technologists because of a smaller sample size. The steady level of total inflation adjusted earnings might have obscured changes in the distribution of earnings over time, but this does not appear to be the case for engineering technicians. For technologists, there is a very modest drift to the right over the 40-year period, with more recent cohorts appearing to earn slightly more than did earlier cohorts.

Figures 4-1 through 4-4 show steadily increasing employment for engineering technicians and technologists but relatively stable real annual income. The performance of this workforce is largely comparable to the engineering workforce, although engineers have experienced somewhat stronger employment growth and modest real annual income growth. This suggests that in both cases growth in supply and demand has remained relatively balanced, perhaps with somewhat stronger demand growth for engineers. If demand for engineering technologists grew faster than did supply, wages and salaries would grow as employers competed for scarce available workers. This does not appear to be the case. It is critical to separate the question of whether supply or demand is growing faster during a particular period from the question of labor "shortages." The two issues are often conflated. The issue of shortages is discussed later in this chapter.

Unlike the relative stability of real annual income, data from the CPS indicate that the average age of engineering technicians and engineering technologists has shifted dramatically over the past 40 years (Figure 4-5). Less dramatic, but still significant, is the factor of aging in the engineering workforce.

In the period between 1974 and 1983, the average age of technicians and technologists was 35.4 years. By the period between 2004 and 2015, the average age was 43.5 years (Figure 4-5). The increase in average age also is apparent for engineers. The distributions of ages also tend to have a higher concentration of older technicians and technologists (Figure 4-6) and engineers (Figure 4-7) for later employment periods.

The age distribution data presented in Figure 4-6 are useful because they help us think about the age density of each worker cohort, by decade, separate from the issue of the changing size of the engineering technician and technologist workforce. In contrast, Figure 4-8 presents actual age frequencies of engineering technicians and technologists over the past 4 decades, thus reflecting both the age distribution and the total number of these workers. We see that the overall engineering technician and technolo-

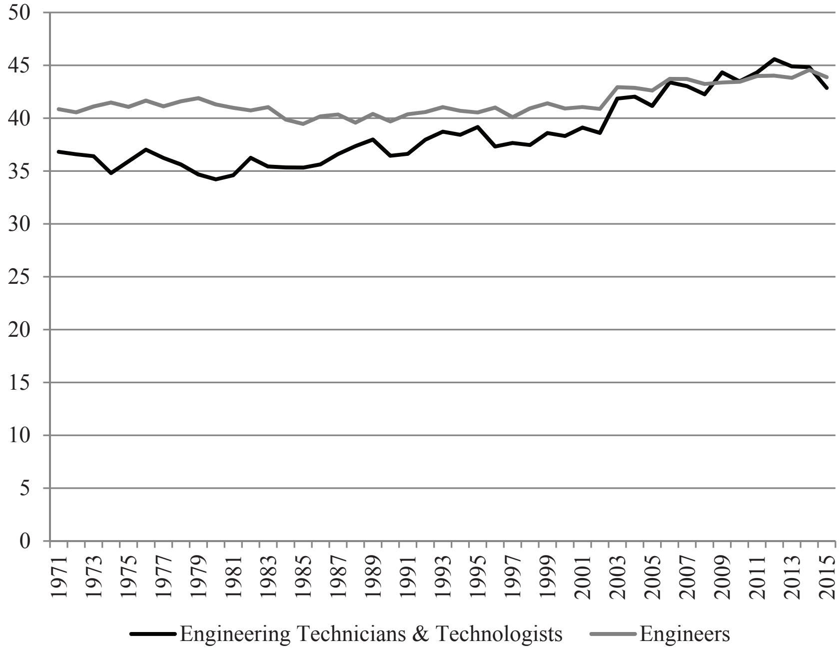

FIGURE 4-5 Average age of engineering technicians, engineering technologists, and engineers, 1971-2015. SOURCE: Calculations from 1971-2015 March CPS.

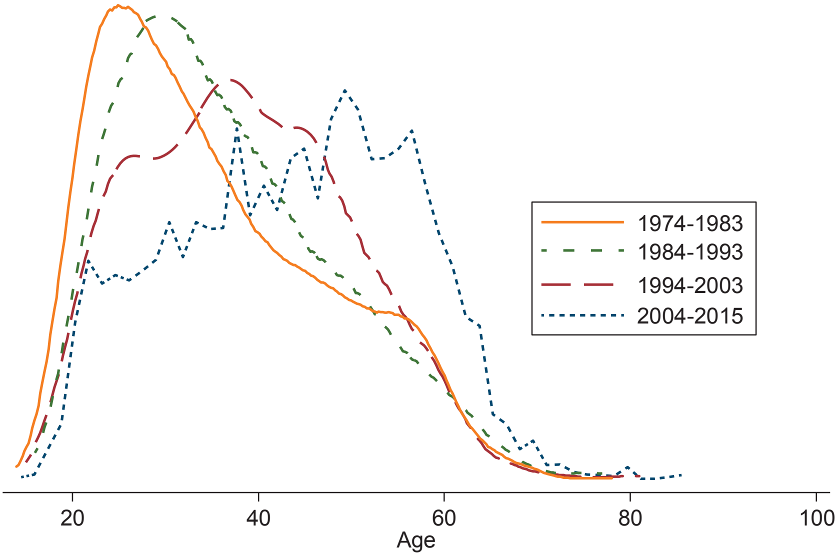

FIGURE 4-6 Age distribution of engineering technicians and technologists. SOURCE: Calculations from the 1974-2015 March CPS.

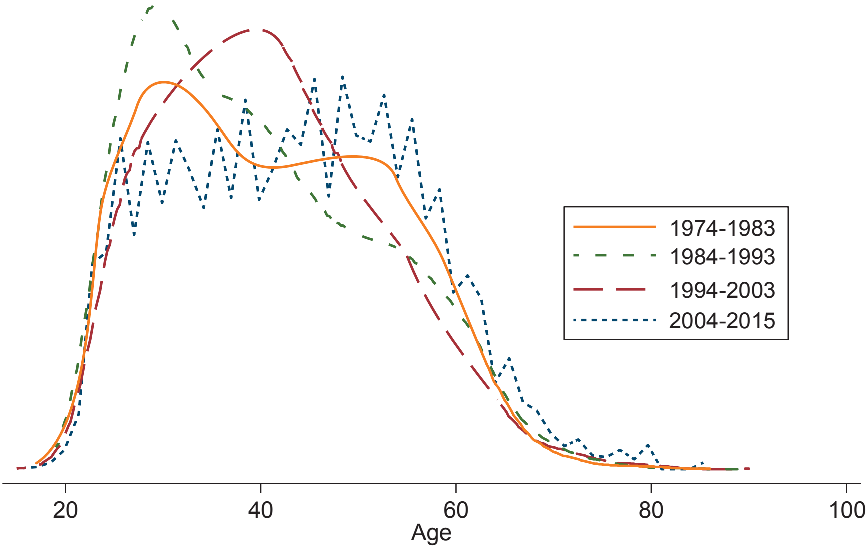

FIGURE 4-7 Age distribution of engineers. SOURCE: Calculations from the 1974-2015 March CPS.

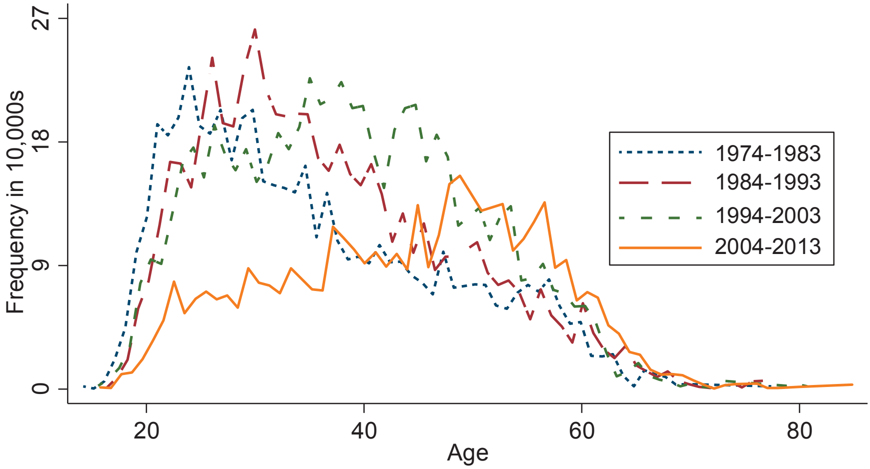

FIGURE 4-8 Age frequencies of engineering technicians and technologists. SOURCE: Calculations from the 1974-2013 March CPS.

gist workforce has aged over the past 40 years faster than could be mediated by taking on younger workers. In addition to the aging of this workforce, the workforce itself has been reduced. The number of workers over the age of 50, for example, is roughly comparable from 1994 to 2003 and again from 2004 to 2013, despite the fact that workers over the age of 50 comprise a much greater share of the total engineering technician and technologist workforce in the latter period.

Figure 4-9 displays comparable frequency distributions for engineers. The engineering workforce also has exhibited persistent aging over this period, although the trends are not as stark as in the engineering technician and technologist workforce. In the 2004–2013 period, the distribution of engineers across the age range is relatively uniform, whereas engineering technicians and technologists tend to be older. Nevertheless, the engineering workforce in the past decade is still older than the same workforce was in the 1970s and 1980s.

One possible explanation for the increasing age distribution is the flattening of occupational hierarchies in engineering and engineering-related occupations (see Kuehn and Salzman, 2016; Lynn et al., 2016; Lynn and Salzman, 2010). Engineers have increasingly taken on managerial responsibilities without transitioning from a technical to a management classifica-

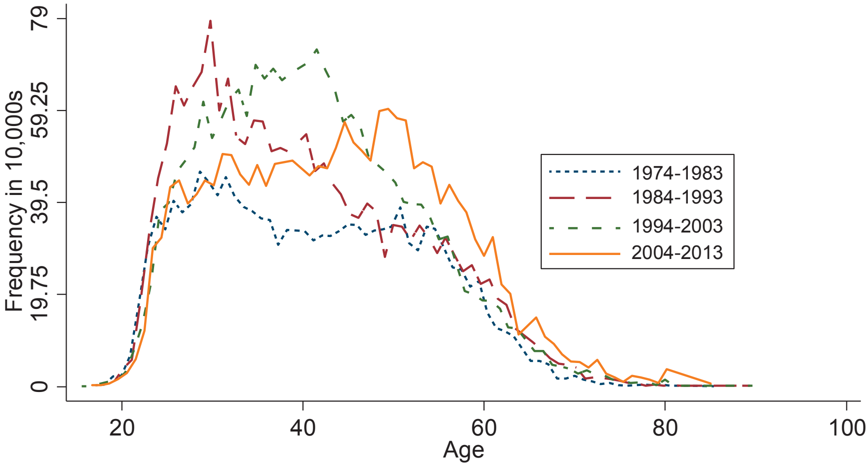

FIGURE 4-9 Age frequencies of engineers. SOURCE: Calculations from the 1974-2013 March CPS.

tion. As this occupational transition for older workers has declined over time, the average age of the engineering technician and technologist workforce will naturally increase.

Even so, younger workers are still not entering the field at rates comparable to older cohorts, driving the age distribution to the right. The increasing average age of engineering technicians and technologists raises questions about the need for increased production of these workers to replace aging workers. Caution is required, however, in making direct inferences from an aging workforce to replacement demand in the future. Freeman (2007) demonstrates that, historically, aging occupational groups typically are not associated with a strong eventual resurgence in demand for younger workers. The reason for this is relatively straightforward: Workforces that are declining in size and importance in the economy demand and attract fewer workers, so that the average wage increases until the labor market achieves a new steady-state equilibrium. Workforces where employers expect future growth typically recruit younger workers before the day of reckoning comes, and they exhibit *declining* average ages until they achieve their own, higher, steady-state equilibrium.

Although this empirical work shows that occupational groups generally age when they are declining, not when they are on the verge of future growth and replacement demand, a specific occupational illustration may be helpful. Analysis of data from the March CPS indicates that between 1983 and 2013 textile manufacturing occupations declined from more than 1 million to approximately 100,000 due primarily to international competition. Over this same 30-year period, the average age of a textile worker increased from about 38 years to about 48 years. Without future growth prospects and no reason to expect increasing death or retirement rates, the industry achieved a new employment equilibrium by reducing the intake of younger workers. These dynamics are not restricted to workforces, of course. Human populations follow the same patterns, with shrinking populations generally characterized by increasing average ages until a new equilibrium is reached (e.g., Japan), and with swiftly growing populations characterized by declining average ages (e.g., Nigeria).

Freeman's (2007) study of the behavior of aging workforces does not *guarantee* there will not be strong replacement demand for young engineering technicians and technologists in the future, of course. Something unexpected may change in the field that employers are not currently considering in their hiring practices. An example from the oil and gas extraction industry involving petroleum engineers is illustrative. In the 2000s, an aging petroleum engineering workforce and a retirement bubble came at exactly the same time the industry was facing growing demand due to drilling opportunities in the Bakken shale formation. As a result, petroleum engineering wages were bid up and a large cohort of young graduates was hired to replace the previously aging workforce (Lynn et al., 2016).

If an aging workforce is paired with strong new sources of demand, then employers will likely seek new graduates to replace an aging workforce. But, typically, an aging workforce does not seem to be a portent of strong future demand for young workers, and it is certainly not a reason in and of itself to expect growing demand.

WORK ROLES, SKILLS, AND JOB PERFORMANCE

As noted earlier, the federal government, through the system of SOC codes, has described the work done by engineering technicians and technologists, mainly for the purposes of interpreting data from employment surveys. These descriptions do not distinguish the job duties performed by technicians from those performed by technologists. In order to understand more about the potential differences in work performed by the two groups, the committee included questions about work roles in its survey of employers. The survey asked employers to review a list of job duties and indicate which were done most frequently by those with a 4-year degree in ET (Table 4-4) and which were performed mainly by those with a 2-year

TABLE 4-4 Most Frequent Work Roles for Employees with a Bachelor's Degree in Engineering Technology, Percent (N=115).

	Percent
Troubleshooting and repairing equipment/technologies	74.8
Conducting quality control checks	67.8
Collecting and analyzing data	69.6
Testing or maintaining equipment/technologies	69.6
Building or setting up equipment/technologies	64.3
Designing new products or systems	53.9
Producing technical drawings	50.4
Managing the work of other technical staff	47.8
Creating mathematical, simulation-based, or physical models	40.9
Conducting experiments	25.2
Don't know	5.2
Other	3.5

degree (Table 4-5). The results suggest that bachelor's degree holders have quite wide-ranging responsibilities, including those related to design, while the work of those with an associate's degree is more restricted. Employers indicated that the work of engineering technicians centers on testing and maintaining equipment; troubleshooting and repairing; and conducting quality control checks.

The committee survey, conducted by the National Association of Colleges and Employers (NACE), also asked employers to indicate the skills those with an educational background in ET should have in order to operate in today's economy (not distinguishing in this case between 2- and 4-year degree holders). Respondents were given a list of relevant skills/knowledge and picked the first, second, and third most important. Answers were weighted, with five points given to a first-place vote; three points to a second-place vote; and one point to a third-place vote. The points for each skill were then summed and divided by the total number of points generated for all skill items. Three skills dominate the rankings (Figure 4-10): the ability to communicate and work in teams; the ability to problem solve or troubleshoot in new or unfamiliar situations; and knowledge of a specific engineering discipline. The first two areas are cited frequently as increasingly important components of the professional skill set for all workers in the 21st century (e.g., NRC, 2012; OECD, 2005).

Greater than 80 percent of employers said they have methods in place to communicate clearly with higher education about their employment needs. The most popular method for conveying skills and knowledge needed by

TABLE 4-5 Most Frequent Work Roles for Employees with an Associate's Degree in Engineering Technology, Percent (N=47).

	Percent
Testing or maintaining equipment/technologies	66.0
Troubleshooting and repairing equipment/technologies	66.0
Conducting quality control checks	55.3
Building or setting up equipment/technologies	48.9
Collecting and analyzing data	38.3
Producing technical drawings	38.3
Conducting experiments	23.4
Don't know	12.8
Designing new products or systems	8.5
Managing the work of other technical staff	6.4
Other	6.4
Creating mathematical, simulation-based, or physical models	0.0

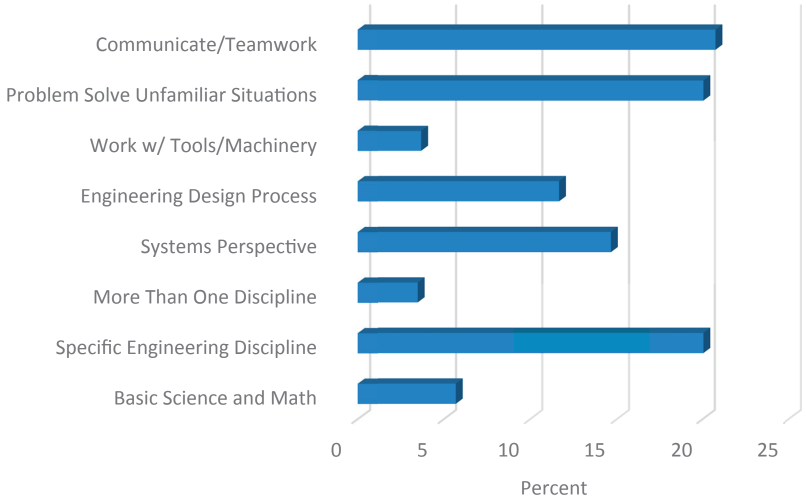

FIGURE 4-10 Relative importance of skills/knowledge needed by ET graduates, by percentage (N=114).

prospective employees, according to respondents, was relationships with educational institutions' career services personnel (Figure 4-11). Many employers also rely on the participation of industry advisory boards to communicate employment needs.

The majority of employers we surveyed indicated that their employees with an ET education had the right mix of skills/knowledge to do their jobs; 87.5 percent of 112 respondents indicated satisfaction with these workers. ET educators, responding to a similar question, likewise believed that their graduates had the skills to meet the needs of employers (Table 4-6).

The committee's two surveys also probed perceptions about the differences in work performed by engineers and engineering technologists. More than one-half of employer respondents either did not know what the differences were or believed there was too much variability in performance to discern differences (Table 4-7). Small and roughly similar percentages of respondents believed that ET graduates perform better than engineers do when given applied work. Eight percent of respondents indicated no difference in the work performed by the two types of employees. Land's 2012 survey of companies known to hire ET graduates also examined employer views of these differences. Although some of the roughly 200 employers participating in the survey indicated they did assign job roles based on

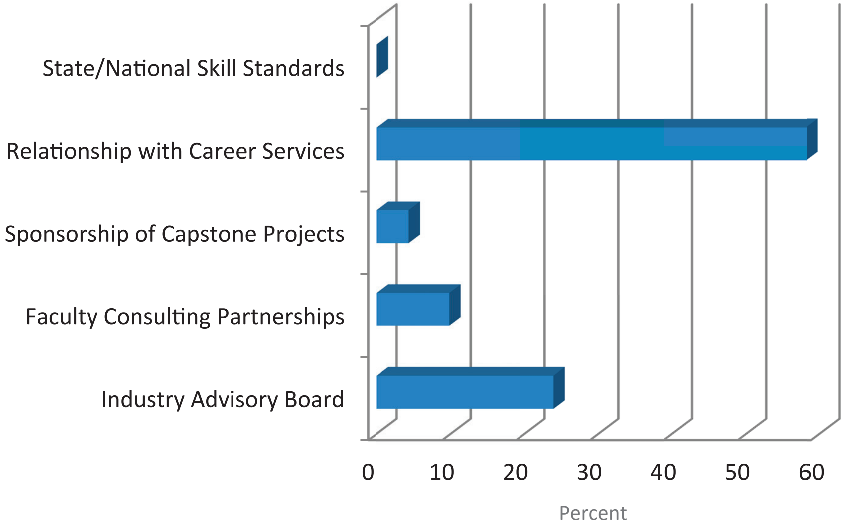

FIGURE 4-11 Methods used to communicate skill needs to educators (N=184).

TABLE 4-6 Educator Views on the Degree to Which Their Graduates are Meeting the Skill Needs of Employers, by Percent

	Graduates of 2-Year Programs (N=86)	Graduates of 4-Year Programs (N=70)
Extremely well	33.7	48.6
Well	52.3	47.1
OK, but could be better	11.6	2.9
Not so well	2.3	1.4
Not at all	0	0

the degree held, the majority (67 percent) said there was no difference in roles and responsibilities assigned based on degree. A similar percentage of respondents indicated they saw no significant differences in the capabilities of engineering and ET degree holders when performing similar roles. Land (2012) notes that the survey sample consisted of companies with existing relationships with 4-year ET programs, a fact that "may well have influenced the results" (p. 63).

ET educators believed much more strongly than did employers that their graduates are better equipped than are engineers to do applied work. A full 80 percent indicated this to be the case, with a significant majority of these

TABLE 4-7 Employer Views on the Differences in Work Performance Between Employees with 4-Year Degrees in ET and 4-Year Degrees in Engineering (N=111)

	Percentage Selecting Answer Choice
Engineering technology graduates perform better when doing applied work, while engineering graduates perform better in the use of higher-level science and mathematics.	14.4
Engineering technology graduates perform better when doing applied work, while engineering graduates perform better in doing engineering design.	18.0
Engineering technology and engineering graduates are essentially the same in terms of work performance.	8.1
There is too much variability in the work performance of engineering technology and engineering graduates to answer this question.	25.2
Don't know.	34.2

respondents indicating that the comparative strength of engineering graduates is in preparation to do higher-level mathematics and science (Table 4-8). Almost 20 percent of these educators believed that the two sets of graduates have similar skills or that there is too much variability among the educational programs to answer such a question.

Awareness of Engineering Technology Education

Employer opinions about work roles, skills, and job performance need to be seen in light of the somewhat surprising finding that nearly one-third of those who initially responded to our survey indicated they had never heard of a postsecondary academic program called engineering technology (Table 4-9).[3] This same gap in knowledge held true even for firms in manufacturing, and for some sectors within manufacturing, such as pharmaceuticals, the number who had heard of ET was much lower. One of the employer groups least likely to have heard of the discipline was "small employers," that is, those with fewer than 100 employees. Only 52 percent of this group were

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[3] Respondents who indicated no awareness of ET education did not answer any survey questions that depended on knowledge of ET.

TABLE 4-8 Educator Views on the Differences Between the Skills/Knowledge of Graduates with 4-Year Degrees in ET and 4-Year Degrees in Engineering, by Percent (N=51)

	Percentage Selecting Answer Choice
Engineering technology graduates are better prepared to do applied work, while engineering graduates have more preparation in higher-level science and mathematics.	60.8
Engineering technology graduates are better prepared to do applied work, while engineering graduates are better prepared to do engineering design.	19.6
Engineering technology and engineering graduates are essentially the same.	5.9
There is too much variability among engineering technology and engineering programs to answer this question.	11.8
Don't know	2.0

TABLE 4-9 Employer Awareness of ET Education, by Percent

	Percentage Aware
All Respondents (N=249)	70
All Manufacturing Employers (N=117)	70
Chemical Manufacturing (Pharmaceutical) (N=25)	48
Large Employers (more than 20,000 employees; N=32)	78
Mid-Size Employers (5,000 to 20,000 employees; N=45)	80
Small Employers (fewer than 100 employees; N=29)	52

aware of the field. The background and experience of those filling out the committee's survey could have impacted these results. The survey instrument did not collect job-title information from respondents, but many of NACE's employer members are involved in college recruiting.

Employers' lack of familiarity with ET education may be explained in part by factors discussed in Chapter 1, such as the field's inconsistent terminology as well as its close and sometimes confusing relationship to engineering. Some industry sectors, such as pharmaceutical manufacturing, may simply not hire many with a background in ET, which presumably would contribute to their lack of familiarity with the field.

CAREER PATHWAYS AND HIRING PATTERNS

College graduates often do not work directly in their field of study and instead apply their knowledge or follow their interests to different occupations. The question of where ET graduates work is perhaps of greater significance than where technicians work because the former are more likely to have similar academic coursework and skills as engineers do and therefore more closely resemble them. As a result, a large share of ET graduates may, in practice, be classified as engineers.

Table 4-10 presents the occupational distribution of the ET graduates in the Baccalaureate and Beyond (B&B) Longitudinal Survey 2008/2009. These graduates work in a wide variety of occupations in their early careers, suggesting that an education in ET is valuable to employers in many different fields. What is striking about Table 4-10, however, is the relatively low share of ET graduates who are working as engineering technologists and the high share who are working as engineers.

Keep in mind that these estimates are based on only about 220 unweighted individual observations; thus, the data should be interpreted with caution. Based on what the committee has learned throughout this project, there may be some confusion on the part of survey respondents about what it means to be an "engineering technologist," and this may introduce even more uncertainty in the B&B results. In addition to the 29 percent of the sample employed as engineers who may be doing work comparable to engineering technologists, other technical workers may be doing work that is similar to ET but assigned to other occupational sectors. Despite these caveats and concerns, the share of ET graduates who are working as engineering technologists is still surprisingly low, based on this admittedly small sample. If this is not entirely due to the small unweighted sample size and misclassification, it may reflect the graduates' difficulty in finding jobs in ET fields. Graduates may eventually move into ET positions, but it could take them time to connect to these jobs.

Perhaps even more surprising than the low share of ET graduates who are working as engineering technologists is the high share of engineering technologists who have degrees outside of ET. This is true not only for recent graduates, as captured by the B&B (Table 4-11), but also for the broader (and larger) population of degree holders captured by ACS and NSCG (Table 4-12). In all three datasets, the plurality of technologists have a degree in engineering. ACS and NSCG suggest that 30 to 40 percent of those working as engineering technologists do not have a 4-year degree in any science, technology, engineering, and mathematics (STEM) field.

TABLE 4-10 Early Career Occupational Distribution of 4-Year ET Graduates, Weighted Results

	Number	Percent
Agriculture occupations	2	0.01
Air transportation professionals	2	0.01
Artists and designers	1,254	8.28
Business managers	2,466	16.28
Business occupations (non-management)	253	1.67
Business/legal support (non-secretarial)	903	5.96
Computer/information systems occupations	867	5.73
Construction/mining occupations	17	0.11
Engineering technicians (“technologists”)	222	1.47
Engineers	4,465	29.49
Fitters, tradesmen, and mechanics	331	2.19
Food service occupations	122	0.81
Healthcare professionals (non-nurses)	31	0.20
Life scientists	63	0.42
Other educators	283	1.87
Other healthcare occupations	530	3.50
Personal care occupations	101	0.67
Physical scientists	0	0.00
PK-12 educators	187	1.23
Postsecondary educators	17	0.11
Protective service occupations	27	0.18
Sales occupations	299	1.97
Social service professionals	36	0.24
Transport support occupations	3	0.02
Unemployed or not in labor force	2,662	17.58
Total	15,143	100

SOURCE: Calculations from the 2008/09 B&B. All unweighted values are rounded to conform to National Center for Education Statistics (NCES) reporting standards.

These data suggest that the population of those who are working as engineering technologists may include a large number of individuals who start in a related field, such as IT, and then enter the ET workforce by acquiring the required skills on the job. Alternatively, given the growing importance of sub-baccalaureate qualifications, graduates in entirely unrelated fields with weak job prospects may have transitioned to the ET workforce by acquiring certificates in that field. This is speculative, however, as none of these federal datasets provides a way to track individuals’ accumulation of nondegree training or certificates.

TABLE 4-11 Majors of Early Career Engineering Technologists with Bachelor's Degrees, Weighted Results

	Number	Percent
Architecture and related services	941	16.37
Business, management, marketing, and related support services	118	2.05
Communication, journalism, and related programs	121	2.11
Computer and information science and support services	31	0.54
Education	0	0.00
Engineering	1,761	30.64
Engineering technology	222	3.86
History	118	2.05
Homeland security, law enforcement, firefighting, and related protective services	470	8.18
Liberal arts and sciences, general studies, and humanities	219	3.81
Multi/interdisciplinary studies	1	0.02
Philosophy and religious studies	39	0.68
Physical sciences	289	5.03
Psychology	258	4.49
Science technologies/technicians	98	1.71
Social sciences	921	16.03
Theology and religious vocations	6	0.10
Visual and performing arts	134	2.33

SOURCE: Calculations from the 2008/09 B&B. All unweighted values are rounded to conform to NCES reporting standards.

TABLE 4-12 Field of Degree of Engineering Technologists

	ACS	NSCG
Architecture	0.84%	1.31%
Arts and humanities	11.09%	7.23%
Business/management	16.16%	11.01%
Computer science/information technology	4.76%	5.57%
Education	4.18%	0.91%
Engineering technology	4.98%	11.68%
Engineering	23.00%	38.72%
Health	1.57%	0.60%
Life sciences	15.87%	3.65%
Mathematics	0.99%	2.19%
Other professional fields	6.02%	3.90%
Physical sciences	7.78%	5.78%
Social sciences	2.76%	7.46%
STEM (includes health)	58.95%	70.09%
Non-STEM	41.05%	29.90%

SOURCE: Calculations from the 2013 ACS and the 2013 NSCG.

The B&B survey is of particular interest because it reports on ET graduates at the time that they make their initial connections to the workforce. However, other datasets that include workers of all ages also can be used to assess these issues. Table 4-13 summarizes the occupational distribution of all ET bachelor's degree holders using the 2013 NSCG. The broad job categories most commonly held by those with a 4-year ET degree, as well as a category for all other jobs, are included.

According to NSCG, a small share (about 12 percent) of ET graduates report working as engineering technologists. This is larger than the share presented in B&B (about 1.5 percent; Table 4-10), but the number of graduates is still fewer than those who report they are working as engineers or in computer and IT occupations. The single largest occupational category for ET graduates is managers (23 percent of the total). This category includes engineering managers as well as other types of managers.[4] The second largest category is engineer (Box 4-1).

The NSCG data provide a snapshot in time. However, we also would like information about how the types of jobs held by those with ET degrees change over a worker's career. Generally speaking, engineers enjoy rapid earnings growth early in their career, either due to the wage structure they face in a given firm or to movement between firms in pursuit of a strong (and better paying) job match. This period is followed by flatter wage growth and movement into management positions for more senior engineers or those with management skills (Biddle and Roberts, 1994; Brown and Linden, 2008). We know less about whether engineering technicians and technologists follow this pathway or a similar pathway. The pathway to management positions for technicians and technologists may be closed, particularly in a work environment that also includes engineers who may be groomed for promotion to management. Alternatively, promotion of technicians and technologists may include transitions to an engineering position, with on-the-job experience substituting for formal training in engineering. The fluid identity and work of engineering technicians and technologists opens a wide number of potential career pathways that need to be assessed in the data.

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[4] NSCG uses different occupational categories from those used by other labor market surveys, although most (including all engineers, engineering technologists, and computer and IT occupations) closely match SOC categories. For this report, respondents are considered to be in a "manager" position if they report they are some sort of science and engineering manager, "top-level" managers, administrators, "mid-level" managers, or in some other management-related occupation. Respondents are considered to be in a "sales" position if they report they are in a sales or business services occupation. Everyone else is included in an "other" category.

TABLE 4-13 Occupational Distribution of Those with Four-Year ET Degrees

	Number	Percent
Computer and IT occupations	35,977	9.70
Engineer	58,864	15.87
Engineering technologist	44,903	12.11
Manager	86,081	23.21
Other	126,461	34.10
Sales or business services	18,604	5.02
Total	370,890	100.00

SOURCE: Calculations from the 2013 NSCG.

BOX 4-1
Engineering Technologists Working as Engineers

Nick Wilson, president and founder of Morrison Container Handling Solutions, Glenwood, Illinois, recounted the following story during the committee's December 2014 workshop. In the late 2000s, he noticed that the nature of the equipment his factories were building and using was changing, and that his employees needed new skills. Together with Purdue University Calumet, Mr. Wilson helped establish the first 4-year mechatronics engineering technology (ET) program in the country. He estimated that within his company about one-third of his employees are engineers by title, and two-thirds of that group have ET degrees.

Using data from NSCG for four 10-year age groups, Figure 4-12 presents the share of ET bachelor's degree holders working (1) in computer and IT occupations, (2) as engineering technologists or engineers, (3) in management, (4) in sales, or (5) in other occupations. Engineers and engineering technologists are not broken out separately because of the high share of ET degree holders who report they are working as engineers.

The career pathways of ET bachelor's degree holders share many important characteristics that we typically expect to see for engineers. Between the ages of 25 and 34, 39 percent of these ET graduates work as engineers or engineering technologists. Almost 52 percent work in technical fields more broadly (i.e., including computer and IT occupations). This share declines quickly for 35- to 44-year-olds at the same time that employment in mana-

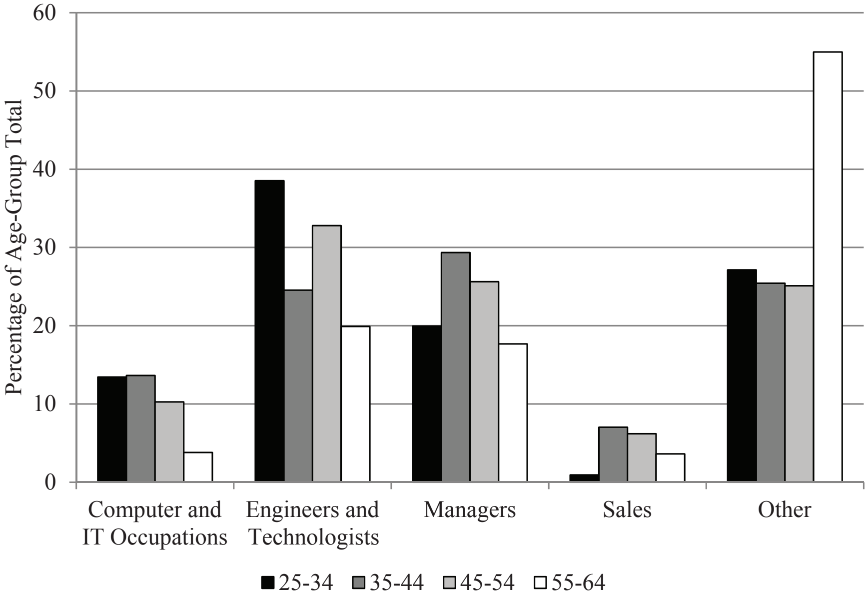

FIGURE 4-12 Major occupational categories of ET degree holders by age. SOURCE: Calculations from the 2013 NSCG.

gerial occupations increases. In the 45 to 54 and the 55 to 64 age groups, ET degree holders diffuse into a wide variety of occupations, with the highest share employed in "other" occupations. There are some important differences between the job trajectories of engineering technologists and engineers, as can be seen in Figure 4-13. Notably, later in their careers, those with engineering degrees are much more likely to move into management and much less likely to be working in other nonengineering and non-STEM fields.

Tables 4-10 through 4-13 and Figure 4-10 raise concerns that confusion about occupational categories may be hampering our understanding of how ET graduates connect to the labor market. An alternative to expecting respondents to reliably report whether they are working as engineering technologists, engineers, or in some other job is simply to ask them whether their ET degree is related to their current employment. This information, also from the B&B, is reported in Table 4-14. In this case, more than one-half of ET graduates report that their job is closely related to their studies, and three-quarters say it is closely or somewhat related. Although this is a lower level of self-reported relatedness of degree and job than for engineering graduates, it nevertheless exceeds that of all other graduates with 4-year degrees.

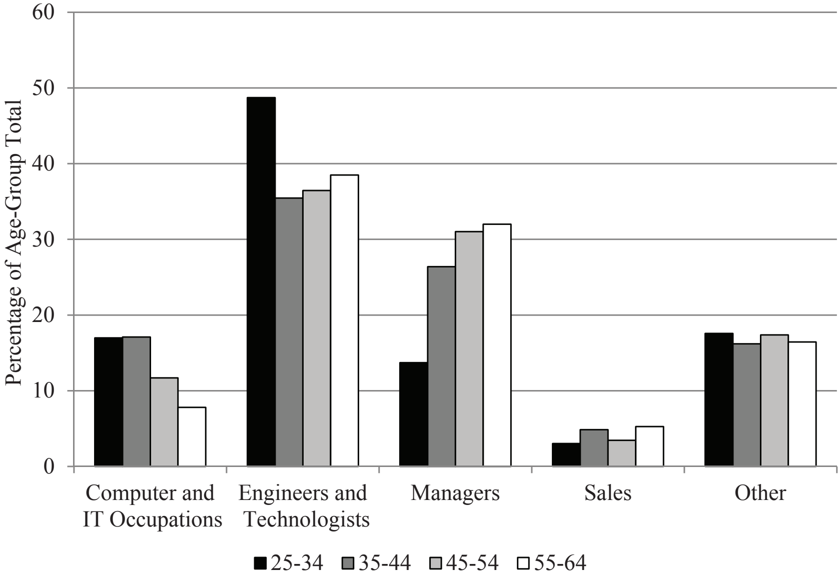

FIGURE 4-13 Major occupational categories of engineering degree holders by age. SOURCE: Calculations from the 2013 NSCG.

Interestingly, more than one-half of those with degrees in the field who say they are not working as engineering technologists still report that their work is related to their degree. The small sample size of the ET population in the B&B sample, as noted previously, merits caution in interpreting these data.

In attempting to reconcile the data in Table 4-14 with those from Tables 4-10 through 4-13 and Figure 4-10, we arrive at a seemingly contradictory conclusion: ET graduates report that their jobs are highly related to their degree even if the information they supply on employment surveys does not classify them as engineering technologists. However, it need not be contradictory. Presumably a wider range of STEM and technical jobs utilize skills acquired over the course of an ET education. Moreover, managers in organizations where technical work is done could easily make use of their ET education even though they are not working as engineering technologists.

Understanding why as many as one-quarter of ET graduates may not be working in jobs related to their field of study is critical for making inferences about whether shortages are a problem in this labor market. The topic of shortages is dealt with in detail in the next section.

TABLE 4-14 Early Career Job Relatedness for ET, Engineering, and Other Degree Holders, Weighted Results (Unweighted N=~220, Technologists; Unweighted N=~5,750, Engineers)

	Number	Percent
Engineering technology graduates		
Closely related	6,607	53.86
Somewhat related	2,663	21.71
Unrelated	2,997	24.43
Engineering graduates		
Closely related	43,794	59.21
Somewhat related	22,423	30.32
Unrelated	7,749	10.48
Other graduates		
Closely related	546,781	44.96
Somewhat related	326,724	26.86
Unrelated	342,725	28.18
Engineering technology graduates not working as technologists		
Closely related	6,538	54.28
Somewhat related	2,511	20.85
Unrelated	2,997	24.88

SOURCE: Calculations from Baccalaureate and Beyond Survey 2008/09. All unweighted values are rounded to conform to NCES reporting standards.

SHORTAGES

Economists are often skeptical of claims about labor market shortages; to a large extent, this is because of how they conceive of the problem of a shortage. A shortage is defined as a situation in which the number of workers who supply their labor at a given market wage is less than the number of workers demanded by employers at that wage. In this situation, economists would expect dissatisfied employers to bid up wages in an attempt to attract scarce workers. These higher wages would draw more workers into the market, lead some employers to reduce their quantity demanded, and thereby push the labor market back into equilibrium. In other words, market actors do not face any incentives to maintain shortages, so shortages should be fleeting problems.

Studies of the labor market for scientists and engineers seem to confirm this intuition with evidence that these skilled workers are responsive to wage signals (sometimes with a lag, because it takes time to earn a degree), and they adjust their entry into specific STEM fields based on relative job prospects. Because STEM skills are quite specific and often are not transferable across fields, analysts have instead raised the opposite concern: gluts or surpluses would form if scientists could not easily transition to other fields when demand for their services weakened.[5]

Despite skepticism about the prospect of persistent shortages, economists have recognized two versions of the shortage problem that are more likely to occur: "dynamic shortages" and "social demand shortages."[6] Dynamic shortages emerge after positive labor demand shocks or negative labor supply shocks, when the market is not able to adjust immediately to its new equilibrium. Although we would expect market forces to raise wages and eliminate the shortage eventually, workers are technically in "shortage" while that adjustment process takes place. In the skilled labor market, the typical justification for dynamic shortages is that it takes time to train new workers, leaving a large number of job vacancies open until the new workers come online. Substitutability across occupational fields can smooth the transition process.

A social demand shortage is a situation in which the market itself is in a state of equilibrium—that is, no more workers are demanded by employers at a given wage rate than are available—but some sort of social objective is not being achieved that requires more workers. For example, consider the case where there is no indication that the labor market for aerospace engineers is out of equilibrium or in shortage. However, some individuals believe that the United States should be exploring the Moon, asteroids, and Mars much more energetically, through both public and private efforts, than is currently the case. Insofar as we accept this to be true, we can claim that a social demand shortage for aerospace engineers exists, but it is not a proper shortage in the economic sense. No indicators generated from labor market data can inform analysts that a social demand shortage exists. It is a wholly subjective (and often political) judgment that is beyond the scope of economic analysis.

Dynamic labor shortages may be more plausible in the market for engineering technicians and technologists than in other STEM fields. Many of these workers, particularly at the technician level, are educated at community colleges and therefore may be more tied to their communities than other workers are. Indeed, students often attend community colleges because they

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[5] The most prominent example of such a glut is the case of biological scientists, detailed by Stephan (2012).

[6] Both terms were used initially by Arrow and Capron (1959) and more recently have been summarized by Barnow et al. (2013).

are geographically immobile, at least relative to those who attend 4-year-degree-granting schools. Younger 2-year-degree or -certificate earners may be resource constrained, while older students may have families and other obligations that tie them to their community and make community college the best option. This introduces labor market rigidities that could prevent rapid readjustment to new demands. Community colleges also often develop their curriculum in response to and sometimes in partnership with local businesses. A large increase in demand for engineering technicians and technologists may occur in a region without a preexisting program at a community college, and the development of such programs to supply businesses with these workers may take time.

As noted earlier, the reason an individual works in a job that is not related to his or her field of study may shed light on whether shortages are a problem in a particular labor market. Graduates may be working outside their field for a number of reasons. Some obstacles to working in a related occupation, such as family-related reasons or difficulties finding a related job in the same geographic region, may prevent labor supply from responding to changes in demand and thus introduce the prospect of a shortage. Others, such as the inability to find work in field or higher-quality job opportunities out of field, suggest the prospect of a surplus of workers over jobs available (or at least ample competition for the skills of ET graduates).

Because supply and demand curves cannot be directly observed, economists use a number of indirect approaches to assess whether a labor market is experiencing a shortage. One approach is to try to identify institutional barriers—such as salary or quantity regulations—that would prevent a market from reaching equilibrium as well as to find evidence that such barriers prevent workers and firms from being responsive to price signals. This is particularly relevant for medical or other highly regulated labor markets. Otherwise, the case for dynamic shortages is best made by identifying wage increases that lead to adjustments in the number of workers in a given occupation. Such an adjustment would indicate that firms are competing over scarce labor resources without an immediate increase in supply to meet increasing demand and generally tight labor market conditions.

Different industries and regions of the country naturally have different wage structures, so pinpointing regions that are exhibiting higher-than-usual engineering technician and technologist wages will be a misleading indicator of labor market shortage. It is likely that engineering technicians in Brooklyn, New York, might earn more than technicians in Bismarck, North Dakota, earn because of a higher cost of living, but North Dakota is more likely to be facing a shortage as a result of recent growth in the oil and gas extraction industry. A better approach would be to identify high engineering technician and technologist wages relative to some reference wage, such as for engineers, workers of the same education level, or all workers.

To test this approach, the committee used the 2000 and 2010 OES to assess the possibility of state-level labor shortages. First, we calculated earnings differentials between detailed engineer and engineering technician occupational categories as a percentage of the engineering technician annual income level in each state. Six detailed categories were considered for each state: aerospace, civil, electrical and electronic, environmental, industrial, and mechanical engineers and engineering technicians and technologists. Because we expect engineers to earn more than technicians and technologists do, a *small* earnings differential for a given subfield in a state is indicative of *high* engineering technician and technologist earnings relative to engineers. Although this interpretation of observed earnings differentials is the most natural, other explanations are possible. Earnings differentials may reflect a loose engineering labor market rather than a tight market for technicians and technologists. Similarly, co-occurring shortages in both labor markets may mask the shortage in the market for technicians and technologists. These possibilities are worth keeping in mind.

The state and occupational subfield of the lowest 10 percent of all earnings differentials (and therefore the highest relative technician and technologist earnings) are presented in Table 4-15. Industrial engineering technicians and technologists are much more likely to have high relative earnings than

TABLE 4-15 State and Field of the Highest-Earning Engineering Technicians and Technologists Relative to Their Engineer Counterparts, 2000

Engineering Technician and Technologist Category	States in the Bottom Decile of the Total Distribution of Engineer Wage Premiums Over Technicians and Technologists
Aerospace	AZ, CO, IL, MA, MN, WI
Civil	AK, CT
Electrical and Electronic	DE, GU, MT
Environmental	SC
Industrial	AZ, IA, KS, LA, MA, MI, MT, NY, PA, VA, WA
Mechanical	AK, MT, OR, PR

SOURCE: Calculations from the 2000 May OES. GU = Guam. PR = Puerto Rico.

are those in any other subfield, while the environmental and civil subfields maintain broader gaps between the earnings of technicians and technologists and engineers. Potentially of greater interest is the repeated presence of Montana (three cases) and Arizona, Alaska, and Massachusetts (two cases each) in the list of cases with relatively high engineering technician and technologist earnings. Montana, Alaska, and perhaps even Arizona may struggle with labor mobility and attracting technicians and technologists, driving up earnings before the market adjusts. This seems less plausible in the case of Massachusetts, although other explanations (such as labor market regulation or rapid growth in science- and engineering-related sectors of the economy) may be more relevant.

Any state with an earnings differential that is substantially lower than the average is a candidate for a local labor market shortage, should there be a sudden increase in demand. Further analysis is required to determine what is actually driving the wage differential (Katz and Murphy, 1992). The next step would be to identify whether engineering technician and technologist employment in candidate localities and subfields substantially increased after a given interval of time, relative to the average change in employment. If this is the case it would suggest that a scarcity of workers drove up wages, which resulted in drawing additional workers into the market. This pattern of a lagged employment response to wage signals has been identified in the market for physicists (Freeman 1975), petroleum engineers (Lynn et al., 2016), and computer scientists (Salzman et al., 2013).

In Figure 4-14, the earnings differentials for states and engineering subfields discussed above are plotted against employment changes for technicians and technologists from 2000 to 2010. Recall that relatively *low* earnings differentials imply relatively *high* technician and technologist wages because they represent a lower earnings premium of engineers over technicians and technologists. Figure 4-14 suggests a weak relationship between earnings differentials and changes in employment. To the extent that there is a relationship, it appears to be positive, which is unexpected if a shortage of engineering technicians and technologists is anticipated. A positive relationship suggests that as the earnings gap between technicians and technologists and the reference group of engineers widens (i.e., as the relative earnings of technicians and technologists are reduced), employment growth over the next decade increases. This would be the case if, for example, demand for engineering technicians and technologists increased over this period. (This positive relationship also was apparent when we examined the employment change between 2000 and 2005.) It might also be the case if more ET gradu-

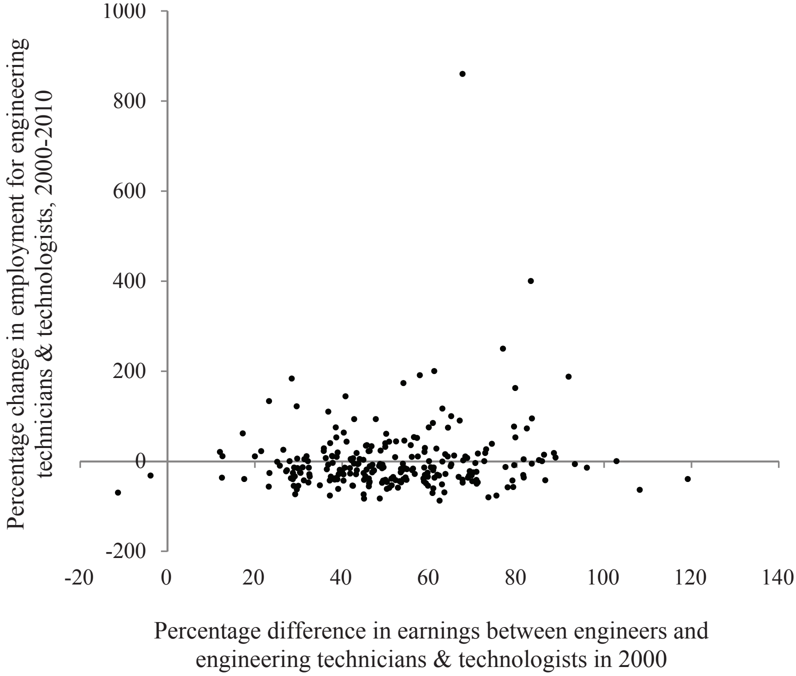

FIGURE 4-14 State and subfield earnings differentials in 2000 vs. percentage change in technician and technologist employment, 2000-2010. SOURCE: Calculation from the 2000 and 2010 OES.

ates are being hired into positions labeled “engineer” because of the demand growth for that type of worker.

Two potential narratives are suggested by Figure 4-14. First, we could conclude that in the engineering technician and technologists labor market, supply and demand have kept pace with each other, resulting in stable growth in the workforce without strong real income growth or shortage problems. Under this narrative, the observed dispersion of earnings differentials is due to idiosyncratic differences across states and fields rather than shortages. For example, civil and environmental engineers may consistently earn more than do their technician and technologist counterparts because of the nature of the work, while certain states may have wider income distributions than do other more egalitarian states. Perhaps the technicians and technologists work on very advanced tasks that allow them to command higher wages than usual, or the local community college system generates highly productive graduates.

The second narrative is that shortages of technicians and technologists exist and they are persistent. Employment does not respond to earnings differentials, and large gaps in earnings can persist without the market adjusting to a new equilibrium. This narrative probably requires an institutional or regulatory explanation for persistent shortage. Normal labor market frictions are an insufficient explanation of why employment growth remains retarded after a decade has passed. Occupational certification and licensing restrictions and fees, the robustness of the local community college system, unionization rates, and the activities of local Workforce Investment Boards could all introduce or remove barriers to labor market adjustment. Exploration of these possibilities would require additional research[7] and is beyond the scope of the current project. The preponderance of the literature in labor economics and the analysis presented here militates against the assumptions in the shortage narrative in this case.

To reiterate, the discussion of shortages here is relatively speculative. The analysis explores at a first approximation what we would expect to see in the case of a shortage. Even at a first approximation, there are no obvious signs that a shortage exists.

For another perspective on the shortage issue, the committee examined federal estimates of expected future job growth. Table 4-16 provides employment projections for engineering technician occupations produced by the Bureau of Labor Statistics (BLS; 2014). Estimates for all occupations are also provided as a reference point. In addition to projecting employment changes, the BLS estimates how many job openings there will be in each occupation between 2014 and 2024 due to both replacement demand as well as growth. It is critical to note that the BLS does not project shortages per se. It estimates equilibrium changes in employment. Nevertheless, projected increases in employment can indicate future demand growth, which *may* result in shortages if supply is not as responsive as the BLS anticipates it will be. Generally, though, the BLS data show employment growth in engineering technician occupations is expected to be weaker than employment growth nationally. The only exception is environmental engineering technicians, who are expected to experience 9.7 percent growth from 2014 to 2024. Industrial engineering technicians, electrical and electronics engineering technicians, and “other” miscellaneous engineering technicians are projected to have declining rates of employment over this period. With the exception

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[7] For example, state licensing information is collected at the Career One Stop website by the US Department of Labor, and notifications about Workforce Investment Board activities and programs are publicly available.

TABLE 4-16 Employment Projections for Engineering Technician Occupations, 2014-2024

Title	Employment, 2014 (thousands)	Employment, 2024 (thousands)	Percentage Change in Employment, 2014-2024	Job Openings Due to Replacement and Growth (thousands)
Total, all occupations	150,540	160,329	6.5%	46,507
Aerospace engineering and operations technicians	11.4	11.8	3.6%	3.2
Civil engineering technicians	74.0	77.6	4.8%	21.6
Electrical and electronics engineering technicians	139.4	136.6	–2.0%	34.1
Electro-mechanical technicians	14.7	14.8	0.7%	3.7
Engineering technicians, except drafters, all other	70.1	69.9	–0.2%	17.1
Environmental engineering technicians	18.6	20.4	10%	6.4
Industrial engineering technicians	66.5	63.5	–4.5%	16.3
Mechanical engineering technicians	48.4	49.3	2.0%	12.8

of environmental engineering technicians, there is no evidence in the BLS projections of strong impending demand growth that might result in future shortages.

The committee included questions related to the possibility of shortages in its surveys of employers and educators. Compared to those who perceive a shortage of talent, slight majorities of employers indicated there is a sufficient supply of 2- and 4-year graduates with ET degrees (Table 4-17). It is notable that about 40 percent of employers did not know whether or not there were sufficient numbers of workers with 2-year degrees. When these results were filtered to include only the 49 employers who said they hire ET graduates at the associate's degree level, the percentage of unsure respondents dropped to 16 percent; of this group of 49 employers, 65 percent believed that the supply of workers with 2-year degrees was sufficient.

TABLE 4-17 Employers' Views on the Adequacy of the Current Supply of Graduates with 2- and 4-Year ET Degrees, by Percent

	Yes	No	Don't Know
Sufficient supply of applicants with 2-year degrees (N=102)	31.4	26.5	42.2
Sufficient supply of applicants with 4-year degrees (N=113)	49.6	40.7	9.7

Employers who indicated there was a current shortage were mostly midsize manufacturing firms, particularly in the electronics industry, located in the mid-Atlantic and Great Lakes regions. Nearly 75 percent (N=19) of employers with between 100 and 5,000 employees reported a shortage, as did 27 percent (N=7) of employers with between 100 and 500 workers and 35 percent (N=9) of employers with between 1,000 and 5,000 workers. The largest employer sector to indicate a shortage was computer and electronics manufacturers, where 26 percent (N=7) did so. Finally, 53 percent of the respondents who see an insufficient supply of ET graduates with associate's degrees were located in either the mid-Atlantic states (N=7; Delaware, Maryland, New Jersey, New York, and Pennsylvania) or the Great Lakes region (N=6; Illinois, Indiana, Michigan, Ohio, and Wisconsin).

Few data regarding possible shortages drill down into specific subfields of ET. OP-TEC, the National Center for Optics and Photonics Education funded by the National Science Foundation, has surveyed employers of photonics technicians, who may have a 2-year degree in photonics or in electronics with a photonics specialty, to assess the demand for such workers in the United States.[8] Based on extrapolation from the responses of 333 employers, OP-TEC (2012) estimated that the industry needs to hire 1,600 new photonics technicians per year, while it asserts the education system is able to produce only about 300 degreed photonics technicians annually.

We also asked ET educators whether they believed the supply of graduates with 2- and 4-year degrees was sufficient to meet the needs of the marketplace. Unlike employers, educators were of the opinion, by roughly a two-to-one margin, that the supply of graduates was falling short of the need (Table 4-18). Merely one-quarter of the respondents believed that the sup-

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[8] Although the Accreditation Board for Engineering and Technology (ABET) does offer accreditation to photonics engineering technology programs, no such programs are currently accredited, according to the board.

TABLE 4-18 Educators' Views on the Adequacy of the Current Supply of Graduates with 2- and 4-Year ET Degrees, by Percent

	Graduates with 2-Year Degrees (N=86)	Graduates with 4-Year Degrees (N=70)
There are more graduates with these degrees than the job market can support.	3.5	1.4
The number of those with these degrees matches the availability of jobs.	25.6	30.0
There are not enough graduates with these degrees to fill available jobs.	60.5	64.3
Don't know	10.5	4.3

ply of graduates was adequate. These results may reflect the understandable optimism on the part of educators about the employability of their graduates.

We asked employers to look beyond the current situation and say whether they foresaw future shortages of workers with 2- or 4-year ET degrees. Employers who hire those with 2-year degrees were evenly split, at 40 percent each, on whether there would or would not be a future shortage (Table 4-19). With respect to employees with 4-year degrees, slightly more employers believed that there would be sufficient numbers of these workers in the future than believed that there would not (Table 4-20).

TABLE 4-19 Employer Views on the Adequacy of the Future Supply of Workers with 2-Year ET Degrees, by Percent (N=44)

	Percent
Sufficient	40.9
Not sufficient	40.9
Don't know	18.2

TABLE 4-20 Employer Views on the Adequacy of the Future Supply of Workers with 4-Year ET Degrees, by Percent (N=106)

	Percent
Sufficient	45.3
Not sufficient	34.0
Don't know	20.8

THE IMPACT OF AUTOMATION AND TECHNOLOGICAL DEVELOPMENT

Existing studies of the impact of technological development on the American labor market are in many ways inadequate for assessing the significance of these trends for engineering technicians and technologists. Most of the relevant economic research is highly aggregated across industries and occupations and is focused on the question of whether technological change is biased toward the interests of skilled or unskilled workers (e.g., Berman et al., 1994; Doms et al., 1997). In some prominent cases, technological change is inferred from wage and employment trends for high-skill workers (if both employment and wages are increasing it implies a positive demand shock) without even using any data on changes in production technology itself (Berman et al., 1998; Card and DiNardo, 2002; Manning, 2004).

The consensus is that so-called skills-biased technological change plays a nontrivial role in the polarization, or "hollowing out," of the workforce, with relatively increasing employment opportunities for both high- and low-skill work and declining opportunities for middle-skill work (see, e.g., Autor et al., 2003). However, Holzer (2010) notes that findings of job market polarization are sensitive to how skill levels are defined. This may be particularly relevant for engineering technicians and technologists, who may be seen as straddling the boundary between high- and middle-skill workers. Even aside from the ambiguities of categorizing the skill levels of technicians and technologists, the unique role that these workers play in facilitating and maintaining new technologies makes it difficult to generalize previous, already highly generalized research.

The committee included questions in its surveys about the impact of new technologies—additive manufacturing, advanced digital manufacturing, and complex control systems, among others—on the skills needed by those with ET degrees. Employers (Figure 4-15) expressed a clear expectation that these technologies will impact the skills and knowledge needed by their workers. Nearly 64 percent of respondents believed that such technologies would impact workers' skill requirements substantially or by a fair amount. Similarly, substantial majorities of educators of 2- and 4-year ET students noted that the presence of these new technologies is changing the skills their students need to succeed (Table 4-21). Nevertheless, most educators believe that the changing technological landscape either is not affecting the employability of their students or is making it easier for them to be hired (Table 4-22). This suggests that these educators see technological change as a net plus for the employability of graduates.

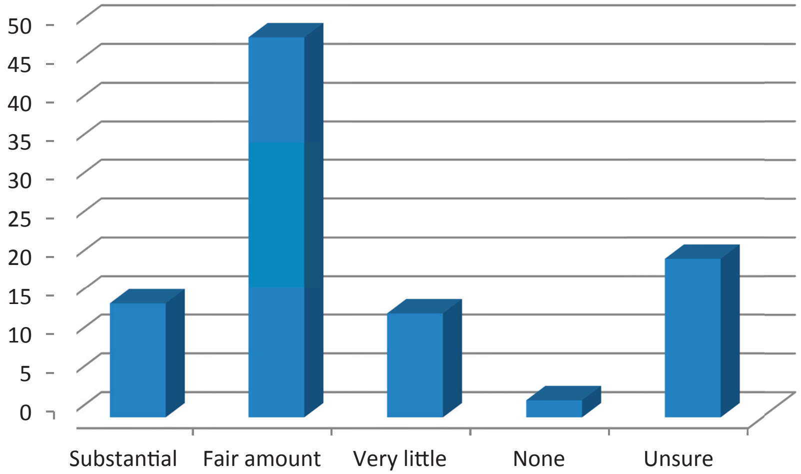

FIGURE 4-15 Employers' views on how much the integration of new technologies is affecting skill requirements for workers with ET degrees (N=224).

TABLE 4-21 Educators' Views on How Much the Integration of New Technologies Is Affecting Skill Requirements for 2- and 4-Year ET students, by Percent

	2-Year ET Students (N=86)	4-Year ET Students (N=70)
Substantially	26.7	31.4
A fair amount	47.7	41.4
Very little	16.3	24.3
Not at all	2.3	0.0
Don't know	7.0	2.9

TABLE 4-22 Educators' Views on How Much Technological Change Is Affecting the Employability of 2- and 4-Year ET Graduates, by Percent

	2-Year ET Students (N=86)	4-Year ET Students (N=70)
Making it harder for graduates to find work	2.3	0.0
Making it easier for graduates to find work	43.0	57.1
No difference in employability	36.1	30.0
Don't know	18.6	12.9

APPENDIX 4A

Methodology for Survey of Employers and Demographics of Respondents

The project's survey of employers was conducted by the National Association of Colleges and Employers (NACE) under contract to the National Academy of Engineering (NAE). Established in 1956, NACE connects more than 6,300 college career services professionals at nearly 2,000 colleges and universities nationwide, more than 2,700 university relations and recruiting professionals, and the business affiliates that serve this community. NACE has a long-standing research and survey program that gathers information about the employment of the college educated, forecasts hiring and trends in the job market, and tracks starting salaries, recruiting, and hiring practices.

For the NAE engineering technology (ET) survey, NACE sent a link to the survey instrument, hosted on the website SurveyMonkey, to its approximately 1,000 corporate members. NACE corporate members are midsize to large companies spanning virtually all major industry sectors. Recipients of the survey link were mostly those responsible for college recruiting. A total of 245 NACE members opened the survey link. NACE also sent the survey link to employer groups that are part of the Employer Associations of America (EAA). These associations predominantly represent small manufacturers. Only nine responses were received from this source. For purposes of analysis, responses from EAA members were combined with responses from NACE members. The survey was open from October 8, 2014, until January 15, 2015.

Because the bulk of survey items were about ET education, the survey included a screening question intended to allow those who were not familiar with ET to skip questions related to the focus topic. Out of the total of 254 respondents, 246 answered the screening question, which asked whether the company hired employees with either a 4-year ET degree or either of two types of 2-year ET degrees: the associate of science (AS) and the associate of applied science (AAS). A total of 124 companies (50 percent) hired ET majors at either the bachelor's or associate's degree level. Forty-nine companies (20 percent) hired workers with associate's degrees.

The screening question also asked whether respondents hired employees with 4-year engineering degrees, and 244, or greater than 99 percent, indicated they did. The fact that nearly all survey respondents said they hire engineers provides some assurance that the NACE sample was generally representative of firms engaged in work requiring engineering-related skills.

Respondents who indicated they hired no employees with either engineering or ET degrees or who indicated they hired those with engineering degrees but not those with ET degrees were diverted to items near the end of the survey that did not require specific knowledge of ET.

Demographically, respondents represented a fairly broad range of employer types and employer locations. In terms of size, approximately 30 percent of respondents met the Small Business Administration definition of a small employer (500 employees or less); another 23 percent were employers with a workforce that exceeded 10,000 employees (Table 4A-1). Nearly one-half of the respondents were manufacturers, with the largest single group representing the computer and electronics sector (Table 4A-2). Finally, respondents were distributed fairly evenly across the United States. Table 4A-3 shows that although the mid-Atlantic and Great Lakes states accounted for about 42 percent of respondents, there was representation from other areas of the country as well.

TABLE 4A-1 Respondent Firms by Employees Population

Employees	Firms	Percent
Fewer than 100	29	11.6
Between 101 and 500	49	19.5
Between 501 and 1,000	28	11.2
Between 1,001 and 5,000	59	23.5
Between 5,001 and 10,000	20	8.0
Between 10,001 and 20,000	26	10.4
More than 20,000	32	12.7
Don't know	8	3.2
Total	251	100.0

TABLE 4A-2 Respondent Firms by Industry Sector

	Firms	Percent
Accounting Services	4	1.6
Agriculture	1	0.4
Chemical (Pharmaceutical) Mfg.	26	10.2
Computer & Electronics Mfg.	33	13.0
Construction	10	3.9
Engineering Services	15	5.9
Finance, Insurance & Real Estate	14	5.5
Food & Beverage Mfg.	10	3.9
Government	4	1.6
Information	17	6.7
Management Consulting	7	2.8
Messaging & Warehouse	0	0.0
Misc. Mfg.	42	16.5
Misc. Prof. Services[a]	13	5.1
Misc. Support Services	2	0.8
Motor Vehicle Mfg.	8	3.1
Oil & Gas Extraction	12	4.7
Recreation & Hospitality	5	2.0
Retail Trade	2	0.8
Social Services	1	0.4
Transportation	7	2.8
Utilities	11	4.3
Wholesale Trade	10	3.9
Total	254	100.0

[a] "Professional services" predominantly consists of engineering services firms.

TABLE 4A-3 Respondent Firms by Geographic Region

	Firms	Percent
Far West	26	10.2
Great Lakes	50	19.7
Mid-Atlantic	56	22.0
New England	15	5.9
Plains	21	8.3
Rockies	6	2.4
Southeast	35	13.8
Southwest	45	17.7
Total	254	100.0

APPENDIX 4B

NAE Survey Instrument for Employers of Engineering Technology Graduates

On behalf of the National Academy of Engineering (NAE), the National Association of Colleges and Employers (NACE) is conducting an online survey of its employer members to learn more about workers with engineering-related education and skills.

The results from this survey will inform an ongoing NAE study funded by the National Science Foundation. Your participation is critically important to the success of the NAE project.

The survey will take approximately 15 minutes to complete, and your participation is entirely voluntary. Your specific responses will be completely confidential, and any information that could be used to identify you will not be shared with NAE staff or the committee that is involved in overseeing the study. In addition, any information that could be used to identify you will be destroyed within one year of the conclusion of the NAE study. Finally, you will not be personally identified in any public reports or presentations of survey results.

By clicking the "SUBMIT" button at the end of the survey, you are declaring that you have read and understood the information above and agree to take part in this survey. If you so choose, you may end participation in the survey at any time.

1. What is the name of your company? [text field]

2. What is your job title? [text field]

3. In which states are the engineering-related divisions of your company located? Check all that apply. [drop-down list of states]

4. Which of the following industry sectors best characterizes your company?
    a. Natural resources and mining ("natural resources" includes agriculture, forestry, and fishing and hunting)
    b. Construction

c. Manufacturing (includes manufacturing related to food, textiles, apparel, wood, paper, printing, petroleum, chemicals, plastics, nonmetallic minerals, metal, machinery, computers and electronics, transportation, furniture)
d. Trade, transportation, and utilities
e. Information
f. Financial activities (includes finance and insurance, real estate and renting and leasing)
g. Professional and business services (includes professional, scientific, and technical services; management of companies and enterprises; administrative and support and waste management and remediation services)
h. Education and health services
i. Leisure and hospitality
j. Other services, except public administration
k. Public administration
l. Other

5. How many people are employed by the divisions of your company that do the bulk of engineering-related work?
   a. Fewer than 100
   b. Between 100 and 500
   c. Between 500 and 1,000
   d. Between 1,000 and 5,000
   e. Between 5,000 and 10,000
   f. Between 10,000 and 20,000
   g. More than 20,000
   h. Don't know

6. Which of the following best characterizes the type of engineering-related work conducted by your company?
   a. Manufacturing
   b. Design
   c. Maintenance
   d. Research and Development
   e. Field Services
   f. Sales
   g. Other

7. Have you heard of a post-secondary academic program called "engineering technology" that graduates students with either 2- or 4-year degrees?
   a. Yes
   b. No

8. In your company, do you hire people with any of the following degrees? Check all that apply. [check-box format for each answer choice: yes, no, don't know] [Note: If "no" and/or "don't know" to all choices, skips to Q22 and also skips Q27]
   a. Bachelor of Science in Engineering, 4-year degree [if this and/or b are the only answer(s) checked, skips to Q22 and skips Q27]
   b. Associate of Science in Engineering, 2-year degree [if this is and/or a are the only answer(s) checked, skips to Q22 and skips Q27]
   c. Bachelor of Engineering Technology, 4-year degree [if checked, to Q9]
   d. Associate of Applied Science in engineering technology (AAS), 2-year degree [if checked, to Q10]
   e. Associate of Science (AS) in engineering technology, 2-year degree [if checked, to Q10]

9. Which of the following job roles would typically be assigned to an employee with 4-year engineering technology degree? Check all that apply. [randomize answer choices a-j for each survey participant]
   a. Designing new products or systems
   b. Managing the work of other technical staff
   c. Creating mathematical, simulation-based, or physical models
   d. Conducting experiments
   e. Conducting quality control checks
   f. Producing technical drawings
   g. Collecting and analyzing data
   h. Building or setting up equipment/technologies
   i. Testing or maintaining equipment/technologies
   j. Troubleshooting and repairing equipment/technologies
   k. Other
   l. Don't know

10. Which of the following job roles would typically be assigned to an employee with a 2-year (AS or AAS) engineering technology degree? Check all that apply. [randomize answer choices a-j for each survey participant]
    a. Designing new products or systems
    b. Managing the work of other technical staff
    c. Creating mathematical, simulation-based, or physical models
    d. Conducting experiments
    e. Conducting quality control checks
    f. Producing technical drawings
    g. Collecting and analyzing data
    h. Building or setting up equipment/technologies
    i. Testing or maintaining equipment/technologies
    j. Troubleshooting and repairing equipment/technologies
    k. Other
    l. Don't know

11. Thinking about *recruitment of new staff* with expertise in engineering technology, is the supply of skilled applicants sufficient for your needs today?
    a. Sufficient supply of applicants with 2-year degrees [choices: yes/no/don't know]
    b. Sufficient supply of applicants with 4-year degrees [choices: yes/no/don't know]

12. Thinking about your *current staffing needs* related to engineering technology, what are the TOP THREE most important skills/knowledge that new applicants need to have? [randomize answer choices a-h for each survey taker]
    a. Knowledge of basic science and mathematics
    b. Knowledge of a specific engineering discipline (e.g., mechanical, electrical, civil)
    c. Knowledge across more than one engineering discipline
    d. Ability to see problems and solutions from a systems perspective
    e. Knowledge of the engineering design process
    f. Ability to work with tools and machinery
    g. Ability to problem solve or troubleshoot in new or unfamiliar situations
    h. Ability to communicate and work in teams

   i. Other
   j. Don't know

13. Thinking about your *current workforce*, do your employees with educational background in engineering technology have the right mix of skills/knowledge to meet your needs?
   a. Yes [goes to Q15]
   b. No [goes to Q14]

14. What one area of skill/knowledge would you most want your engineering technology employees to have that they currently do not? [randomize answer choices a-h for each survey taker]
   a. Knowledge of basic science and mathematics
   b. Knowledge of a specific engineering discipline (e.g., mechanical, electrical, civil)
   c. Knowledge across more than one engineering discipline
   d. Ability to see problems and solutions from a systems perspective
   e. Knowledge of the engineering design process
   f. Ability to work with tools and machinery
   g. Ability to problem solve or troubleshoot in new or unfamiliar situations
   h. Ability to communicate and work in teams
   i. Other
   j. Don't know

15. In your opinion, which of the following statements best characterizes the difference in work performance between employees with 4-year degrees in *engineering technology* and 4-year degrees in *engineering*?
   a. Engineering technology graduates perform better when doing applied work, while engineering graduates perform better in the use of higher-level science and mathematics.
   b. Engineering technology graduates perform better when doing applied work, while engineering graduates perform better in doing engineering design.
   c. Engineering technology and engineering graduates are essentially the same in terms of work performance.

   d. There is too much variability in the work performance of engineering technology and engineering graduates to answer this question.
   e. Don't know

16. As you consider your *strategic needs for the future*, how much will the skills/knowledge you require of workers with engineering technology degrees change?
    a. Substantially [goes to Q17]
    b. A fair amount [goes to Q17]
    c. Very little [goes to Q18]
    d. Not at all [goes to Q18]
    e. Don't know [goes to Q18]

17. Please tell us the one, most important new skills/knowledge workers with engineering technology degrees at your company will need in the future. [open response]

18. [Q18 only for those answering yes to Q8 d and/or e] As you consider your *strategic needs for the future*, do you anticipate that the supply of skilled workers with 2-year (AS or AAS) engineering technology degrees will be sufficient?
    a. Yes [goes to Q22]
    b. No [goes to Q19]
    c. Don't know [goes to Q22]

19. Which of the following best describes why you believe the supply of engineering technology workers with 2-year degrees will not be sufficient?
    a. The overall number of such workers will be fewer than needed
    b. The number of workers will be adequate, but their level of skill/knowledge will not be
    c. Neither the number of workers nor their skill/knowledge level will be adequate
    d. Other [open response]

20. [Q20 only for those answering yes to Q8 c] As you consider your strategic needs for the future, do you anticipate that the supply of skilled workers with 4-year engineering technology degrees will be sufficient?
    a. Yes [goes to Q22]
    b. No [goes to Q21]
    c. Don't know [goes to Q22]

21. Which of the following best describes why you believe the supply of engineering technology workers with 4-year degrees will not be sufficient?
    a. The overall number of such workers will be fewer than needed
    b. The number of workers will be adequate, but their level of skill/knowledge will not be
    c. Neither the number of workers nor their skill/knowledge level will be adequate
    d. Other [open response]

22. How much, if at all, is the increasing integration of new technologies (e.g., additive manufacturing, advanced digital manufacturing, complex control systems, optics and sensors) into the workplace changing the skills/knowledge technically trained employees need?
    a. Substantially
    b. A fair amount
    c. Very little
    d. Not at all
    e. Don't know

23. Does your company have ways to inform educational institutions of your employment/skill needs (e.g., industry advisory board, industry-faculty consulting partnerships, industry sponsorship of capstone projects, relationships with career services personnel)?
    a. Yes [to Q24]
    b. No [skips to Q25]
    c. Don't know [skips to Q25]

24. Which of the following methods does your company most rely on to communicate your employment needs to educational institutions? Check all that apply.

   a. Industry advisory board
   b. Industry faculty consulting partnerships
   c. Industry sponsorship of capstone projects
   d. Relationships with career services personnel
   e. State or national skills standards
   f. Other
   g. Don't know

25. Which, if any, of the following types of work-related experiences do you offer students? Check all that apply.
   a. Apprenticeship (paid vocational programs for certification)
   b. Internship (paid or unpaid, at your company, coordinated with the academic curriculum)
   c. Cooperative work experience (semester- or quarter-based work experience as an alternative to campus-based learning)
   d. Summer technical work experiences (paid or unpaid) independent of the college/university
   e. Other
   f. Don't know

26. In recruiting and hiring new talent, do you prefer candidates who have participated in the types of student work-related experiences, such as apprenticeships, internships, and co-ops?
   a. Yes, strongly
   b. Yes, but it is not a priority
   c. No
   d. Don't know

27. What challenges and opportunities does your company face identifying, hiring, training, or retaining those with engineering technology degrees at the 2- and 4-year degree level? (200 words maximum)

28. What other information, if any, would you like the committee overseeing this project to have that was not covered in the previous survey questions? (200 words maximum)

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5

Findings and Recommendations

The vitality of the innovation economy in the United States depends on the availability of a highly educated technical workforce. A key component of this workforce consists of engineers, engineering technicians, and engineering technologists. Much has been written about the role of engineers, their academic preparation, and their value to the nation. Our purpose in this report has been to shed light on the relatively underappreciated roles and contributions of engineering technicians and technologists. Very abstractly, if engineers are viewed as being responsible for designing the nation's technological systems, then engineering technicians and technologists are the ones who help build and keep those systems running. However, the reality is more nuanced than that.

Craftsmen and technicians have always been associated with industrial operations. As we note in Chapter 2, the field of "engineering technology (ET) education" evolved following World War II as engineering education became more theoretical and science focused. Chapter 3 describes the characteristics of a multi-tiered ET education system that produces engineering technicians with one or more certificates of specialization (each typically earned in a year's time or less); engineering technicians with 2-year associate's (AS or AAS) degrees; and engineering technologists with 4-year bachelor's (BS) degrees. In Chapter 4, we share detailed information about how these degree holders are employed in both technical and nontechnical occupations, and we discuss the significant share of those working as engineering technologists who have degrees in fields other than ET.

In this final chapter, the committee lays out its findings and a small number of related recommendations in four key areas:

- the nature of ET education,
- supply and demand,
- educational and employment pathways, and
- data collection and analysis.

As an overarching concern, the committee believes that the national discussion about engineering needs to broaden to encompass the spectrum of degree types and skills discussed in this report. Our ability to attract and retain talented men and women across this continuum is necessary to maintaining the nation's health, safety, and economic security. We hope this report serves as a useful start to the dialog.

THE NATURE OF ENGINEERING TECHNOLOGY EDUCATION

This study has highlighted the challenges associated with describing the field of ET education in ways that are clear and that distinguish it from engineering. This is particularly an issue at the 4-year-degree level. We also have come to realize that ET is in many ways a "stealth" profession, existing under the radar of many prospective students, other postsecondary educators, and employers. At the same time, ET provides important value to employers and rich opportunities for job security and meaningful work for those in the field.

From the perspectives of workforce and education policy in the United States, there appears to be little awareness of ET as a field of study or a category of employment. This can be explained by a combination of factors, including the field's challenges with branding and marketing itself; curricula and worker skills that overlap in some significant ways with those of engineering; and gaps in research and data collection that make it difficult to determine how differences between the two fields affect employment opportunities and benefit employers. Certainly, the large number of degree titles (nearly 50, by our count) associated with the field (Appendix 3C) does not help in understanding ET's brand.

Thirty percent of almost 250 respondents to our employer survey had never heard of the field of ET education; this lack of awareness rose to almost 50 percent for smaller employers (Table 4-9). Even among respondents who indicated an awareness of ET, one-third said they did not know the difference between work performed by engineers and work performed by engineering technologists, and one-quarter indicated there was too much variability in work roles to clearly distinguish between the two (Table 4-7). This confusion is mirrored to some degree in the terminology used in international equivalency agreements, such as the Sydney Accord (Table 1-5), whose signatory countries use "engineer," "technologist," and variants of these (e.g., "Professional Technologist [Engineering]") to describe individuals with comparable academic backgrounds.

The committee observes that policy discussions about the US technical workforce often omit mention of ET, focusing instead on the need for those with training in engineering and science. The committee could find little evidence at either the federal or the state level that those responsible for determining education spending or policy include ET in their planning. For example, when the administration's Council on Jobs and Competitiveness announced in 2011 a goal of educating 10,000 more engineers a year (White House, 2011), the baseline figure it used included only those with traditional 4-year engineering degrees. The roughly 18,000 graduates with 4-year ET degrees were left out of the calculation.

Lack of awareness of ET appears to extend into the K-12 education system, where many young people are first exposed to possible career paths. The committee found little evidence of formal outreach or communication to K-12 teachers, students, or students' parents concerning ET and its connection to postsecondary education and employment. This is true even while engineering as a curricular subject is becoming more relevant in precollege settings through initiatives such as the *Next Generation Science Standards* (NGSS Lead States, 2013).

> FINDING 1: Data collected in this project and by others show that, as a practical matter, ET remains relatively hidden and misunderstood compared with the better-known domain of engineering.
>
> **RECOMMENDATION 1:** Within academia, it is critical for leaders of 2-year and 4-year ET programs to engage more meaningfully in discussion with leaders in postsecondary engineering education about the similarities and differences between the two variants of engineering and

> how they might complement one another while serving the interests of a diverse student population. This engagement can be accomplished in dialog within and between individual institutions; through work by discipline-based and affinity engineering professional societies; and by leaders within the American Society for Engineering Education, such as the Engineering Technology Council, the Engineering Deans Council, and the Corporate Member Council.

Our side-by-side comparison of recommended coursework at several institutions that have both engineering and ET programs (Table 1-6) suggests underlying differences in the relative emphasis on mathematics and science coursework. In addition, a solid majority of 4-year ET educators in our survey believe that their students are better able than engineering students are to do applied work, but they are less prepared in science and mathematics (Table 4-8). From an accreditation standpoint, the different emphases on theory and application are apparent, however subtly, in the student outcomes criteria promulgated by the Accreditation Board on Engineering and Technology (Table 1-7).

> FINDING 2a: A useful distinction between 4-year engineering and 4-year ET programs can be made by pointing to the generally greater curricular emphasis on science and mathematics knowledge in the former and on applied training in the latter.

At the 4-year-degree level, ET's emphasis on application is seen as an asset by many employers—one-third in our sample (Table 4-7)—compared with traditional engineering's focus on theory and design. For certain populations, particularly adults already in the workforce and returning military veterans, ET programs can provide opportunity for a range of well-paying jobs requiring technical skills. Compared with some other academic areas, ET education may provide more flexibility (combining work and study) and allows students to enter the technical workforce at higher, solidly middle-income wages.

> FINDING 2b: ET education is an important and underappreciated component of the US education system. The field's historical focus on application has advantages—for certain students and for some types of work—compared with traditional, more theory- and design-focused engineering education.

> **RECOMMENDATION 2:** The ET education community should consider ways to make the field's value proposition more evident to K-12 teachers, students, and students' parents, as well as to employers. Such an effort might include new messaging developed in collaboration with a qualified public relations firm and based on data from market research on student and employer knowledge and perceptions of ET. The research might test the appeal and believability of rebranding ET as "applied engineering" or other appropriate names identified by the market research. Attention also should be paid to ways to reduce confusion associated with the term "engineering technology" and to simplifying degree nomenclature. To encourage collaboration and avoid duplication, plans for any major new outreach should be communicated with appropriate leadership within the engineering education community, such as the Engineering Deans Council and Engineering Technology Council of the American Society for Engineering Education.

SUPPLY AND DEMAND

Examining supply and demand issues in ET is complicated both by the definitional confusion surrounding the field and by certain gaps in data collection by the federal government (see "Data Collection and Analysis," below), among other factors. Shortages and surpluses cannot be observed directly; they can only be indirectly inferred from the responsiveness of employment to wage changes.

Even with these limitations, available data do not show any clear indication of a shortage or a surplus of engineering technicians or technologists. This does not preclude the possibility of market imbalances in certain geographic areas, as noted in Chapter 4's "Shortages" discussion, or temporary imbalances that resolve themselves. Our employer survey shows that many businesses believe that there is an undersupply of these workers (Table 4-16), despite the absence of strong empirical evidence. It is difficult to make sense of reports of hiring difficulties without an understanding of the wage structure, and this information is not easily obtainable.

The significant graying of the ET workforce (Figures 4-5 and 4-6) suggests that these skills may well be needed in greater numbers in the future, as some of our survey respondents from industry indicated (Table 4-19). However, it is worth remembering Freeman's (2007) caution (Chapter 4, "Trends in Employment, Income, and Age") about attributing an aging workforce to a demand for future growth in employment. If an aging workforce is paired with strong new sources of demand, then employers will likely seek new graduates to replace an aging workforce. But, typically, an aging workforce is an indication of business expectations of weak future demand.

EDUCATIONAL AND EMPLOYMENT PATHWAYS

Based on the committee's review of federal data, almost 1,500 programs at more than 700 institutions around the United States provide some form of ET education.[1]

We found 915 programs at 470 institutions—mostly community colleges and technical institutes—that awarded at least one 2-year degree. Forty-seven institutions awarded more than 100 such degrees in 2012, and there also were 47 institutions that awarded 100 or more 4-year ET degrees. Altogether, 527 programs at 235 institutions awarded at least one 4-year degree. In 2013, these programs awarded about 18,000 4-year and about 37,000 2-year degrees in ET. By comparison, US engineering schools awarded approximately 87,000 4-year degrees and 3,800 2-year degrees that year.

The total of 4- and 2-year degrees awarded each year in ET, although less than the total awarded in engineering, is nevertheless significant. The large number of ET education programs suggests there is a substantial national infrastructure—comprising both personnel and facilities—devoted to educating students in this field.

The majority of ET students enter 2- or 4-year degree programs from high school. In contrast to the situation for most college graduates, who are in their early 20s, however, more than one-quarter of graduates with 4-year degrees are older than 35 (Figure 3-6). Our survey of educators reveals that the proportion of adults, which includes some returning veterans, enrolling in 2-year programs may be even higher (Figure 3-7).

In terms of diversity, the share of students earning 4-year degrees in ET that is black is almost three times the share of students earning 4-year degrees in engineering (10.7 percent vs. 3.8 percent; Table 3-6). Blacks comprise

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[1] The number of programs could have been considerably higher, particularly at the associate's-degree level, had the committee chosen to count programs that do not contain the words "engineering" and "technology" (see Appendix Table 3A). This may be an issue particularly for programs in areas of emerging technology (e.g., photonics, advanced materials, nanotechnology, and biotechnology). Future research might look at the similarities and differences between these technician-training initiatives and traditional ET programs.

more than 11 percent of those earning 2-year degrees and more than 17 percent of those earning certificates in ET; in engineering, the proportion earning 2-year degrees is slightly less than 6 percent (NSF, 2013). The percentage of 2-year ET degrees awarded to blacks approaches their representation in the US population, 12.4 percent, and their share of certificates exceeds it. The proportion of 4-year degrees in engineering and ET earned by Hispanics is comparable, about 10 percent. By comparison, the share of Hispanics in the US population is slightly greater than 17 percent. The share of Asians or Pacific Islanders that earns 4-year engineering degrees is almost three times the share that earns 4-year degrees in ET.

In 2013, nearly 18,000 graduates of 2- and 4-year ET programs combined were nonwhite compared with about 27,000 graduates of 2- and 4-year engineering programs. In percentage terms, 32.7 percent of ET graduates and 29.7 percent of engineering graduates were nonwhite. The absolute number of nonwhite, 2-year graduates was much higher in ET, where there were nine times as many degrees awarded as there were in engineering.

Women's share of 4-year engineering degrees was 65 percent higher than was their share of 4-year degrees in ET (19.8 percent vs. 12 percent), although in both fields women remain significantly underrepresented. Women accounted for only 10 percent and 12 percent, respectively, of those earning ET certificates and 2-year ET degrees. Black women were the only group of women who earned a larger share of 4-year ET degrees (2.1 percent of the total) than 4-year engineering degrees (1 percent of the total). Their share of 2-year ET degrees (1.7 percent) and ET certificates (1.5 percent) also surpassed their share of 4-year engineering degrees.

> FINDING 3: Compared with engineering, ET education programs, particularly at the 2-year level, are more attractive to older students and students currently underrepresented in STEM fields and of less appeal to women overall.

> **RECOMMENDATION 3:** Research is needed to understand why certain segments of the population graduate at higher frequencies from ET programs than they do from engineering programs and why women are even less engaged in ET than they are in engineering. Understanding the reasons for these preferences and trends may allow programs in both domains of engineering to better attract and retain more diverse student populations. The National Science Foundation should consider funding research on factors affecting matriculation, retention, and graduation in

> ET. The research might consider, among other factors, socioeconomic issues, such as the need for some students to work while attending school; issues related to the adequacy of secondary school preparation in mathematics and science; the presence and nature of mentoring, peer support, and other mechanisms known to increase enrollment and retention of women and underrepresented groups in science, technology, engineering, and mathematics (STEM) fields; and the nature of curricular differences between 2- and 4-year ET programs and between 4-year ET and 4-year engineering programs.

Our survey of ET educators indicates that three sources (recent high school graduates, adults changing careers or "upskilling," and returning military veterans) account for the majority of those entering 2-year ET programs. In 4-year programs, adults and veterans are less dominant sources of students, while transfers from 4-year engineering programs are second only to high school graduates as a source of students. Our survey of educators found that between 30 and 60 percent of 2-year ET programs allow students to transfer to 4-year programs in either ET or engineering (Table 3-7). However, our survey was not very helpful in elucidating the actual movement of students between different types of programs.

ET programs draw students from a number of segments of the population, indicating the field has potentially broad appeal. Our survey of educators showed that transfer options are most available to those in AAS degree programs, but weaknesses in the study's data collection hamper our ability to gauge the popularity of specific student pathway choices.

Employment of engineering technicians and technologists, which stood at about 400,000 in 2013, has been rising slowly over the past 40 years, growing about 50 percent from 1971 to 2013. By comparison, the engineering workforce nearly doubled during this period, to about 2 million. The committee estimates that about 80 percent of the current ET workforce, or 320,000 individuals, is composed of technician-level workers (Table 4-1). The other 20 percent, roughly 80,000 people, work as technologists. The stock of those with 4-year ET degrees is about 400,000—roughly five times the number of those employed as technologists. By comparison, the stock of those with 4-year engineering degrees is about 4 million, or two times the size of the engineering workforce. It is important to remember that occupational data used in this report are based on work roles associated with specific job titles, not on the degrees individuals may have earned.

A closer look at the workforce reveals that a very small share of technologists—5 percent according to the American Community Survey and 12 percent according to the National Survey of College Graduates (NSCG)—has 4-year degrees in ET. This is in stark contrast to engineering, where 38 percent of those with 4-year degrees work in engineering.[2] The largest share of technologists (either 23 or 39 percent, depending on the dataset) has degrees in engineering; smaller, but still significant, shares have degrees in business/management or the life sciences (Table 4-12). Apart from the category "Other," those with 4-year ET degrees were most likely to be employed as managers (23 percent), as engineers (16 percent), or in computer and information technology occupations (10 percent). These data appear to be somewhat at odds with information collected by the Baccalaureate and Beyond (B&B) survey, which revealed that three-quarters of recent ET degree earners believe their work to be either "closely related" or "somewhat related" to their degree (Table 4-14). However, as noted in Chapter 3, the sample size of ET degree holders in the B&B survey is very small, so extrapolations to the population at large should be viewed with caution.

Over their careers, workers with 4-year ET degrees move increasingly into management-related jobs and, late in their professional lives, into a variety of other occupations, including jobs outside the STEM disciplines in such areas as health care and education (Figure 4-12). The movement of graduates with 4-year engineering degrees into management occurs earlier and is more pronounced, and their employment in other, non-STEM job categories is less of a factor (Figure 4-12).

> FINDING 4a: The connection between an ET education and the ET workforce is fairly weak. Those with ET degrees work in a broad range of occupations, and those employed as engineering technologists have a diverse degree background.

Among the factors that influence career choice (and participation in educational programs related to career) is the perceived connection between particular types of work and one's income-earning potential. Engineering technicians and technologists have received roughly the same compensation, about $50,000 annually (average, in 2015 dollars), over the past 40 years. Average real wages for engineers, on the other hand, have risen a mod-

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[2] From an analysis of 2013 NSCG data conducted by Donna K. Ginther, Kansas State University, and Shulamit Kahn, Boston University, for the NAE Committee on Understanding the Engineering Education-Workforce Continuum.

est 23 percent, from $70,000 to $86,000 annually, during this period. This roughly 50 percent premium in earnings potential for engineers may help explain why the significant share of those with 4-year ET degrees works as engineers. To the extent that those with ET degrees are doing similar or the same work as those with 4-year engineering degrees, as some of our survey respondents indicate (Table 4-7), employers may have an incentive to hire the less-expensive (i.e., ET-degreed) worker.

As noted in Chapter 4's discussion of trends in employment, income, and age, two datasets—the Current Population Survey (CPS) and the American Community Survey (ACS)—compare salaries of technicians to those of technologists. Although CPS shows a salary differential between technicians and technologists of almost 25 percent for a single year (2013 in Table 4-3), the gap nearly vanishes when we look at CPS salary data over a longer span (Figure 4-2). The more stable ACS indicates a wage gap of about 9 percent. In contrast to the situation in ET, there is a 77 percent salary differential between engineers and engineering technologists according to ACS.

> FINDING 4b: Though average salary data hide potential low- and high-salaried outliers, the overall gap in earnings between technicians and technologists is quite small compared with the differential between engineering technologists and engineers. The relatively small salary premium for technologists, as compared with technicians, may be reducing incentives for entry into 4-year ET programs as well as tamping down overall interest in technologist jobs. Conversely, the relatively high salary potential of technician-level jobs may serve to increase interest in these jobs and educational pathways to them.

> **RECOMMENDATION 4:** Research is needed to better understand the reasons for the apparent loose coupling of degree attainment and employment in engineering technology. Such research might consider how factors such as the salary differential between ET and engineering jobs and lack of ET wage growth may be influencing students' academic and career choices. These and related questions might be addressed in studies supported by the National Science Foundation (NSF) or by revisions in relevant survey instruments administered by NSF, the National Center for Education Statistics, and the Bureau of Labor Statistics.

DATA COLLECTION AND ANALYSIS

This report presents data both from federal sources and from the committee's own surveys that shed light on the education and employment of engineering technicians and technologists. However, as noted earlier in this chapter and detailed in other parts of the report, there is considerable confusion surrounding the nature of ET. Unclear terminology and the proliferation of ET degree titles further muddy understanding of this important segment of the technical workforce.

This confusion and lack of clarity are almost certainly relevant to aspects of data collection and analysis. For example, as noted in Chapter 3's discussion of degree fields, it is up to a small number of individuals within postsecondary institutions to decide how to code information about the degrees awarded by their academic programs. A full accounting of degree production is part of compliance with the reporting requirements of the Integrated Postsecondary Educational Data System (IPEDS). The coding scheme itself, the Classification of Instructional Programs (CIP), currently includes field and subfield titles within the ET designation that do not contain the term "engineering technology." It is difficult for the committee to believe that every institutional representative providing data to IPEDS is aware of the nuances surrounding the field of ET. In addition, some federal datasets that utilize postsecondary degree information rely only on CIP's main field categories, making it impossible to separately analyze subfields within ET.

> FINDING 5a: Given the widespread confusion about what constitutes ET education and the inconsistent terminology within the CIP, there is reasonable likelihood of inconsistent coding of ET degree data by postsecondary institutions.

Unlike IPEDS, which is based on institutional reporting, other datasets, such as ACS and NSCG, rely on the submission of self-reports by individual survey participants. These surveys indicate that the stock of 4-year ET degree earners stands at between 435,000 and 480,000, and there are roughly 10 times as many individuals with 4-year degrees in engineering as there are with 4-year degrees in ET (Table 3-1). Both because these data are self-reported and because of confusion about degree types within engineering-related fields, it is possible some individuals with degrees in ET are reporting they have a degree in engineering (and are therefore being counted as engineering-degree recipients). In addition, although we can count the number of 2-year ET degrees awarded in a particular year, it is not currently possible to accurately gauge the entire stock of these awards.

Despite the popularity of community colleges and the large number of 2-year degrees and certificates awarded by these institutions, there are gaps in our understanding of how these types of credentials relate to further education or employment in ET. In the employment arena, none of the four federal datasets used for this report (ACS, CPS, Occupational Employment Statistics [OES], and NSCG), which capture occupational information, tallies technicians and technologists separately. In Table 4-1, we attempt to estimate the number of employed technicians by pulling out those workers who have a 2-year degree but not a 4-year degree.[3] (None of these databases captures information about field for those with 2-year degrees; only ACS and NSCG collect information about field for those with 4-year degrees.) This approach has shortcomings, as we note in Chapter 4, including the possibility that someone with a 2-year degree may have risen through the ranks to assume responsibilities consistent with someone with a 4-year degree in ET or engineering. Or, conversely, someone we counted as a technologist, because the person had a 4-year degree, may have earned that degree in a field unrelated to ET but ended up doing ET-related work after earning one or more certificates or a 2-year degree in the field, or because of relevant on-the-job training.

Just as with the situation of how to sort educational data, the committee believes that an underlying problem with ET employment data relates to the coding process, in this case the System of Occupational Classification (SOC). ACS, CPS, and OES each use the SOC to assign individuals to specific job types.[4] The SOC currently does not provide separate job descriptions for technicians and technologists, combining them all into a category called "Engineering technicians, except drafters." An interagency work group revising the SOC is considering whether to create separate occupational categories for ET technicians and technologists.

> FINDING 5b: There are significant, data-related limitations in our ability to understand differences in degree histories, specific job attributes, and educational and employment choices of those working as engineering

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[3] This can be done only for ACS and CPS, because OES does not collect educational attainment information, and NSCG only collects information about 4-year degrees.

[4] NSCG, overseen by the National Science Foundation, uses its own coding system rather than the SOC.

technicians and technologists. This is particularly an issue for tracking of 2-year degrees and for the technician workforce.

RECOMMENDATION 5: The National Center for Education Statistics should consider collecting more comprehensive survey data on individuals participating in sub-baccalaureate postsecondary education. In addition, existing nationally representative surveys, such as ACS, CPS, and NSCG, should consider collecting more detailed information from 4-year degree holders and add questions pertaining to sub-baccalaureate populations, as appropriate. ACS and NSCG, which rely on self-reported data, might consider including prompts in their survey instruments to encourage more accurate reporting of degree information from those with ET degrees.

A FINAL WORD

This report identifies and analyzes information from a variety of sources that sheds light on the education and employment of engineering technicians and technologists in the United States. This important segment of the nation's STEM workforce has strong historical connections to traditional engineering and shares the same general sensibility toward technical problem solving. At the same time, the pedigree of ET is rooted in application-focused and hands-on learning, perhaps to a greater extent than in engineering.

Our review of the data uncovered a number of issues related to lack of awareness of the field, definitional confusion, pay differentials with engineering, engagement of populations typically underrepresented in STEM education, and the preparedness of ET students to cope with technological change. Data were insufficient to map educational pathways to and from ET in detail, although there is movement between engineering and ET and between 2- and 4-year tracks in ET programs. We found no empirical evidence of national shortages of workers with ET skills, despite an aging ET workforce.

We hope our report spurs greater understanding and further exploration of ET education and of workers with ET-related skills. The recommendations in this final chapter suggest the importance of increasing the public understanding of the field. They encourage the ET education community to undertake a critical self-examination aimed at articulating a clear and compelling value proposition, and to do so in collaboration with colleagues in engineering. And they propose strengthening federal data collection efforts in ways that will provide more accurate, actionable information for use by both educators and policy makers.

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Appendix A

Committee Biographies

Katharine G. Frase (NAE), *committee cochair*, is vice president, Education Business Development for IBM. In this capacity she sets strategy for IBM's education solutions, including partnerships and customer engagement. Prior to this role, as chief technology officer, IBM Public Sector, she provided thought leadership for IBM and its customers on innovation and strategic transformation specific to government, education, life sciences, health care, and cities, driving the creation of new solutions. Earlier roles included industry solutions research, technical and business strategy for IBM's software business, corporate assignments on technology assessment and strategy, and roles in IBM Microelectronics in the management of process development, design/modeling methodology and production of chip carriers, assemblies and test. She is a member of the IBM Academy of Technology and sits on numerous external committees and boards. She was elected to the National Academy of Engineering in 2006. Dr. Frase received her AB in chemistry from Bryn Mawr College and PhD in materials science and engineering from the University of Pennsylvania.

Ronald M. Latanision (NAE), *committee cochair*, is a senior fellow at Exponent, Inc., an engineering and scientific consulting company, and an emeritus professor at MIT. He was a principal and corporate vice president at Exponent before assuming his current role. Before joining Exponent, he was director of the H.H. Uhlig Corrosion Laboratory in the Department of Materials Science and Engineering at MIT, where he was also on the faculty of the Department of Nuclear Engineering. He was director of the MIT School of Engineering's Materials Processing Center from 1985 to 1991 and the first holder of the Shell Distinguished Chair in Materials Science (1983–1988). In April 2015 he was appointed an adjunct professor in the Key Laboratory of Nuclear Materials and Safety Assessment of the Institute of Metal Research of the Chinese Academy of Sciences. He was a founder of Altran Materials Engineering Corporation, established in 1992. He is a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences, ASM International, and NACE International. He has served as a science advisor to the US House of Representatives Committee on Science and Technology, and in 2002 he was appointed by President George W. Bush to membership on the US Nuclear Waste Technical Review Board, reappointed for a second four-year term by President Barack Obama. Dr. Latanision received a BS in metallurgy from Pennsylvania State University and a PhD in metallurgical engineering from Ohio State University. He is an honorary alumnus of MIT.

Walter Buchanan is a professor in the Department of Engineering Technology and Industrial Distribution, College of Engineering, Texas A&M University. Previously, he was professor and director of the School of Engineering Technology at Northeastern University. Other academic posts include professor and dean of Engineering and Industrial Technologies at the Oregon Institute of Technology; associate professor and chair of Engineering Technology and Industrial Studies at Middle Tennessee State University; assistant professor and coordinator of the Electrical Engineering Technology Associate Degree Program at the University of Central Florida; and assistant professor of electrical engineering technology at Indiana University–Purdue University Indianapolis. He has also been an electronics engineer for the Naval Avionics Center, an engineering officer for the US Navy, an aerospace engineer for Boeing Co. and Martin Co., and an attorney for the Veterans Administration in Indianapolis. He is a fellow and past president of the American Society for Engineering Education (ASEE), a fellow of the National Society of Professional Engineers (NSPE), and a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and Society of Manufacturing Engineers (SME). He served on the NSPE board of directors, and chaired the ASEE Engineering Technology Council and NSPE Professional Engineers in Higher Education. He is a past member of the Executive Committee of the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET). He has received the ASEE James H. McGraw Award and Frederick J. Berger Award, the NSPE Outstanding Service Award, and the International Conference on Engineering and Computer Education Award. He is on the editorial or advisory boards of several journals, including the *Journal of Engineering Technology*, *American Journal of Engineering Education*, and *International Journal of Engineering Research & Innovation*, and has authored or coauthored more than 200 publications. He has consulted for more than 20 organizations and been a principal investigator for the National Science Foundation (NSF) and other grants. He holds a bachelor's degree in mathematics and languages from Indiana University, and bachelor's and master's degrees in interdisciplinary engineering from Purdue University, as well as a law degree and PhD in higher education from Indiana University.

Imelda (Mel) E. Cossette is executive director and principal investigator of the National Resource Center for Materials Education Technology, an NSF Advanced Technological Education Center at Edmonds Community College in Lynnwood, Washington, that engages nationally with materials science, advanced manufacturing, and engineering technology programs. Ms. Cossette manages the Materials in STEM (M-STEM) Workshop, a 3-day professional development forum that brings 2- and 4-year instructors, K–12 teachers, and industry together around materials science and STEM education. She is also a co-PI on two other NSF grants: the National Resource Center for Aerospace Technical Education (SpaceTEC), an NSF ATE center in eastern Florida, where she helped develop a national certification for composites and assisted in the development of a national certification examination in manufacturing; and the Revolutionizing Metallic Biomaterials Engineering Research Center, at North Carolina Agricultural and Technology State University. She was the PI on an NSF-funded project on Proven Practices and Strategies for Recruitment of Women and Underrepresented Populations into STEM Careers. She was previously program manager and trainer with the International Association of Machinists/Boeing Joint Programs and supervisor of work-based learning programs at Lake Washington Institute of Technology. She serves on numerous boards, including the Institute for Advanced Composites Manufacturing Innovation, PowerAmerica Institute, and the Latino Educational Training Institute. Ms. Cossette has a master's of education degree from City University of Seattle and a vocational education certificate from Shoreline Community College, both in Washington State.

Werner Eikenbusch is head of talent management in the Americas for BMW Group Corporate Human Resources, responsible for the development and adaptation of talent management strategies and concepts in the region. Drawing on his experiences in apprenticeship and engineering programs in Germany and the United States, Mr. Eikenbusch helped create new talent development programs for BMW in the Americas. For example, the BMW Scholars program is a dual study/work education program, modeled after the German system, in which students enroll full-time at local technical colleges for 2 years while training as apprentices in the BMW factory in South Carolina for 20 hours a week; and the Engineering & Operations Management Development Program works with recent college graduates through a 2-year rotational program. Mr. Eikenbusch began his career as a manufacturing engineer for BMW in Munich. He has served on several boards for education and workforce development topics. He holds an MS degree in management engineering from New Jersey Institute of Technology, where he was a Fulbright Scholar; and a Dipl. Ing. (FH) Maschinenbau, earned in Germany.

Christopher Russell Fox (until January 5, 2015) is a former manufacturing engineering teacher at Atholton High School (2009–2013) and technology education teacher at Folly Quarter Middle School (2003–2009), both in Howard County, Maryland. He has helped write curriculum for the Howard County Public School System, the Utah Online Charter Schools (in computer science), the International Technology and Engineering Educators Association (Engineering by Design program), and the State of Maryland (Voluntary State Curriculum), and raised money to support student teams participating in FIRST robotics in Howard County. He has advanced degrees in career and technical education from the University of Maryland Eastern Shore, and in administration and supervision from the Johns Hopkins University. His undergraduate degree is from Western Michigan University in vocational education with a concentration in machine tool technology and computer-aided drafting. He has an associate's degree in applied science in machine tool technology from Southwestern Michigan College, and a certificate in engineering education through Project Lead the Way, earned at the University of Maryland Baltimore County.

Joyce M. Gleason has been a science educator for more than 40 years. As an educational consultant, her clients have included Annenberg Media and the Smithsonian Institution, and she has conducted staff development sessions for Boston, Southbridge, and Hadley Public Schools in Massachusetts and strategic planning workshops for the National Science Teachers Association, the Connecticut Science Teachers Association, and the Massachusetts Association of Science Teachers. Previous positions include director of outreach for the Annenberg/CPB Channel (now Annenberg Learner), based at the Science Media Group of Harvard-Smithsonian Center for Astrophysics; science curriculum liaison with the Worcester (MA) public school system, where she helped introduce a K–12 technology/design engineering curriculum; and 26 years as a high school biology teacher. She was in 2000 selected as Science Teacher of the Year by the Massachusetts Association of Science Teachers. She has an AB degree in the biological sciences from Mount Holyoke College, an MALS in science from Wesleyan University, and a CAES in curriculum and instruction from Boston College.

Daniel Hull is the principal investigator and executive director of the NSF/ATE-funded National Center for Optics and Photonics Education (OP-TEC). Prior to his role at OP-TEC, he founded the Center for Occupational Research and Development (CORD), which focuses on technician preparation, and led it from 1979 to 2006. He also founded the National Coalition for Advanced Technology Centers (NCATC) and National Career Pathways Network (NCPN), and is cofounder of the NSF/ATE HI-TEC Conference. He is the author of seven books on technician education and contextual teaching, including *Career Pathways for STEM Technicians* (2012), *Adult Career Pathways* (2007), and *Career Pathways: Education with a Purpose* (2005). He is a registered professional engineer with 13 years of practice in the laser field and more than 30 years of experience leading education reform efforts in the United States and throughout the world. He is a senior member of the Society for Optics and Photonics, the Optical Society of America, and the Laser Institute of America.

Sharon Levin is professor of economics emerita at the University of Missouri–St. Louis. She joined the department in 1974 and chaired it from 1987 to 1998. Before accepting an early retirement in December 2002, she was also director of graduate studies and department cochair. Her research focuses on factors affecting the productivity, quality, and composition of the scientific workforce. Major themes have been the effects on the careers of US scientists and engineers of the diffusion of information technology and immigration. Her research has been funded by the Alfred P. Sloan Foundation, Andrew W. Mellon Foundation, Exxon Education Foundation, and NSF. She has assisted the National Research Council and has been a member of the Scientific and Engineering Workforce Project sponsored by the National Bureau of Economic Research in conjunction with the Sloan Foundation. She was a consultant to the Howard Hughes Medical Institute on issues concerning scientific productivity over the life cycle. In 1993 she received the Chancellor's Award for Excellence in Research and Creativity from the University of Missouri–St. Louis. She has published numerous articles in journals including *The American Economic Review*, *Management Science*, *Science*, and *The Review of Economics and Statistics*. In 1992 she coauthored, with Paula Stephan, *Striking the Mother Lode in Science* (Oxford University Press). Her research on the careers of scientists and engineers has also been the focus of articles in *The Economist*, *Science*, *The Scientist*, and other newspapers and magazines in the United States and abroad. Dr. Levin graduated from the Bronx High School of Science and earned her BA from the City College of New York (Phi Beta Kappa) and her MA and PhD from the University of Michigan, all in economics.

Jeffrey Ray is dean of the College of Engineering and Technology at Western Carolina University (WCU). The College is home to accredited programs in construction, engineering, and technology. He has held several positions in academia including dean of engineering technology and management at Southern Polytechnic State University (now Kennesaw State University) in Marietta, Georgia; and director of Grand Valley State University's School of Engineering, with responsibility for the interdisciplinary industry-sponsored senior capstone design program. As an educator, Mr. Ray likes to draw on his precollege experience as a journeyman industrial electrician and machinery troubleshooter. His attention to diversity issues, contacts with the K–12 community, and transformative approach to engineering and engineering technology education have had a major impact on thousands of students. He has held leadership positions with the American Society for Engineering Education (ASEE), including vice president of the executive board and chair of the engineering technology council. He received his bachelor's and master's degrees from Tennessee Technological University and his doctorate from Vanderbilt University, all in mechanical engineering.

Michael Richey is an associate technical fellow assigned to support technology and innovation research at the Boeing Company. He leads a team conducting engineering education research to improve the learning experience for students, incumbent engineers, and technicians. His research encompasses sociotechnical systems, learning curves, and engineering education. His responsibility to provide business leadership for engineering technical and professional educational programs includes development of certificate and master's engineering programs in advanced aircraft construction, composite structures, systems engineering, product lifecycle management, and digital manufacturing. Under his leadership, the Boeing Company has won multiple awards for excellence and innovation for industry academic partnerships and joint programs. Dr. Richey has served on the editorial board of the *Journal of Engineering Education*, Boeing Higher Education Integration Board, American Society for Engineering Education Project Board, and the NSF Industry-University Collaborative Research Center (I-UCRC) Advisory Board. He has authored or coauthored more than 30 publications in leading journals, including *Science* and *The Journal of Engineering Education*, addressing topics in large-scale system integration, learning sciences, and systems engineering. He often represents Boeing internationally and domestically as a speaker and has authored multiple patents on computer-aided design/manufacturing, with disclosures focused on system engineering and elegant design. He holds a BA and MS from ESC Lille in program project management and a PhD from SKEMA Business School with a focus on engineering education research.

Melvin L. Roberts is a registered professional engineer and immediate past dean of the Division of Business, Computer, and Technical Studies at Camden County College, in Blackwood, New Jersey. Since November 2013 he has also been dean of Occupational Skills & Customized Training at the college. Before those assignments, he spent a combined 17 years as associate professor and then chair of the college's Computer-Integrated Manufacturing Engineering Technology program, where he taught courses in PLC programming and industrial automation. After 7½ years as dean, he returned to the faculty ranks in August 2014, and was recently promoted to professor of engineering science and computer-integrated manufacturing engineering technology. From 2007 through 2014, Dr. Roberts was program chair of the ASEE Two-Year College (TYC) Division and he has been the TYC Division Chair as well since 2009. He holds a BS in mechanical engineering cum laude from Howard University, an MS in mechanical engineering from the Georgia Institute of Technology, and a PhD in educational leadership from Wilmington University, Delaware.

James R. Stone III is director of the National Research Center for Career and Technical Education (NRCCTE) at the Southern Regional Education Board. NRCCTE is the nation's primary agent for research in career and technical education (CTE) and an important source of professional development and technical assistance for CTE professionals, particularly at state and local leadership levels. Dr. Stone's research has focused on strategies that improve the capacity of CTE programs to improve the engagement, achievement, and transition of secondary and postsecondary CTE participants, including longitudinal studies on the effects of work-based learning and the effect of whole-school, CTE-based school reforms on educational outcomes of youth in high-poverty communities. Dr. Stone led an interdisciplinary team in a randomized controlled trial of an innovative pedagogic and professional development strategy to integrate mathematics into high school CTE curricula (Math-in-CTE). A former editor for the *Journal of Vocational Education Research*, he has published numerous articles, books, and book chapters on CTE. His most recent book is *College and Career Readiness for the 21st Century: Making High School Matter* (2012, Teacher's College Press). He was previously a professor and Distinguished University Scholar, Department of Leadership, Foundations & Human Resource Education, College of Education and Human Development, University of Louisville, and is now professor emeritus, University of Minnesota College of Education and Human Development. He holds an Ed.D. in vocational-technical education from Virginia Polytechnic Institute & State University, an M.Ed. in school administration from George Mason University, and a BS degree in distributive education from Virginia Polytechnic Institute & State University.

Will Tyson is an associate professor of sociology at the University of South Florida. His research examines STEM educational and career pathways with a focus on student- and institutional-level influences on high school and college science and math course taking and STEM degree attainment. He was the principal investigator of the NSF-funded project "Successful Academic and Employment Pathways in Advanced Technologies" (PathTech; 4 years, $1.2 million), a collaboration with Tampa Bay area high schools, community colleges, and local technology and manufacturing industry to better understand pathways to engineering technology AS degree and certificate programs and back into the local workforce. Dr. Tyson is also the PI of the follow-up study "PathTech LIFE: A National Survey of LIFE (Learning, Interests, Family, and Employment) Experiences Influencing Pathways into Advanced Technologies" (3 years, $776,888), involving a national survey of community college students who are completing coursework, certificates, and degrees in engineering technology and related technology fields. He is coeditor of *Becoming an Engineer in Public Universities: Pathways for Women and Minorities* (2010) based on NSF-funded research in colleges of engineering in Florida universities and has published on secondary and postsecondary pathways to engineering and other STEM bachelor's degrees as well as faculty climate in STEM programs. He holds PhD and master's degrees in sociology from Duke University and a BA in sociology and psychology from Wake Forest University.

Appendix B

Descriptions of Datasets Used in the Committee's Analyses

ACS—American Community Survey is the annual, nationally representative household survey conducted by the US Census Bureau. The ACS serves as the "annual census" and is sufficiently large to allow for analysis of relatively small geographies.

B&B—Baccalaureate and Beyond, 2008/09, is a nationally representative survey of college graduates in 2008 and 2009 produced by the National Center for Education Statistics. It provides detailed course taking and employment information on graduates.

CPS—Current Population Survey is the monthly, nationally representative household survey conducted by the US Census Bureau for the Bureau of Labor Statistics. CPS is the principal labor market survey produced by the federal government.

IPEDS—The Integrated Postsecondary Education Data System is a detailed annual data file produced by the National Center for Education Statistics reporting degree awards by field and degree level for all accredited colleges and universities in the United States. Numerous additional institutional characteristics are also available.

NAICS—NAICS is the North American Industrial Classification System—the standard used by federal statistical agencies and economists to classify businesses according to the products they produce and their industry.

NSCG—National Survey of College Graduates is the irregular survey of 4-year degree holders by the National Science Foundation. NSCG collects information on educational and job experiences and particularly focuses on the science and engineering workforce.

OES—Occupational Employment Statistics are the Bureau of Labor Statistics' annual estimates of employment and earnings by detailed occupation. OES is produced from an establishment survey, rather than from a household survey.