Defining Skilled Technical Work

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1. Introduction

Somewhere between professional occupations and low-paid service occupations lay the group of workers known as "middle-skilled." They are varying called trades workers, technicians, blue collar workers, or craft professionals. Here, I will refer to them as skilled technical workers.

Compared to other groups, there is little research on skilled technical workers. Labor economists overwhelmingly focuses on workers at the highest and lower pay levels and typically distinguishes those with a bachelor's degree from those with a high school diploma. The limited research may partly be the result of government data collection. For example, the two largest and most regular surveys of individuals—the Census Bureau's American Community Surveys and Current Population Surveys—do not ask workers about their informal (or non-degree yielding) training, nor do they ask people about their field of study for two-year or lower levels of post-secondary education, even as they do collect this information for bachelor's degree fields. Informal training and sub-bachelor's level higher education are the two most common pathways to a skilled technical career.

[1] The views expressed here are the author's own and do not necessarily reflect those of the Brookings Institution. The author would like to thank Harry Holzer and participants at the 2015 National Academies Symposium for Pathways on Middle Skilled Jobs for helpful comments on an earlier draft.

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At a policy level, meanwhile, two-year or lower training programs receive substantially less financial support on a per student basis than four-year or higher programs (Kahlenberg 2015). The higher subsidy for four-year and higher education could be justified by the relatively high social returns to bachelor's degree training. The evidence that a year of bachelor's training produces more public benefits than a year of training at a two-year college is mixed. One study finds that the higher salary of Bachelor's degree earners relative to associate's degree earners appears to be attributable to their higher academic ability and longer time of study (Kane and Rouse 1995). If so, two-year or lower training may be the optimal level for many adults whose childhood education or interests do not prepare them to succeed at the bachelor's level. Analyzing recent graduates living in the state of Florida, Backes, Holzer, and Dunlop Velez (2014) find that credits earned in a bachelor's degree program for those who do not finish a degree are worth about as much in the labor market as those earned from a community college. On the other hand, there is also robust evidence suggesting that two-year college tend to be of lower quality than four-year colleges for students with relatively low test scores (Goodman, Hurwitz, and Smith 2015; Zimmerman 2014) or more broadly (Long and Kurlaender 2009; Reynolds 2012).

Regardless of the comparison to bachelor's programs, stronger evidence shows that post-secondary training certificates, degrees, or course work at two-year colleges enhances earnings relative to a high school diploma (Huff Stevens, Kurlaender and Grosz, 2015; Bahr 2014; Jacobson, LaLonde, Sullivan 2005; Kane and Rouse 1995). For two-year degree completers, alumni earnings data show that returns are especially high in the more technical science-based fields of study but are very low for humanities degree majors (Backes, Holzer and Dunlop Velez 2014; Rothwell 2015). Low completion rates are a problem for both groups, and non-completion is associated with diminished earnings (Backes, Holzer and Dunlop Velez 2014; Rothwell 2015).

This chapter seeks to better define what is meant by skilled technical workers. Below, I will discuss the limited scholarship on this population, before offering a new way to define and operationalize the study of these workers. Next, I will examine the educational and training requirements typically needed to work in skilled technical occupations and describe the tasks performed by these workers. The final section will discuss policy implications.

2. How the literature defines skilled technical workers

The study of skilled technical workers goes back to the origins of economics as a disciple. In *The Wealth of Nations,* Adam Smith (1776) offered a succinct definition of skilled laborers: "The policy of Europe considers the labor of all mechanics, artificers, and manufacturers, as skilled labor." He distinguished this group from skilled professionals, such as academics and lawyers.

Of contemporary scholarship on skilled technical workers, some of the most comprehensive work comes out of Australia, where research has examined the role of these workers in innovation and productivity (Toner 2012; Toner, Turpin, and Woolley 2011) and hiring difficulty (Mok, Mason, Stevens, and Timmins 2012). There, research is facilitated by the occupational categorizations. The Australian New Zealand Standard Classification of Occupations (ANZSCO) includes a broad category called Trades and Technical Workers.

In the United States, economists have defined skilled technical workers using occupational categories and their wage and educational characteristics (Holzer and Lerman 2005; Holzer 2015; Autor, Katz, Kierney 2006). This approach ranks occupations by either wages or educational requirements and considers middle-skilled jobs to fall within the middle third of the distribution (Autor, Katz, Kierney, 2006). Holzer defines middle-wage occupations as having earnings between 75 and 150 percent of the US median wage. Within middle-skilled jobs, economists have also distinguished between occupations that perform routine versus non-routine tasks (Autor, Katz, Kierney, 2006; Autor 2013) or those in newer and growing versus older and declining occupations (Holzer 2015). A report from the National Research Council (2014) defines middle-skilled jobs as requiring education or training beyond high school but less than a four-year degree, as does the National Skills Coalition.

There are strengths in weaknesses in these definitions, as Holzer (2015) has noted. Using wages to gauge middle-skilled occupations can be misleading because workers in the middle of the wage distribution may be relatively unskilled but compensated well because of union contracts or other characteristics of the industries in which they commonly work. Likewise, some low wage occupations may be relatively skilled but experiencing negative wage trends as a result of trade or technological change. Using educational requirements also runs into difficulty because there is tremendous variation in the practical skills of people who, on the one hand, drop out of college after taking remedial courses, compared to those who earn a technical degree from a strong community college program.

Each of these approaches relies on occupational categories to organize the tasks and responsibility of workers, which raises another set of problems. Worker skill, task orientation, and competency vary to some extent within occupations. For example, Autor and Handel (2012) show that workers who perform more abstract tasks earn more than workers in the same occupation who do less abstract tasks. As a result of these limitations, Handel (2012) recommends that the analysis of skill should include direct measures of skill, rather than only proxies.

For the purposes of this analysis—a study of work—within-occupation heterogeneity may in some ways be irrelevant. In the United States, detailed occupational categories are defined by the type of work performed as well as skill and educational requirements.[2] It is important, however, to differentiate occupations using skill, rather than only education or wages.

3. A new definition

[2] U.S. Bureau of Labor Statistics, Revising the Standard Occupational Classification System, available at http://www.bls.gov/soc/revising_the_standard_occupational_classification_2018.pdf

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To date, I am unaware of any scholarly attempt to define "skilled technical work," as such, though the above concepts are clearly closely related.

Here, to be considered a skilled technical occupation, two criteria must be met:

1. the occupation requires a high level of knowledge in a technical domain
2. and does not require a bachelor's degree for entry

The first criterion distinguishes low-skilled jobs from skilled jobs. It also distinguishes occupations that require non-technical knowledge, in domains such as writing, law, foreign-language, management, and sales, from those requiring technical knowledge. For the purposes of this definition, technical knowledge refers to the domains listed in Table 1. These domains represent 12 of the 33 domains for which O*NET collects data. These domains were chosen because they are at the intersection of science and technology. It is a broader list than what recent research has used to define science, technology, engineering, and math (STEM) knowledge (Rothwell 2013), which was limited only to the core scientific domains, plus engineering and computers. Here, the idea is that technical knowledge is somewhat broader than STEM because the level of mastery covers topics that go beyond core scientific or academic fields to how those fields are applied in a practical way to produce something of value.

With these fields chosen, defining what constitute a "high" level of knowledge is not entirely straightforward. Rothwell (2013) matches O*NET to census microdata and classified occupations as "high" if their knowledge score exceeds 1.5 standard deviations above the mean for all individuals with occupations. The problem with that approach is that the bar for high versus low would change every year, making annual comparisons impossible, unless the new definition is applied retrospectively. Moreover, if the skill orientation of the workforce increases, it would mechanically raise the threshold needed to be considered a skilled worker.

Here, I propose using the O*NET scale as a guide to what should be considered high. A score of four is naturally in the middle on a scale of one to seven. A score above four, therefore, connotes a high score. I use 4.5, which proves to explain the variation in cognitive math skill better than other cutoffs, as explained below.

The second criterion is needed to distinguish skilled technical work from skilled professional work. Jobs requiring both technical knowledge and high levels of education are among the most skilled and highest paid. These occupations have been studied extensively by others (Committee on Prospering in the Global Economy of the 21st Century 2007; Rothwell 2013; National Science Board 2015) and are beyond the scope of this project.

Finally, although not formalized in the above criteria, a definition of skilled technical workers should be empirically practical. In that sense, it should make use of available data whenever possible so that it can be replicated by other scholars and regularly updated as needed by statistical agencies or other parties interested in the data. Using Standard Occupational Classification and O*NET satisfy this more subjective criteria in that both are freely and readily available to researchers.

4. Data sources and methods

The core approach here follows Rothwell (2013) in using O*NET's knowledge requirements survey to measure technical knowledge or skill. O*NET is a data collection project sponsored by the Department of Labor and stands for Occupational Information Network Data Collection Program. It relies on detailed surveys of workers in 942 detailed occupational categories to document their job characteristics, skill, and knowledge requirements. O*NET has been reviewed and evaluated by a variety of scholars but has only rarely been used by social scientists.[3]

For version 19, which is used here, the sample size for O*NET ranges from 20 observation per occupation to 563, with a mean of 84 observations per occupation (or 79,000 individuals). Yet, not all respondents answer every survey, so the knowledge and education surveys have a mean sample size of 29.

The knowledge survey asks workers to rate the level of knowledge needed to perform their job across 33 distinct knowledge domains on a 1-7 scale, with "anchors" providing a description of what level of knowledge is required to meet that number.[4]

Other O*NET surveys could have been used in the definition but were rejected in favor of the knowledge survey. The O*NET skill survey, for example, does not lend itself to any straightforward way of categorizing which skills apply to skilled technical workers and which do not. It presents a field called "technical skill" but this omits science, math, and problem solving skills, which are likely to be important for the occupational groups of interest here. In separate analysis, the skill survey data are used to analyze the extent to which skilled technical workers

[3] National Research Council Panel to Review the Occupational Information Network (O*NET), "A Database for a Changing Economy: Review of the Occupational Information Network (O*NET) (Washington: The National Academies Press, 2010); Norman Peterson and others, "Understanding work using the Occupational Information Network (O*NET): Implications for practice and research," *Personnel Psychology 54* (2) (2001), 451–492.

[4] They are also asked to rate themselves on the importance of knowledge in each field, but a field may be important without requiring a high level of knowledge.

need social skills. The O*NET work context survey will be used below to analyze the extent to which they perform routine tasks.

O*NET also asks workers to report their level of education and training. These data are used for the second criteria. An occupation is deemed to require less than a bachelor's degree if the majority of workers in that occupation possess less than a bachelor's degree. Admittedly, this is a rough indication. The Bureau of Labor Statistics Employment Projections Program (BLS EPP) discusses some of the complications that arise.[5] For one important occupation—Registered Nurses—I partially deviate from the above rule, and categorize the occupation as requiring less than a bachelor's degree, consistent with the BLS EPP.[6]

An alternative method would use the American Community Survey (ACS) data on education. Unfortunately, matching the ACS to O*NET results in significant loss of detail. The 2013 ACS, as categorized by IPUMS, contains only 479 unique occupational categories compared to 942 in O*NET. In practice, the O*NET education measures are very closely related to the ACS measures for the 471 matched occupations. Using the share of workers with a bachelor's degree or higher, the correlation coefficient is 0.93.

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[5] Bureau of Labor Statistics, Employment Projections Program, Measures of Education and Training, available at http://www.bls.gov/emp/ep_education_tech.htm

[6] O*NET provides education and skill data for four additional occupations under the six digit code for "registered nurses." These specialty nursing jobs tend to require higher levels of education, and thus averaging across them suggests that 61 percent of workers in the job have at least a bachelor's, when only 23 percent of workers labeled RNs have a bachelor's. Furthermore, the RN licensing exam does not require one to have a bachelor's degree. In this case, therefore, I follow the BLS EPP and deem registered nursing as a sub-bachelor's level occupation.

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To calculate summary statistics on the size of the labor force, occupations from the O*NET database are matched to the Bureau of Labor Statistics Occupational Employment Survey (BLS OES). The BLS OES survey is the most comprehensive source of U.S. data at the occupational level. It is a three-year rolling survey of approximately 1.2 million establishments (employing 70 percent of the U.S. workforce). Its primary limitations are that it excludes the military and military occupations and does not survey private household workers or most agricultural industries. For cases in which O*NET provided greater occupational detail (8 digits) than BLS OES, characteristics—such as skilled and education—were averaged across O*NET occupations to aggregate them to BLS OES occupations.

Finally, as a way to check the cognitive skill level of workers in skilled technical occupations, data was obtained from ACT's WorkKeys assessments. WorkKeys aims to measure skills of job applicants that are of relevance to employers. Millions of workers have taken its assessments, and ACT provided summary data in the form of mean test scores (on a 1-6 scale) by detailed occupational category of the worker taking the assessment. Data was obtained for three categories of assessment: Applied Math, Locating Information, and Reading for Information. These data were matched to most O*NET occupations. For those for which the most detailed six-digit occupational codes could not be matched, 5-digit test scores (weighted by employment) were imputed to the six-digit category. It turns out that a cutoff of 4.5 on the raw O*NET math knowledge scale explains variation in occupational math scores—conditional on education and experience—better than cutoffs of 3, 4, 5, 5,5, or 6.[7]

[7] To test this, math ACT scores were regressed on the share of workers with each level of education and average years of experience and a dummy variable for high or low skilled, based on raw O*NET knowledge scores on mathematics. The 4.5 cutoff had the highest adjusted R-squared of the cutoffs tested, suggesting that it best explains variation in cognitive ability and is thus a more accurate binary classification.

Table 1. Defining Technical Knowledge using O*NET Knowledge Domains

Knowledge domain
Biology — Knowledge of plant and animal organisms, their tissues, cells, functions, interdependencies, and interactions with each other and the environment.
Building and Construction — Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.
Chemistry — Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.
Computers and Electronics — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.
Design — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.
Economics and Accounting — Knowledge of economic and accounting principles and practices, the financial markets, banking and the analysis and reporting of financial data.
Engineering and Technology — Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.
Food Production — Knowledge of techniques and equipment for planting, growing, and harvesting food products (both plant and animal) for consumption, including storage/handling techniques.
Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.
Mechanical — Knowledge of machines and tools, including their designs, uses, repair, and maintenance.
Medicine and Dentistry — Knowledge of the information and techniques needed to diagnose and treat human injuries, diseases, and deformities. This includes symptoms, treatment alternatives, drug properties and interactions, and preventive health-care measures.
Physics — Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub- atomic structures and processes.
Production and Processing — Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
Telecommunications — Knowledge of transmission, broadcasting, switching, control, and operation of telecommunications systems.

5. Findings

Evaluation of the definition compared to alternatives

Using the above definition, 16.1 million U.S. workers are employed in skilled technical occupations as of 2014. That amounts to 11.9 percent of the total U.S. workforce.[8]

To further understand how this definition plays out and compare it to alternatives, Table 2 presents summary statistics for skilled technical workers on salary, educational attainment, skill level, task orientation, experience, and training.

The first column shows summary data using the definition described above for skilled technical workers. The second definition includes all occupations for which the majority of workers have at least some post-secondary education but less than a bachelor's degree. The third column included all occupations in the middle third of the salary distribution. The second and third definitions, therefore, are commonly used in defining "middle-skilled" workers.

Table 2. Mean characteristics of Skilled Technical Workers Using Various Definitions, Weighted by 2014 Employment

	Skilled Technical Occupations	Middle Education Occupations	Occupations in Middle of Wage Distribution
Share of all U.S. workers (%)	11.9	16.2	23.1
Average Annual Salary	$52,397	$54,107	$47,490
Education, training, and skill requirements			
High school Diploma or less (%)	31.9	18.9	36.5
Bachelor's degree or higher (%)	18.7	18.5	27.0
Years of on-the-job training required (standardized)	0.46	0.01	0.06
Years of experience required (standardized)	0.33	0.20	0.02
Knowledge score (standardized)	0.70	0.40	-0.11
STEM knowledge score (standardized)	0.57	0.20	-0.16
Technical knowledge score (standardized)	0.63	0.04	-0.05

[8] For reference, another 15.3 million meet the first criteria for the definition but not the second. That is, the occupations are in fields requiring high levels of technical knowledge in one or more relevant fields but more than half of the workers in these occupations have a Bachelor's or higher level education.

Average ACT math score (standardized)	0.11	0.29	0.06
Complex problem solving skills	0.12	0.05	-0.07
Work context			
Routine task score (standardized)	-0.13	0.32	0.27
Social engagement score (standardized)	0.24	0.51	0.28
Teamwork score (standardized)	0.15	0.41	0.15

Source: Author analysis of O*NET Version 19, 2014 Bureau of Labor Statistics Occupational Employment Survey, ACT WorkKeys. Knowledge fields calculate average knowledge scores across all 33 O*NET domains. STEM knowledge encompasses the O*NET categories: Biology, Chemistry, Physics, Mathematics, Engineering and Technology, and Computers and Electronics. Technical knowledge includes all the fields in Table 1. Routine task includes automation and repetition scales. Social engagement scores include all interpersonal relationships in the work context scales.

Of the three, the skilled technical occupations definition, which uses O*NET, is the most restrictive and, not surprisingly, the definition using the middle third of income earnings is the most expansive (23.1 percent of all US workers in 2014).

Average salaries are very similar for occupations in in the first two columns and somewhat lower for occupations in the middle of the wage distribution. Yet, educational differences affect these averages, as we will see below. Since the definition for skilled technical workers places an upper bound but no lower bound on education, almost one third of its workers have a high school diploma and only 18 percent have a Bachelor's degree. The middle-wage occupations have a higher rate of bachelor's attainment and a similar rate of high school or lower attainment.

It is widely believed that tacit or informal knowledge—as opposed to that gained through formal education—is important for skilled technical workers (Toner 2012; Howells 2002). As defined here, skilled technical workers do indeed work in occupations that require more experience and training than the average occupation. The difference is statistically significant with respect to on-the-job training but not experience. Likewise, on-the-job-training requirements are significantly higher for skilled technical workers relative to the other two middle-skilled definitions.

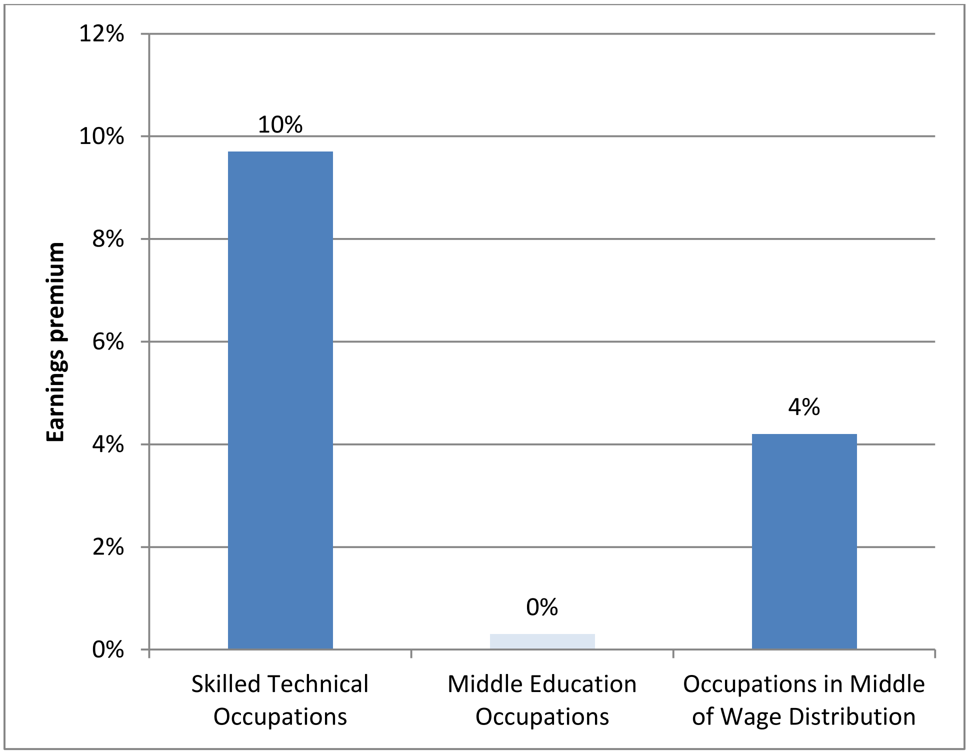
It is notable that the tasks and skill levels of the definitions are quite different. Broadly speaking, the skilled technical occupations perform less routine tasks, report higher general knowledge requirements, grater knowledge in STEM disciplined specifically, and greater knowledge in the fields most relevant for technical work. In fact, aggregate technical knowledge scores are right at the mean for the two middle-skilled definitions, but significantly above the mean for skilled technical workers.

On cognitive skill, however, as measured by the ACT WorkKeys exam, each set of occupations performs slightly above average and the differences are not statistically significant between the definitions.

Overall, there is surprisingly little correlation between the three definitions. Across 820 occupations, an occupation's positive classification as a "skilled technical occupation" exhibits a correlation coefficient with middle-education occupations of .36 and with middle-wage occupations of .29. The latter two have an even lower correlation with each other of just .16.

As a final piece of analysis comparing these definitions, I examine the extent to which working in one of these occupations comes with a wage premium, compared to other occupations that require similar levels of education and experience. To do this, I regress mean earnings at the occupational level on the percentage of workers in the occupation with each level of education and the average years of experience that workers in that occupation have. As Figure 1 shows, the skilled technical occupations predict significantly higher wages than the other two groups. This result holds when all three categories are included in the same regression, in which case only skilled technical occupations predict higher earnings.

Figure 1. Earnings premium for working in skilled technical occupation compared to middle-skilled occupations, conditional on education and experience, using 812 occupational categories



Note: Regression analysis of wages, conditional on education and experience. Dark blue bar indicate that coefficient is significant below five percent p-values.

These results suggest that the use of data on skills (from O*NET) to differentiate skilled technical workers from "middle-skilled" workers yields a set of occupations that can accurately be described as skilled and yet still open to workers who have not graduated from professional four-year degree programs.

Detailed characteristics of skilled technical workers

Skilled technical workers are found in a diverse array of occupations. Indeed, of the 22 major occupational categories, only 5 have zero occupations that meet the criteria. Consistent with previous research (Holzer and Lerman 2005; Holzer 2015), most skilled technical workers are in "blue collar" occupations: installation, maintenance, and repair; construction; production; protective services; and transportation and material moving. Yet, many are in traditionally professional occupational families. The second largest group—representing 3.3 million jobs—is healthcare practitioner and technical occupations and the fifth largest group—representing 0.82 million workers—is computer and mathematical occupations. Architectural and engineering occupations comprise another 0.65 million.

The occupational family with the highest percentage of skilled technical workers is installation, maintenance, and repair, which also has the highest absolute number of such workers. Construction and extraction is next, with just over half of all workers qualifying to be part of the skilled technical workforce. Surprisingly, perhaps, just under one-third of production occupations meet the criteria (29 percent). Most of these jobs simple do not report sufficient skill levels to qualify. Computer and mathematical occupations are almost as likely as production occupations to qualify, with at 22 percent. Three titles—computer user support specialists; computer network architects, and web developers—qualify in this family.

Table 3. Number and percentage of skilled technical workers by major occupational group, 2014

Major occupational group	Skilled technical workers	Skilled Technical Workers as Share of Total Occupation
Installation, Maintenance, and Repair Occupations	4,418,880	84%
Construction and Extraction Occupations	2,825,350	53%
Healthcare Practitioners and Technical Occupations	3,343,020	43%
Production Occupations	2,576,660	29%
Architecture and Engineering Occupations	653,650	27%
Computer and Mathematical Occupations	824,640	22%
Arts, Design, Entertainment, Sports, and Media Occupations	213,330	12%
Protective Service Occupations	308,790	9%
Farming, Fishing, and Forestry Occupations	31,370	7%
Life, Physical, and Social Science Occupations	79,780	7%
Legal Occupations	63,450	6%
Business and Financial Operations Occupations	237,420	3%
Transportation and Material Moving Occupations	231,790	3%
Food Preparation and Serving Related Occupations	118,130	1%
Office and Administrative Support Occupations	137,900	1%
Personal Care and Service Occupations	25,160	1%
Management Occupations	17,930	0%
Sales and Related Occupations	0	0%
Education, Training, and Library Occupations	0	0%
Building and Grounds Cleaning and Maintenance Occupations	0	0%
Healthcare Support Occupations	0	0%
Community and Social Service Occupations	0	0%
Total skilled technical workforce	16,107,249	12%

Author analysis of 2014 Bureau of Labor Statistics Occupational Employment Survey and O*NET Version 19.

Of the occupations that comprise the skilled technical workforce, very few score highly on routine tasks, especially in the largest occupational families (Table 4). This may indicate that they are relatively unlikely to be offshored or supplanted by computers in the short term. Previous research identifies clerical occupations, heavily concentrated in administrative positions, as most likely to be exposed to pressure from automation (Autor 2012), but just one percent of office and administrative support occupations qualify as skilled technical workers. As it happens, skilled technical occupations in professional settings are the most likely to report performing repetitive and automated tasks, especially in legal, science, business, and computer occupations. It is unclear if this reflects vulnerability to automation or an opportunity to benefit, since these occupations frequently use computers.

As noted above, the average skilled technical occupation neither requires particularly high or low levels of social interaction broadly, or specifically as measured by a teamwork scale, but given the diversity of occupational titles, broad averages can be misleading. The average teamwork index is .93 standard deviations above the mean for skilled technical workers in healthcare practitioner and technical occupations. The index is also high in protective service occupations, food preparation and serving related occupations (chef is the only title that qualifies), personal care and service occupations, and management occupations. However, for the blue collar trades, teamwork is right around or even below the mean.

Likewise, skilled technical occupations do not stand out as being highly skilled in complex problem solving, as defined by O*NET. Healthcare occupations have the highest scores—at .53 standard deviations above the mean.

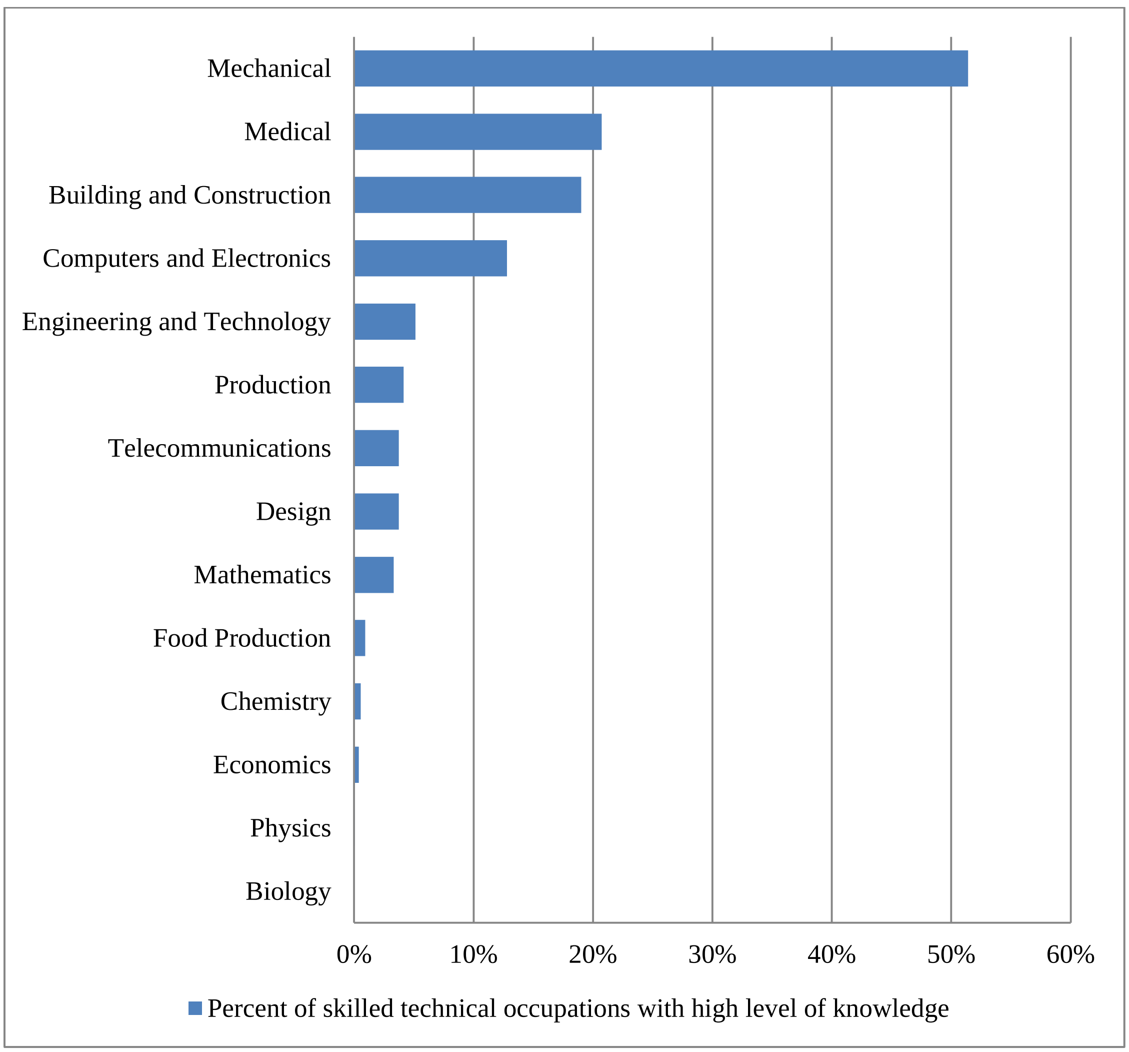
Table 4. Orientation Towards Routine Tasks, Complex Problem Solving, and Teamwork for Skilled Technical Workers, by Major Occupational Title

	Routine	Complex	Teamwork
Installation, Maintenance, and Repair Occupations	-0.75	0.14	-0.22
Healthcare Practitioners and Technical Occupations	0.12	0.53	0.93
Construction and Extraction Occupations	-0.97	-0.21	0.30
Production Occupations	0.37	-0.15	-0.48
Computer and Mathematical Occupations	1.42	0.36	0.21
Architecture and Engineering Occupations	1.13	0.45	0.44
Protective Service Occupations	-1.53	0.21	0.75
Business and Financial Operations Occupations	2.14	0.22	-0.40
Transportation and Material Moving Occupations	0.71	-0.27	-0.02
Arts, Design, Entertainment, Sports, and Media Occupations	-0.24	0.00	-0.53
Office and Administrative Support Occupations	1.39	-0.13	0.45
Food Preparation and Serving Related Occupations	-0.77	-0.08	1.12
Life, Physical, and Social Science Occupations	2.49	0.05	0.33
Legal Occupations	2.93	-1.28	-1.58
Farming, Fishing, and Forestry Occupations	-0.48	-1.08	-1.33
Personal Care and Service Occupations	1.00	0.32	0.87
Management Occupations	0.87	-0.28	0.94

Source: Author analysis of data from O*NET. Routine task index combines standardized scores for work context sub-scores for automation and repetition. Teamwork is a sub-score under work context, and complex problem solving is a skill. Analysis is only for skilled technical workers in each occupation. Occupation titles are sorted by number of skilled technical workers in each group.

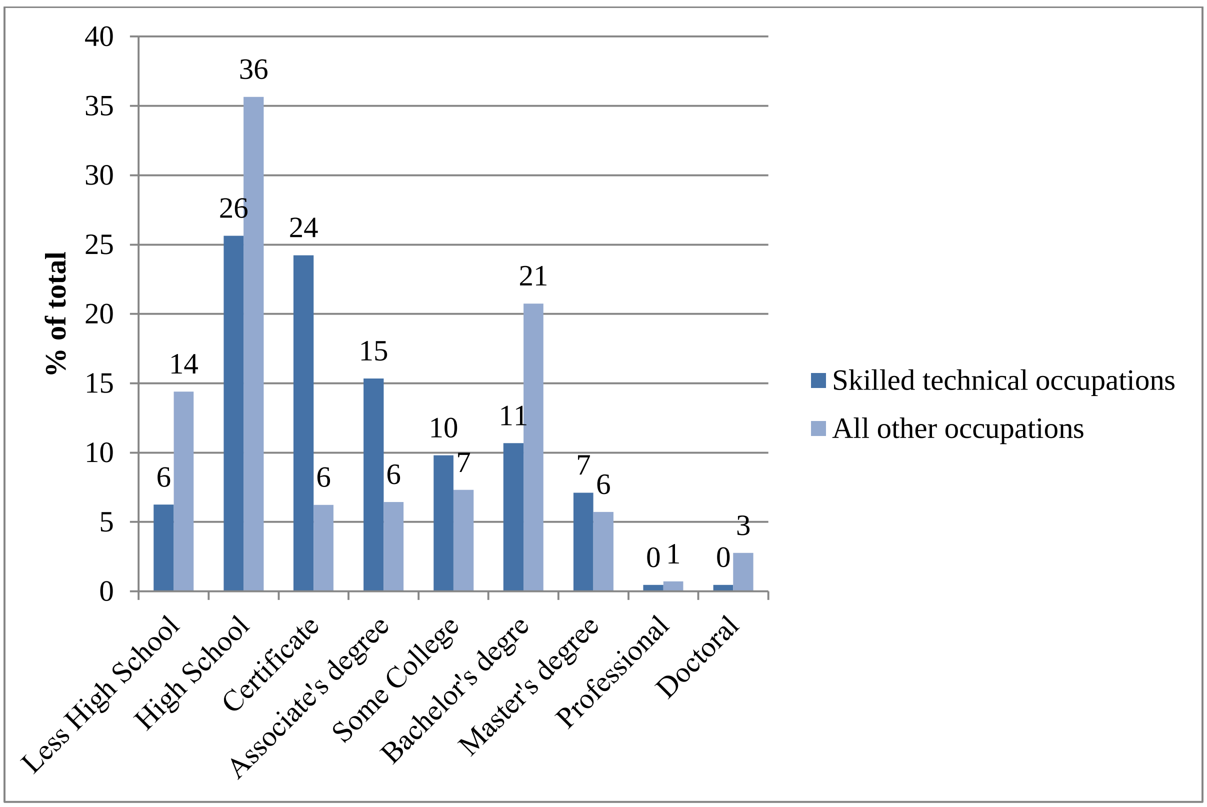
Consistent with their distribution across occupations, a high percentage of skilled technical workers report mechanical expertise (52 percent). A smaller but still large percentage qualify as skilled through medical expertise (21 percent) or knowledge of building and construction (19 percent) or computers and electronics (13 percent). High knowledge scores in other fields are fairly infrequent for skilled technical workers, perhaps because it is difficult to obtain such knowledge without a bachelor's degree.

Figure 2. Percentage of Skilled Technical Workers with High Level of Knowledge by Domain



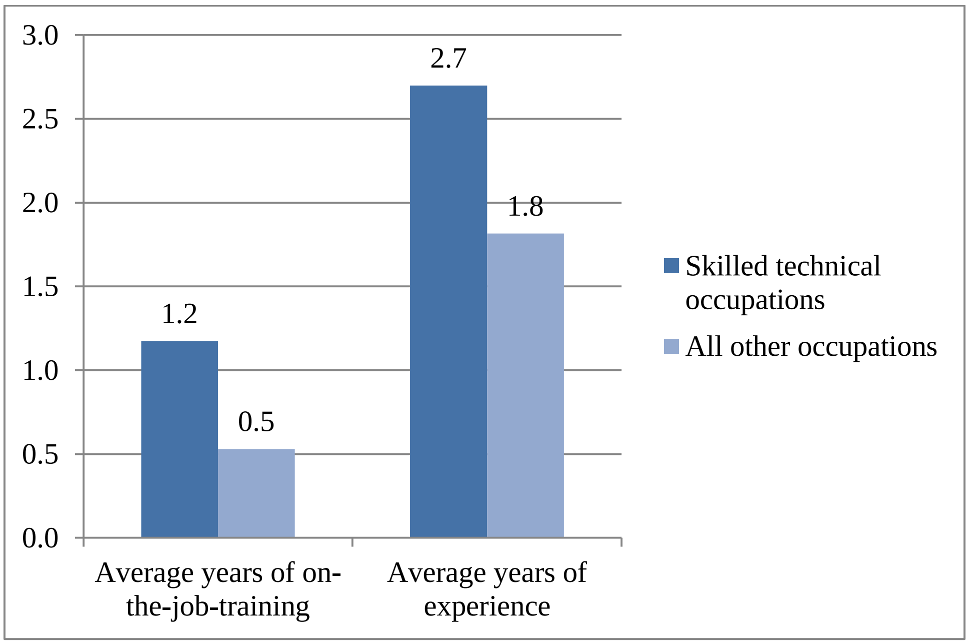
Skilled technical occupations employ disproportionately employ workers with sub-bachelor's level higher educational credentials. Almost one quarter of skilled technical occupations report a post-secondary certificate as their highest level of education, compared to only 6 percent of all other workers. This makes a certificate the most common level of education for skilled technical workers besides a high school diploma. Another 15 percent of skilled technical workers have earned an Associate's degree, compared to 6 percent of all other workers. Relative to the rest of the US workforce, skilled technical workers are much more likely to have a post-secondary education beyond a high school diploma but less likely to have earned a bachelor's or higher degree.

Figure 3. Educational Attainment of Workers in Skilled Technical Occupations Compared to All Other Workers, 2014 (numbers represent % of total)



While bachelor's level education is lower for skilled technical workers, on-the-job training is significantly higher. Skilled technical workers report receiving eight months longer on-the-job-training compared to the average worker in other occupations (weighted by employment). Moreover, skilled technical workers tend to have an extra year of experience. Both differences are statistically significant. Taken together, they provide further that skill levels are relatively high for skilled technical workers, even if acquired through less formalized channels, such as on-the-job training and learning.

Figure 4. On-the-job Training and Experience of Workers in Skilled Technical Occupations Compared to All Other Workers, 2014 (number represent % of total)



6. Policy implications

This task of this chapter was primarily to provide a clear and practical definition of the skilled technical workforce. The expectation is that doing so will facilitate research into other areas—such as supply-demand mismatch—explored elsewhere in this collection. Those deeper analyses are necessarily to inform and formulate appropriate policy responses or inspire civic action.

Still, with this definition and the context of previous literature on the topic, there are a few broad preliminary recommendations that can be offered here.

First, skills play a hugely important role in the labor market. There are large private and public returns to investment in skills, in the form of higher earnings (and related benefits) on the private side, and increased innovation, entrepreneurship, net tax revenue, investment, and consumption on the public side.

Yet, skills and advanced college education are not precisely the same, even if they are highly correlated. During the industrial revolution, throughout recent decades, and for the foreseeable future, a skilled workforce requires a mix of training, education, and experience that includes large numbers of people—typically without bachelor’s degrees—who are able and willing to work in occupations that do not require a bachelor’s degree but do require high levels of skill.

This chapter has defined one segment of this group—skilled technical workers, which may deserve special attention because of the potentially large public benefits their skills bring through their contributions to innovation. For example, these workers are employed at high rates by advanced industries (Muro et al 2015). Thus, as others have noted, fostering and sustaining an economic system that provides workers with these skills is of great strategic importance to the vitality of the United States and other developed economies (Muro et al 2015; Holzer 2015; Carnvale and Smith; Toner 2010).

Implications for government policy

Given the salary premium associated with technical skills, literacy in math and other STEM fields should be fostered as early as possible. Broad literacy in language and math at very early ages predict later success in mastering complex subject matter and expanding earnings later in life (The White House 2014; Chetty et al 2011). Along these lines, a large and growing literature finds that various school reform policies—such as access to high-quality charter schools, vouchers for low-income children, and rigorous teacher accountability and pay policies—raise the quality of publicly funded education, leading to higher test scores, education levels, and future earnings (Angrist, Pathak, and Walters 2013; Peterson, Howell, Wolf, and Campbell 2003; Chingos and Peterson 2012; Sartain and Steinberg 2015; Deming 2014; Chetty, Friedman, and Rockoff 2014a; Chetty, Friedman, and Rockoff 2014b).

School districts and states can also adopt curriculum-based policies that increase learning opportunities in technical fields. For example, the Virginia Beach school district partners with a local community college to allow any high school student in the district to take rigorous STEM or technical courses that directly lead to industry-designed certificates (Virginia Beach Department of Teaching and Learning and Office of Technical and Career Education 2014). Other approaches create STEM or technically focused charter or magnet schools, such as those in New York and Chicago.[9] An advantage of the former approach is that it has the potential to expose any interested student in a skilled-technical curriculum without having them have to commit up front to a school focused only on those subjects.

Meanwhile, state governments can ramp up funding for in-demand career and technical education at community colleges and universities. For example, Florida rewards public colleges for graduating more students in high-demand majors.[10] Governors of Pennsylvania and North Carolina are looking to increase funding for STEM education at regional community colleges.[11]

Likewise, as argued in Holzer (2015), states should use their funding power to provide clear incentives and encouragement to better align funding with high quality college education. One important and readily measurable aspect of quality relates to the earnings of attendees. Research by Rothwell (2015) finds that even fairly crude measures of alumni economic outcomes—such as what can be cobbled together from social media websites and federal loan default data—can be used to construct value-added metrics, which perform better than popular college rankings and can inform the public about community colleges and

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[9] Chelsia Rose Marcius and Ben Chapman, "Kids in tough Brooklyn neighborhoods getting world-class STEM education," *New York Daily News* October 7, 2014. and City of Chicago, "Mayor Emanuel Announces City-Wide Strategy to Increase Access to a High-Quality, Cradle-to-Career Stem Education Pipeline for Students," March 27, 2014.

[10] State University System of Florida, Board of Governors, "Performance Based Funding Model" (June 2014), available at http://www.flbog.edu/about/budget/performance_funding.php.

[11] State of North Carolina, Governor Pat McCrory Proposes Higher Investment for High-Demand Occupations," press release, April 10, 2014, available at http://www.governor.state.nc.us/newsroom/press-releases/20140410/governor-pat-mccrory-proposes-higher-investment-high-demand; Pennsylvania Higher Education Assistance Agency, Pennsylvania Targeted Industry Program (June 2014), available at http://www.pheaa.org/funding-opportunities/pa-tip/.

non-selective four-year schools. States should use tax and high school administrative records to construct comprehensive measures of earnings, test scores, and family income to measure and report the value-added by colleges for each broad field of study.

Finally, as argued by McCarthy (2014) the accreditation process in higher education is flawed as it relates to career and technical education. Presently, institutions rather than fields of study receive accreditation—by one of a variety of bodies. As a result, students may enter a program that does not prepare them for the industry certification exam needed to work in their field but all students at the school are nonetheless eligible for federal Pell aid. At the same time, Pell or other federal aid might be denied to other valuable training programs that are not offered by accredited colleges as part of a degree program. The accreditation would better serve students by being more closely tied to specific programs of study.

Implications for employers

Moving away from an education or wage based measure of skilled technical workers—to one that actually prioritizes skills—has a number of implications for business.

First, businesses should relax requirements for formal educational credentials, when practical, in favor of demonstrated skill. For computer occupations, many start-ups and small businesses are already de-emphasizes formal educational requirements in favor of demonstrated mastery of certain programming languages or technical skills.[12] On the other hand, larger companies have more rigid standards, which may lead them to overlook the many talented programmers who have learned their trade through less formal channels.[13] The increasing prevalence of low-cost on-line learning platforms (eg Udacity, Coursera, Tree House, Kahn Academy) for technical skills will make it all the more likely that people without formal degrees will acquire advanced

[12] Matt Weisfeld, “What Skills Employers Want in a Software Developer: My Conversations with Companies Who Hire Programmers” InformIT, November 12, 2013, http://www.informit.com/articles/article.aspx?p=2156240
[13] Ibid.

programming or other technical skills. Large advanced companies, in particular, should adapt to this reality and implement more flexible skill-specific hiring standards.

Meanwhile, larger and more established companies will need to develop strategies to foster the retention and skill development of incumbent staff. While no firm can afford to invest in the education of workers who take their new skills to a rival, smart management practices can mitigate this risk by offering cost-sharing contracts that are contingent on duration at the company. Moreover, the prevalence of low-cost on-line training resources, means that the risks of company-funded are much smaller than they would be for sponsoring enrollment in a brick-and-mortar degree program.

Over an even longer period, good corporate citizenship can coincide with firm interests with respect to the supply of skilled workers. Hence, firms should invest in education philanthropy or otherwise engage with their local educational institutions to develop the next-generation of skilled workers. To give just a few examples of how this might work, IBM partnered with the New York City school system to create P-Tech, an IT-oriented career and technical high school. A consortium of bio-tech companies called Biowork has fostered successful partnerships with some of North Carolina's community colleges, leading to high placement rates for graduates.[14] In Manchester, New Hampshire, Dyn and Silvertech have invested in a local high school to create STEAM-Ahead, which encourages high school students to obtain one year's worth of college credit in STEM-oriented courses.[15] This applies to sub-bachelor's level workers as well as STEM professionals. For example, in the Minneapolis-St. Paul area, firms in the biomedical

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[14] Nichola Lowe, Harvey Goldstein and Mary Donegan, "Patchwork Intermediation: Challenges and Opportunities for Regionally Coordinated Workforce Development," *Economic Development Quarterly 25 (2011): 158-171*
[15] Rachel Feintzeig, "Recruiting Tech Talent in High School," *The Wall Street Journal*, October 1, 2013

sector work closely with a local community college to crate specialized programs for medical technicians.[16]

7. Conclusion

The skilled technical workforce performs a number of functions that are critical to innovation, healthcare, infrastructure and economic growth. It is therefore important for policy makers to understand the tasks, skills, and training required of these occupations, and consider whether public resources are adequately meeting industry and social demand for these workers. Other chapters in this collection will explore those issues in more depth. The goal of this chapter is to help frame how these workers should be defined and analyzed, with an emphasis on the skills that distinguish them from those in less advanced occupations.

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