Designating the Skilled Technical Workforce Using O*NET-SOC (2019)

Vicki Lancaster, Ph.D.
Principal Scientist
val7zv@virginia.edu

Sarah McDonald, B.S.
Research Assistant

Cesar Montalvo, Ph.D.
Postdoctoral Research Associate
cpm9w@virginia.edu

Leonel Siwe, Ph.D.
Postdoctoral Research Associate
yhu2bk@virginia.edu

University of Virginia
Biocomplexity Institute and Initiative
Social and Decision Analytics Division

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UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

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ABSTRACT

In 2015, Rothwell defined the Skilled Technical Workforce (STW) and operationalized it using the Content Model survey data from the Department of Labor's Occupational Information Network (O*NET). This paper uses Rothwell's metrics and criteria to assign STW designations using the O*NET 25.1 Content Model data which aligns with the most current Bureau of Labor Statistics Standard Occupation Classification (SOC) codes. In the first part of our paper, we provide a discussion of the issues inherent in Rothwell's metrics when used to classify the current occupation titles and offer suggestions on how to address these issues. In the second, we discuss the changes in the STW designations between O*NET-SOC 2010 and O*NET-SOC 2019 using the crosswalk provided by O*NET and discuss the obstacles the current STW definition poses to constructing metrics and pathways. We conclude by providing next steps.

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INTRODUCTION

Skilled technical work is defined as an occupation that does not require a bachelor's degree for entry while requiring a high level of knowledge in at least one of the 14 knowledge domains listed in Table 1 (Rothwell, 2015). The definition was operationalized by Rothwell, who proposed metrics and criteria for inclusion into the STW using education and knowledge data from the Occupational Information Network (O*NET) Content Model, which is collected under the sponsorship of the Department of Labor's (DOL) Employment and Training Administration. The first three paragraphs provide an overview of the U.S. occupation classification system as it relates to the designation of STW occupations.

Table 1. Fourteen Knowledge Domains of the Skilled Technical Workforce

Biology	Economics and Accounting	Medicine and Dentistry
Building and Construction	Engineering and Technology	Physics
Chemistry	Food Production	Production and Processing
Computers and Electronics	Mathematics	Telecommunications
Design	Mechanical	

The criteria for a STW designation are derived using data from the O*NET Content Model. O*NET is a program sponsored by the DOL that establishes and maintains a framework for organizing occupational data aligned with the Bureau of Labor Statistics (BLS) Standard Occupation Classification (SOC) system. The SOC system is the federal standard for classifying workers into occupations based on work performed and is supplemented with data from the O*NET Content Model for most occupations, referred to as data-level occupations. The Content Model database supplies information on the characteristics of occupations and their requirements categorized into six domains: worker requirements; worker characteristics; experience requirements; occupational requirements; workforce characteristics; and occupation-specific information. The data are collected from job incumbents, occupational experts, and occupational analysts; the data are reported as work or percentages along with the sample size, standard errors, and upper and lower confidence bounds. The STW criteria are based on the Content Model worker characteristic variables, education, and knowledge.

Since O*NET is a SOC-based classification system it is often referred to as O*NET-SOC with the year the transition to the latest SOC release was completed; for example this report uses O*NET-SOC 2019 occupations which are based on the transition to the 2018 SOC standard as O*NET-SOC transition was completed in 2019. Each occupation in SOC is designated with a six-digit code; for example, computer support specialist is a STW occupation with SOC code 15-1132. In contrast O*NET-SOC codes are 8-digit codes; for example, robotics technicians is a STW occupation with O*NET-SOC code 17-3024.01. All SOC occupations are included in the O*NET-SOC classification system which breaks out SOC occupations in more detail. New and emerging occupations are created by adding two additional digits to an existing related SOC code; for example, robotics technicians (17-3024.01) was added under electro-mechanical and mechatronics technologists and technicians (17-3024). These O*NET-SOC occupations are included in the next release of SOC if they meet the collectability principle, which means that the BLS or the Census Bureau must be able to collect and report data on that occupation (National Research Council, 2010). Currently BLS data such as Occupational Employment and Wage Statistics, Employment Projections, and Job Openings and Labor Turnover are not collected on the 8-digit O*NET-SOC occupations.

The metrics and criteria for a STW designation are based on the Content Model variables knowledge and education as described in (Rothwell 2015). The survey items for the 14 knowledge domains pose the question "What level of

knowledge is needed to perform your current job?"; the response ranges from zero (the lowest level) to seven (the highest level). The knowledge criterion is met if the occupation scores at least 4.5 in any of the 14 knowledge domains (Table 1). The education criterion of less than a bachelor's degree for entry is met if the majority of workers in an occupation possess less than a bachelor's degree (e.g., no formal educational credential, high school diploma or equivalent, post-secondary nondegree credential, some college but no degree, associate's degree) as determined by the O*NET education survey data. Occupations with Content Model data are referred to as data-level occupations.

Of the 1,016 O*NET-SOC 2019 occupation titles, 923 (91%) are data-level occupations. These include:

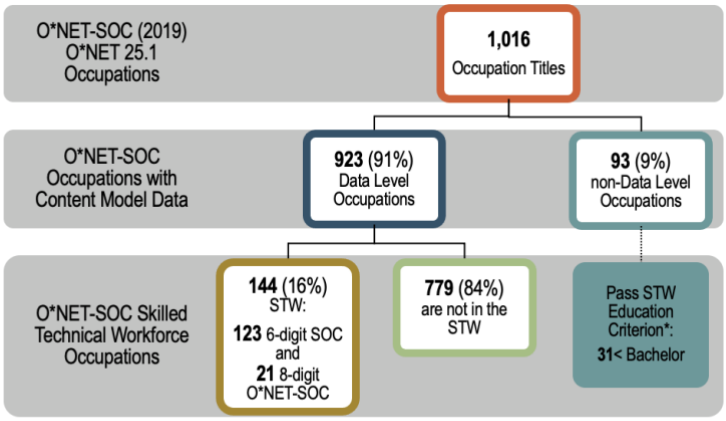
- 722 SOC level occupations with no detailed O*NET-SOC occupations nested under them and
- 52 SOC level occupations with 149 detailed O*NET-SOC occupations nested under them.

A detailed O*NET-SOC occupation is nested under the six-digit SOC code from which it originates and is identified with a two-digit extension. The 93 non-data level occupations include:

- 19 that are military-specific;
- 24 that have the SOC code for "All-Others" (the sixth digit is a 9) with the two-digit extension of a detailed O*NET-SOC occupation ("All Other" titles represents a collection of occupations that span a multitude of roles with characteristics that do not fit a single description and are excluded from the data framework); and
- 50 that have the SOC code for "All-Others" (the six-digit is a 9) without the two-digit extension of a detailed O*NET-SOC occupation.

Using the O*NET 25.1 database of 923 data-level occupations, 144 (16%) meet both the knowledge and education criteria for a STW designation and 779 (86%) do not (Figure 1). Of these 144, 123 (85%) are SOC occupations and 21 (15%) are O*NET-SOC occupations.

Figure 1. O*NET-SOC 2019 (O*NET 25.1) Occupations by Skilled Technical Workforce Designation



*Entry level education requirements are from the 2019 Bureau of Labor Statistics' Employment Projection Project.

In Part I, we explore the issues inherent in Rothwell's classification metrics. We do this by evaluating the fitness-for-use of the education and knowledge Content Model data. For knowledge we evaluate missingness, age of the survey data, survey sample sizes, and the appropriateness of the survey questions. For education we again evaluate

missingness, age of the survey data, and survey sample sizes, but we also evaluate three education data sources that can be used in lieu of the Content Model education data.
In Part II, we explore the lack of a one-to-one correspondence between SOC and O*NET-SOC occupations. O*NET classifies occupations in more detail than SOC for 149 occupations in O*NET 25.1. This poses a problem when the only occupation information available is at the SOC level and a combination of STW and nonSTW occupations are nested under it -- is the SOC in question in the STW or not?

In Part III, we assess changes in STW designations with the release of a new SOC system. We compare the STW designations using the 2010 and 2018 SOC systems and explore the changes when the STW criteria are changed from a point estimate to an interval estimate by incorporating the standard errors available in the Content Model.

PART I: CONTENT MODEL DATA FITNESS-FOR-USE

MISSINGNESS

A breakdown of the availability of Content Model education and knowledge data for the 1,016 occupations is provided in Figure 2. There are 923 occupations (93%) out of the 997 (the 19 military SOCs are not included) that have some content model data; of the 923; 821 (82%) out of the 997 have content model data for both education and knowledge and can be classified. This leaves 176 non-military occupations that cannot be qualified due to missing Content Model data. There are 18 occupations that meet the knowledge criterion for STW that are missing education estimates whereas there are no STW occupations that meet the education criterion but are missing knowledge estimates. We evaluate classifying these 18 occupations using three alternative education sources. A list of these occupation titles and codes are displayed in Table 2 along with the education metric (less than a bachelor's degree for entry) from the three alternative data sources.

Figure 2. Availability of O*NET 25.1 Content Model Data for Education and Knowledge Broken Down by STW Designation, SOC, and O*NET-SOC Codes

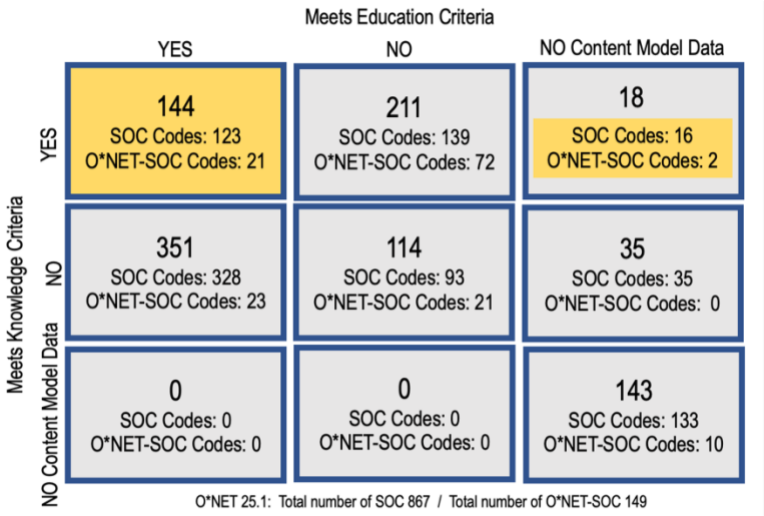


Table 2. 16 SOC and 2 O*NET-SOC Occupations Meeting the STW Knowledge Criterion and are Missing Content Model Education Estimates

Occupation Title	Code	O*NET Job Zone #	BLS Employment Projections	BGT % of Job Ads without Bachelor's Degree Requirements
Farmers, Ranchers, & Other Agricultural Managers	11-9013.00	4	High school diploma or equivalent	75.809
Accountants and Auditors	13-2011.00	4	Bachelor's degree	25.535
Geographic Information Systems Technologists & Technicians	15-1299.02	4	NULL	54.206
Health & Safety Engineers, Except Mining Safety Engineers & Inspectors	17-2111.00	4	Bachelor's degree	25.418
Marine Engineers & Naval Architects	17-2121.00	4	Bachelor's degree	37.791
Architectural & Civil Drafters	**17-3011.00**	3	Associate's degree	80.859
Electrical & Electronics Drafters	**17-3012.00**	3	Associate's degree	64.332
Electrical & Electronic Engineering Technologists & Technicians	**17-3023.00**	3	Associate's degree	92.188
Nanotechnology Engineering Technologists & Technicians	17-3026.01	4	NULL	92.344
Surveying & Mapping Technicians	**17-3031.00**	3	High school diploma or equivalent	82.151
Geological Technicians, Except Hydrologic Technicians	19-4043.00	4	NULL	NULL
Nuclear Technicians	**19-4051.00**	3	Associate's degree	61.458
Librarians & Media Collections Specialists	25-4022.00	5	Bachelor's degree	34.336
Firefighters	33-2011.00	3	Associate's degree	97.410
Carpenters	47-2031.00	2	High school diploma or equivalent	99.962
Plumbers, Pipefitters, & Steamfitters	47-2152.00	3	High school diploma or equivalent	99.973
Automotive Service Technicians & Mechanics	49-3023.00	3	Postsecondary nondegree award	99.914
Heating, Air Conditioning, & Refrigeration Mechanics & Installers	49-9021.00	3	Postsecondary nondegree award	99.784

Orange titles and codes would be classified as STW occupations; bolded orange titles and codes are also STEM occupations.
O*NET Job Zones 1-3 do not require a bachelor's degree.
SOC BLS Employment Projections typical entry-level requirement education.

ALTERNATIVE SOURCES FOR EDUCATION DATA

We evaluated three data sources as proxies for entry level education data: O*NET Job Zone, BLS Employment Projections (2019), and Burning Glass Technology (BGT) job-ads. The Job Zone classification is a guide to the vocational preparation levels of O*NET-SOC occupations; these are grouped into one of five categories based on the level of education, experience, and the on-the-job training an individual would need to do the work. The first three categories meet the STW criterion of less than a bachelor's degree, from Job Zone 1 which requires a high school diploma or GED certificate to Job Zone 3 which requires vocational school training, related on-the-job experience, or an associate's degree. Trained analysts review five sources of information to assign a Job Zone:

main duties and tasks; education, training, and experience levels; the occupation's previously assigned Job Zone; the Job Zones of other O*NET-SOCs; and the BLS Employment Projections. The eight-step procedure by which analysts assign each occupation to a Job Zone is described in *Procedures for O*NET Job Zone Assignment* (March, 2008). The drawbacks to using the Job Zone as a proxy for education levels needed for entry are: they are a composite of information on education, experience, and on-the-job-training, the estimates are based on expert judgement rather than a survey, and Job Zone data is not available for all occupations titles (86% of the 1,016 titles). The upside is that it looks at experiences which can be used by employers in lieu of a nondegree credential.
We also evaluated the BLS 2019 Employment Projections (EP) data separately from its use in the Job Zone composite. BLS economists[1] assign occupations to education categories based on analyses of qualitative and quantitative information. Sources of quantitative data include: educational attainment data from the American Community Survey; data on education, work experience, and on-the-job training requirements from O*NET; and data on postsecondary program completions from the National Center for Education Statistics. In addition, these economists evaluate qualitative information obtained from educators, employers, workers in the occupation, training experts, and representatives of professional and trade associations and unions. There are eight categories of education levels needed for entry. Categories with less than a bachelor's requirement include: no formal education credential; high school diploma or equivalent; some college no degree; postsecondary nondegree award; and associate's degree. The drawback with using the EP education levels needed for entry is that the data are only available at the SOC level. The upside is that the EP education levels are updated yearly.

The third data source we evaluated as a proxy for education requirements was the Burning Glass Technology (BGT) 2019 job-ads. BGT is a labor-market insights company that provides job-ad data, which includes the minimum education requirement. The BGT job-ad 2019 data uses the O*NET-SOC 2010 codes we are interested in the O*NET-SOC 2019 codes, we used the O*NET Resource Center crosswalk from 2010 to 2019. The crosswalk shows that most of the O*NET-SOC codes of interest were previously divided into multiple codes in O*NET-SOC 2010. For example, in the O*NET-SOC 2010, there are three designations for Accountants and Auditors (13-2011.00): Accountants and Auditors (13-2011.00); Accountants (13-2011.01); and Auditors (13-2011.02). In the O*NET-SOC 2019 release, these codes are condensed into one, Accountants and Auditors (13-2011.00). We found that all the codes of interest were previously multiple codes in O*NET-SOC 2010 that have been condensed to a single code in O*NET-SOC 2019, except for Geological and Petroleum Technicians (19-4041.00), which maps to both Geological Technicians, Except Hydrologic Technicians (19-4043.00) and Hydrologic Technicians (19-4044.00) in the 2019. After mapping O*NET-SOC 2010 codes to the O*NET-SOC 2019 codes, we calculated the percentage of job-ads requiring less than a bachelor's degree for each occupation. The drawback with using the BGT data are that they are not publicly available and the job-ads were classified using the O*NET-SOC 2010. The upside is that the 2019 data contain 33,452,673 job-ads and the minimum education requirement was complete for 99.94% of the ads and the data are updated daily. An alternative to paying for labor market information (LMI) job-ad data is scheduled to be released later this year from the National Labor Exchange Research Hub[2]. The intent of the NLx Research Hub is to make real-time labor market information a public utility for research, product development, and analytics tools.

Table 2 displays the two O*NET-SOC and 16 SOC occupations that meet the knowledge criterion but do not have Content Model education estimates. Table 2 includes the Job Zone and BGT job-ad data for all occupations and the

[1] U.S. Bureau of Labor Statistics. Employment Projections, Measures of Education and Training. (September 1, 2020). https://www.bls.gov/emp/documentation/education/tech.htm.
[2] NLx Forms Data Trust to Increase Access to Real-Time Labor Market Information. (June 29, 2020). https://directemployers.org/2020/06/29/nlx-forms-data-trust-to-increase-access-to-real-time-labor-market-information/.

EP education levels needed for entry for 16 SOC occupations. The Job Zone and EP are in agreement for all occupations except Farmers, Ranchers, & Other Agricultural Managers; in this case the BGT job-ad data agrees with the BLS employment projection that a Bachelor's degree is not required. It is not surprising these estimates agree since they are based on more current data than the Job Zone estimate. For those occupations where all three data sources were available, the Job Zone, EP, and BGT data are in agreement in classifying the ten occupations as STW; these occupations are: Architectural & Civil Drafters; Electrical & Electronics Drafters; Electrical & Electronic Engineering Technologists & Technicians; Surveying & Mapping Technicians; Nuclear Technicians; Carpenters; Firefighters; Plumbers, Pipefitters, & Steamfitters; Automotive Service Technicians & Mechanics; and Heating, Air Conditioning, & Refrigeration Mechanics & Installers (bolded in orange in Table 2). They are also in agreement on the four occupations that are not in the STW. For the remaining three occupations that do not have EP estimates, the Job Zone and BGT are in agreement for two of the occupations and for the third (Geological Technicians, Except Hydrologic Technicians (19-4043.00) there were no BGT job-ads since BGT job-ads were coded using the 2010 SOC classification system and this occupation was introduced in the 2018 SOC.

Table 3 provides the coverage for each of the four education data sources for the 997 non-military occupations, 848 SOC occupations and 149 O*NET-SOC occupations. The BLS EP has the worst coverage overall, 88% for SOC and 0% for O*NET-SOC occupations. O*NET Job Zone has the best coverage for O*NET-SOC occupations, 100%, the next highest is BGT job-ads with 93%. The reverse is true for SOC occupations, BGT has the best coverage with 94% and O*NET Job Zone the second best with 91%; the O*NET Content Model Education has the worst coverage with 81%.

Table 3. Coverage of Education Data Sources for the 997 non-Military Occupations (O*NET 25.1)

Data Source	Education Variable	848 SOC 6-digit	149 O*NET-SOC 8-digit
O*NET Content Model Education	Level of education needed to perform the job	(683/848)*100 = 81%	(137/149)*100 = 92%
O*NET Job Zone	Composite: Education, Experience, & On-the-Job-Training	(774/848)*100 = 91%	(149/149)*100 = 100%
Bureau of Labor Statistics Employment Projections	Entry Level Education	(748/848)*100 = 88%	(0/149)*100 = 0%
Burning Glass Technology Job-ads	Minimum Education Required by Employer	(794/848)*100 = 94%	(139/149)*100 = 93%

SAMPLE SIZE AND AGE OF THE EDUCATION AND KNOWLEDGE ESTIMATES

The concept of STW is a function of the nature of work and the demands of employers which are rapidly changing due to emerging technologies which in turn places demands for new education and training programs which are all driven by the skills that employers value and need. Any metric used to assign a STW designation must take this into account. Below are two figures, Figure 3 displays the sample sizes over time for the education surveys; the orange filled circles identify STW occupations and the white, nonSTW occupations; descriptive statistics are included within the figure. Figure 4 displays the same meta data for the knowledge surveys.

Figure 3. Content Model Education Survey Meta Data: Year Collected by Sample Size

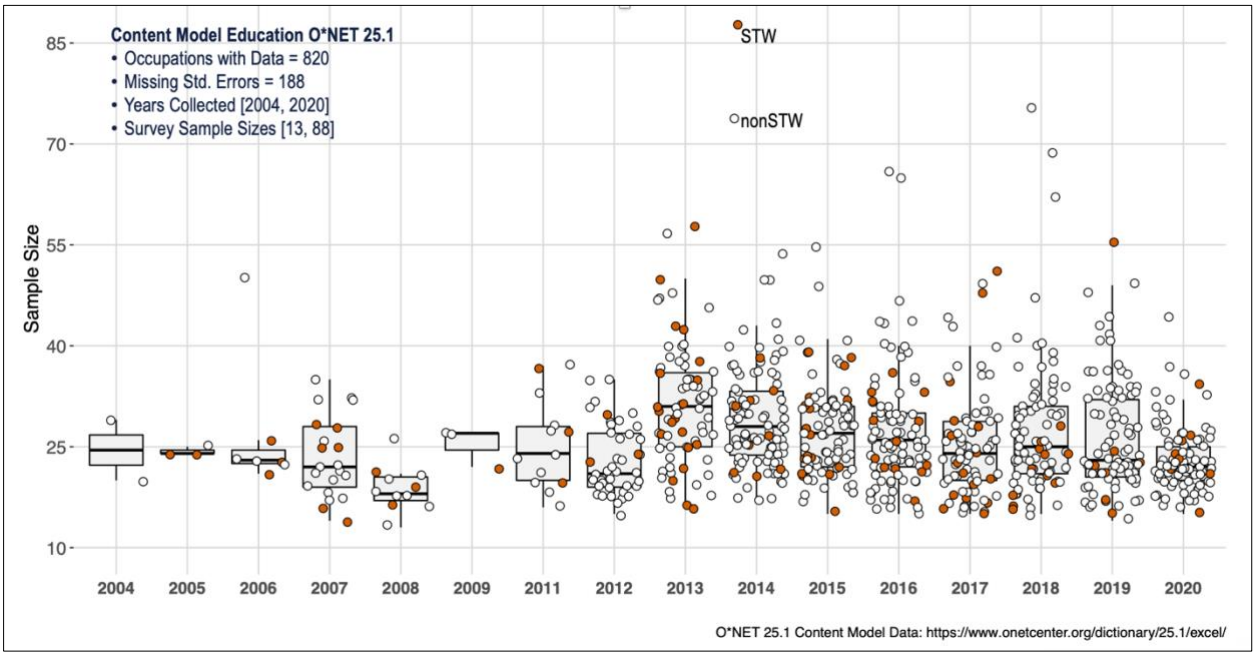
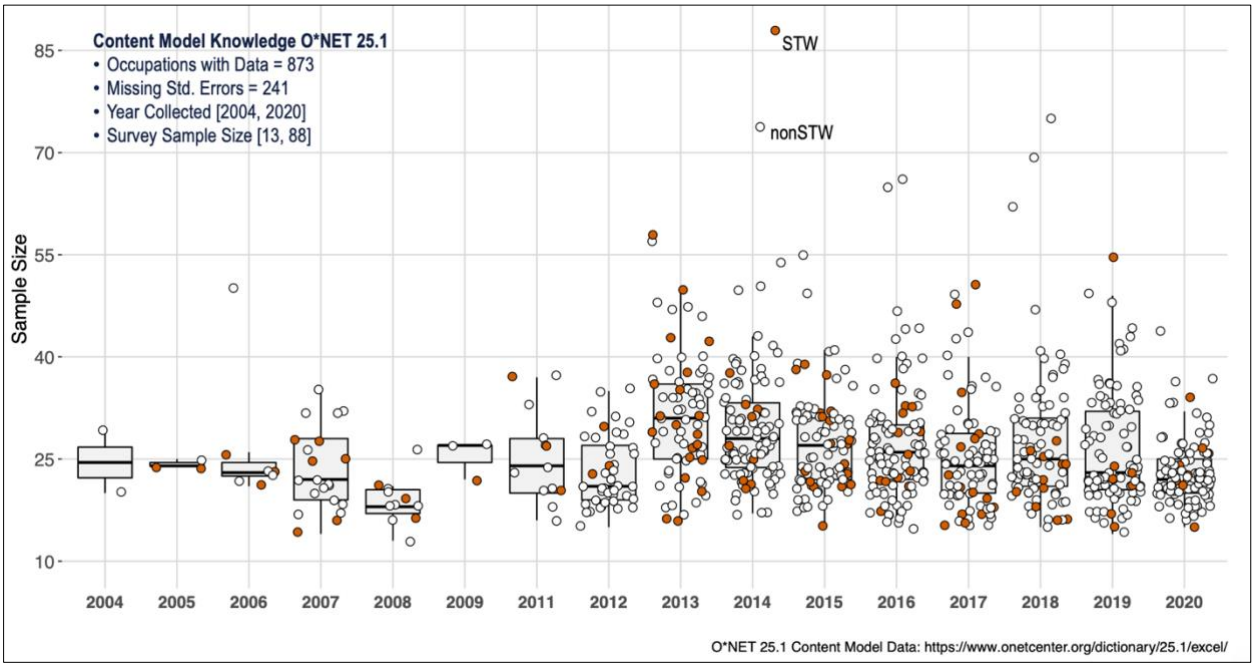


Figure 4. Content Model Knowledge Survey Meta Data: Year Collected by Sample Size



The take-away from these figures is that some of the survey data were collected well over a decade ago and the median sample size is approximately 25. Both of these issues are troubling, the collection date since these occupations are changing rapidly with regard to education and knowledge and the small sample sizes since this could be an indication of large sampling errors which have not been factored in to the calculation of the metrics. This could be because for many of the occupations the standard errors are missing, 23% of the education estimates and 28% of the knowledge.

SAMPLING VARIABILITY OF THE EDUCATION AND KNOWLEDGE METRICS

It is hard to defend using survey data to construct discrete metrics that ignore sampling error. We evaluated what would happen when the standard errors of the metrics were taken into account for 36 occupations that were in the STW in 2010 but in 2019 all 36 occupations failed to pass the knowledge criterion but 27 passed the education criterion and nine had no education data. Figure 5 displays the 2019 knowledge estimates for these 36 occupations along with their standard errors for each of the fourteen knowledge domains (Table 1). Figure 5 provides an answer to the question whether or not the interval contains the 4.5 criterion. The figure shows:

- there are eleven occupations that are missing standard error estimates (light grey filled circles), this includes nine occupations where the O*NET Content Model education data are also missing; and
- there are 13 occupations where the interval includes the 4.5 criterion (orange filled circles), in six of the occupations the interval includes the 4.5 criterion for more than one knowledge domain, all 13 occupations meet the education criterion.

Figure 6 displays seven occupations that passed the education and knowledge criteria in 2010 but failed the education criteria in 2019. The education intervals for these occupations, percentage without a college degree ± standard error, are displayed along with the sample size and the 50% criteria.

The intervals that contain the 50% criterion include:

- in 2010: Mechanical Engineering Technologists (17-3029.07), Precision Agriculture Technicians (19-4099.02), Technical Directors/Managers (27-2012.05,), Film and Video Editors (27-4032.00), and Hearing Aid Specialists (29-2092.00); and
- in 2019: Mechanical Engineering Technicians (17-3027.00), Mechanical Engineering Technologists (17-3029.07), and Hearing Aid Specialists (29-2092.00).

Using the alternative sources of education data, O*NET Job Zone and BLS EP education levels, only two of the seven occupations require a four year college degree in 2019, Computer Systems Analysts and Film and Video Editors. It is interesting to note that the, sample sizes are different from one update to the next, for example, five of the 2019 occupation sample sizes are smaller and in some cases less than half of what they were in 2010. So rather a metric that is an accurate assessment of entry level education requirements it is confounded with the survey sample size.

Figure 5. 36 Content Model Knowledge Estimates ± Standard Errors for Occupations that Failed the Knowledge Criteria in 2019 but were STW Occupations in 2010; Education Estimates Met the Criteria or Were Missing

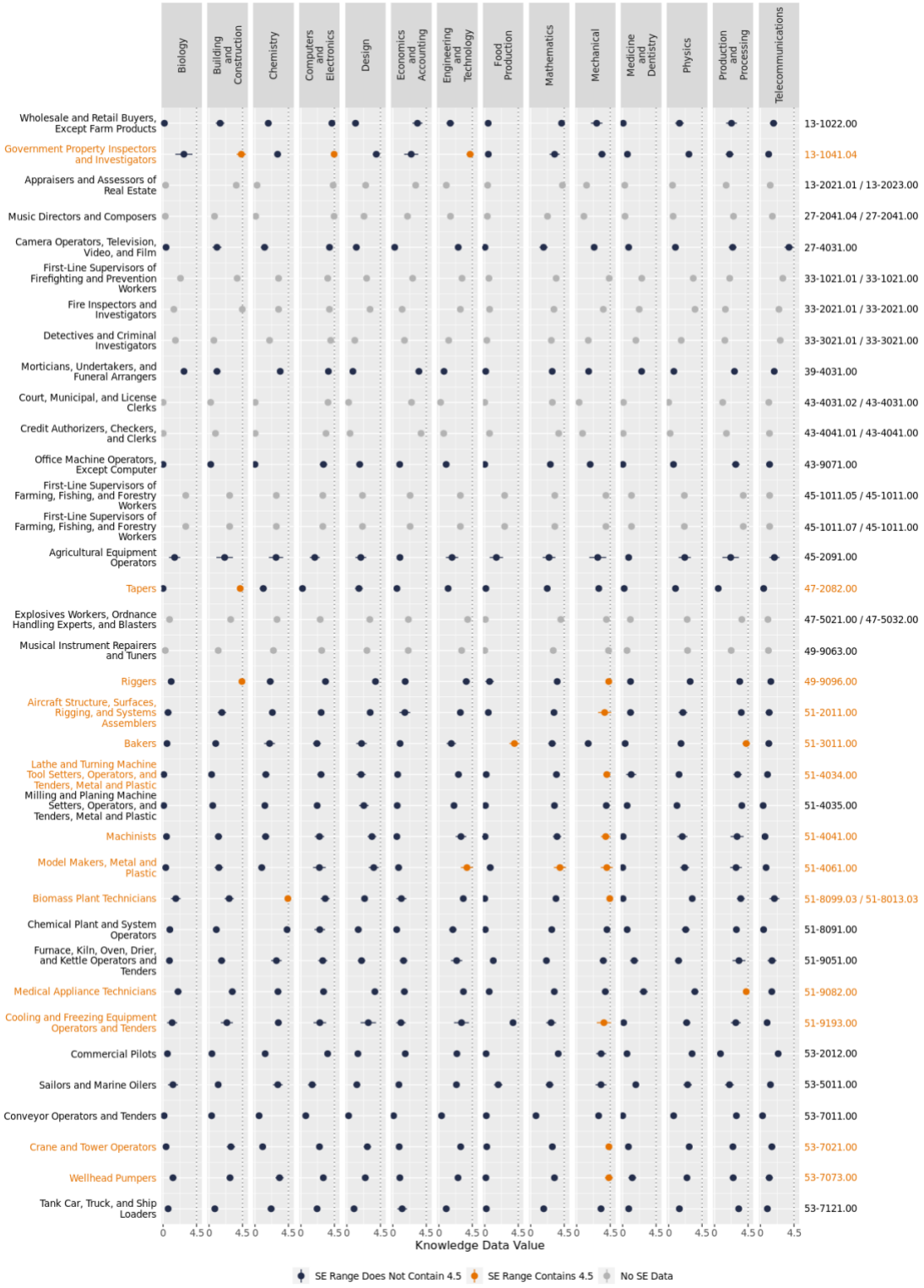
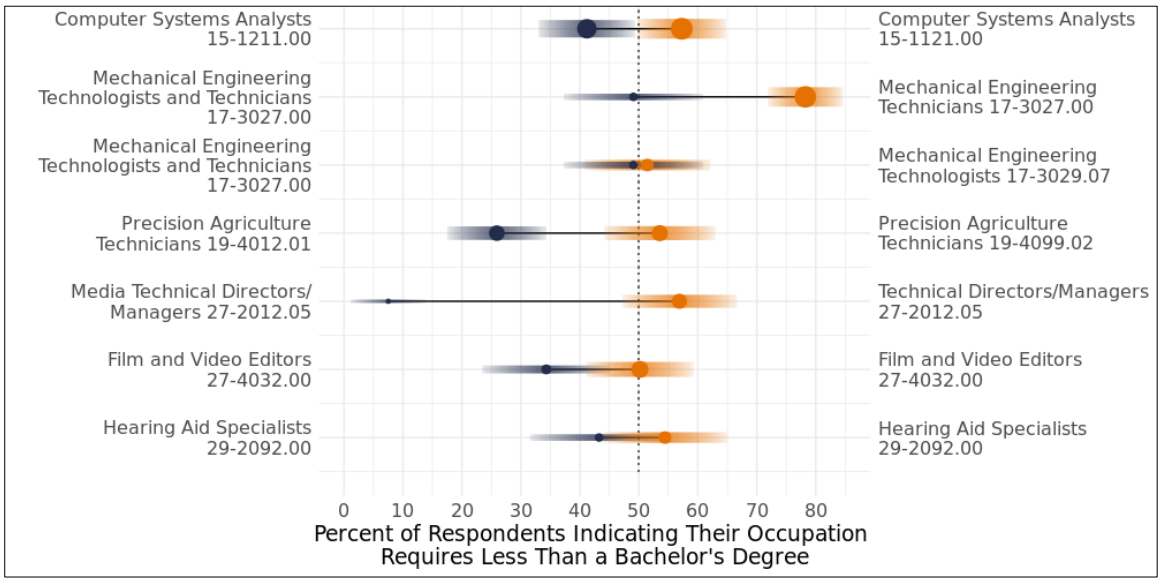


Figure 6. Content Model Education Estimates ± Standard Errors: O*NET-SOC 2019 (left) and O*NET-SOC 2010 (right)
Filled circles indicate sample size: smallest diameter has a sample size of 17, largest a sample size of 43.



PART II: LACK OF ONE-TO-ONE CORRESPONDENCE

There are 27 STW occupations that involve nesting; either the SOC is STW where STW and/or nonSTW O*NET-SOC occupations are nested under it (Table 4) or the SOC is not STW where STW and nonSTW O*NET-SOC occupations are nested under it (Table 5). This poses a problem when the only occupation code that is available is at the SOC level (e.g., Bureau of Labor Statistics surveys, Employment Projections and Occupational Employment Statistics, and the American Community Survey) -- how should the occupation be classified? In three cases the path forward is obvious. For example, in Table 4, First-Line Supervisors of Construction Trades and Extraction Workers (47-1011), Construction and Building Inspectors (47-4011), and Electro-Mechanical and Mechatronics Technologists and Technicians (17-3024) are all in the STW as are the occupations nested under them. In contrast, the five occupations nested under Industrial Production Managers (11-3051), which is in the STW, are both STW and nonSTW.

Table 4. 6 STW SOC Occupations with 5 STW & 5 nonSTW Detailed O*NET-SOC Nested Occupations

Occupation Title (Meets Education Criterion / Meets Knowledge Criterion / O*NET Job Zone #)	**SOC Code**	**O*NET-SOC Code**
Industrial Production Managers (Yes/Yes/4)	11-3051 Bachelor*	11-3051.00
Quality Control Systems Managers (No/Yes/4)		11-3051.01
Geothermal Production Managers (Yes/Yes/3)		11-3051.02
Biofuels Production Managers (No/Yes/4)		11-3051.03
Biomass Power Plant Managers (No/Yes/4)		11-3051.04
Hydroelectric Production Managers (Yes/Yes/3)		11-3051.06
Surveyors (Yes/Yes/4)	**17-1022** Bachelor	17-1022.00
Geodetic Surveyors (No/Yes/4)		17-1022.01
Electro-Mechanical & Mechatronics Technologists & Technicians (Yes/Yes/3)	**17-3024** Associates	17-3024.00
Robotics Technicians (Yes/Yes/3)		17-3024.01
Industrial Engineering Technologists & Technicians (Yes/Yes/3)	**17-3026** Associates	17-3026.00
Nanotechnology Engineering Technologists & Technicians (NA/Yes/4)		17-3026.01
First-Line Supervisors of Construction Trades and Extraction Workers (Yes/Yes/3)	47-1011	47-1011.00

Table 4. 6 STW SOC Occupations with 5 STW & 5 nonSTW Detailed O*NET-SOC Nested Occupations

Occupation Title (Meets Education Criterion / Meets Knowledge Criterion / O*NET Job Zone #)	**SOC Code**	**O*NET-SOC Code**
Solar Energy Installation Managers (Yes/Yes/3)	HS or GED	47-1011.03
Construction and Building Inspectors (Yes/Yes/3)	47-4011	47-4011.00
Energy Auditors (Yes/Yes/3)	HS or GED	47-4011.01

Orange codes are STW occupations; bolded orange codes are also STEM occupations.
NA = Either no O*NET 29.1 Content Model or BLS Employment Projection data available.
O*NET Job Zones 1-3 do not require a bachelor's degree.
*SOC 2019 BLS Employment Projections typical entry-level requirement education.

In Table 5, as in Table 4, unless there is an agreement between the SOC occupation and all the O*NET-SOC occupations listed under it, there is not clear path forward.

Table 5. 13 nonSTW SOC Occupations with 16 STW and 13 nonSTW Detailed O*NET-SOC Nested Occupations

Occupation Title (Meets Education Criterion / Meets Knowledge Criterion / O*NET Job Zone #)	**SOC Code**	**O*NET-SOC Code**
Compliance Officers (NA/No/3)	13-1041	13-1041.00
Environmental Compliance Inspectors (No/No/4)	Bachelors*	13-1041.01
Equal Opportunity Representatives & Officers (No/No/4)		13-1041.03
Government Property Inspectors & Investigators (Yes/Yes/3)		13-1041.04
Coroners (Yes/Yes/3)		13-1041.06
Regulatory Affairs Specialists (No/No/4)		13-1041.07
Customs Brokers (Yes/No/3)		13-1041.08
Computer Network Architects (No/Yes/4)	15-1241	15-1241.00
Telecommunications Engineering Specialists (Yes/Yes/3)	Bachelors	15-1241.01
Mechanical Engineering Technologists & Technicians (No/Yes/3)	17-3027	17-3027.00
Automotive Engineering Technicians (Yes/Yes/3)	Associates	17-3027.01
Engineering Technologists & Technicians, Except Drafters, All Other (NA/NA/NA)	17-3029	17-3029.00
Non-Destructive Testing Specialists (Yes/No/2)	NA	17-3029.01
Photonics Technicians (Yes/Yes/3)		17-3029.08
Life, Physical, and Social Science Technicians, All Other (NA/NA/NA)	19-4099	19-4099.00
Quality Control Analysts (Yes/Yes/3)	Associates	19-4099.01
Remote Sensing Technicians (No/Yes/4)		19-4099.03
Registered Nurses (Yes/No/3)	29-1141	29-1141.00
Acute Care Nurses (Yes/Yes/3)	Bachelors	29-1141.01
Advanced Practice Psychiatric Nurses (No/Yes/5)		29-1141.02
Critical Care Nurses (Yes/Yes/3)		29-1141.03
Critical Nurse Specialists (No/Yes/5)		29-1141.04
Health Technologists & Technicians, All Other (NA/No/NA)	29-2099	29-2099.00
Neurodiagnostic Technologists (Yes/Yes/3)	NA	29-2099.01
Ophthalmic Medical Technologists (Yes/No/3)		29-2099.05
Patient Representatives (Yes/No/3)		29-2099.08
Plumbers, Pipefitters, & Steamfitters (NA/Yes/3)	47-2152	47-2152.00
Solar Thermal Installers & Technicians (Yes/Yes/3)	HS or GED	47-2152.04
Installation, Maintenance, & Repair Workers, All Other (NA/No/NA)	49-9099	49-9099.00
Geothermal Technicians (Yes/Yes/2)	HS or GED	49-9099.01
Power Plant Operators (Yes/No/2)	51-8013	51-8013.00
Biomass Plant Technicians (Yes/No/2)	HS or GED	51-8013.03
Hydroelectric Plant Technicians (Yes/Yes/3)		51-8013.04
Molders, Shapers, & Casters, Except Metal and Plastic (NA/No/2)	51-9195	51-9195.00
Stone Cutters & Carvers, Manufacturing (Yes/No/2)	HS or GED	51-9195.03

Table 5. 13 nonSTW SOC Occupations with 16 STW and 13 nonSTW Detailed O*NET-SOC Nested Occupations

Occupation Title (Meets Education Criterion / Meets Knowledge Criterion / O*NET Job Zone #)	SOC Code	O*NET-SOC Code
Glass Blowers, Molders, Benders, & Finishers (Yes/Yes/2)		51-9195.04
Potters, Manufacturing (Yes/No/3)		51-9195.05
Transportation Inspectors (NA/No/4)	53-6051	53-6051.00
Aviation Inspectors (Yes/Yes/3)	HS or GED	53-6051.01
Transportation Vehicle, Equipment & Systems Inspectors, Except Aviation (Yes/Yes/2)		53-6051.07
Laborers & Freight, Stock, & Material Movers, Hand (Yes/No/2)	53-7062	53-7062.00
Recycling & Reclamation Workers (Yes/Yes/2)	NA	53-7062.04

Orange codes are STW occupations.
NA = Either no O*NET 29.1 Content Model or BLS Employment Projection data available.
O*NET Job Zones 1-3 do not require a bachelor's degree.
*SOC 2019 BLS Employment Projections typical entry-level requirement education.

PART III: STW CHANGES FROM O*NET 19.0 to O*NET 25.1

This section explores the changes in STW occupations between O*NET-SOC 2010 and O*NET-SOC 2019. First, we describe the overall structure of O*NET-SOC 2010, then we discuss the STW occupations that were removed and added between the versions.

OVERALL STRUCTURE

Of the 1,110 O*NET-SOC occupation titles in the 2010 taxonomy, 974 occupations contain Content Model data. The 974 data-level occupations include:

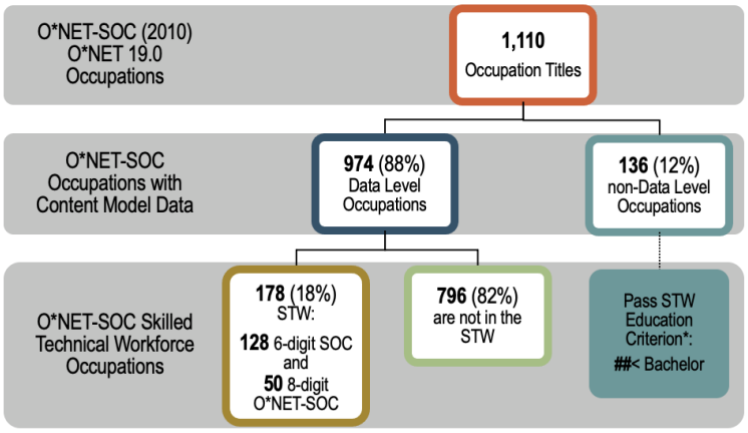
- 667 SOC level occupations with no detailed O*NET-SOC occupations nested under them; and
- 37 SOC level occupations with 269 detailed O*NET-SOC occupations nested under them.

The 136 non-data level occupations include:

- 20 that are military specific;
- 45 SOC level occupations with detailed O*NET-SOC occupations;
- 25 that have the SOC code for "All-Others" (the sixth digit is a 9) with the two-digit extension of a detailed O*NET-SOC; and
- 46 that have the SOC code for "All-Others" (the six-digit is a 9) without the two-digit extension of a detailed O*NET-SOC occupation.

Figure 7 displays the O*NET 19.0 occupations by availability of Content Model data and STW designation. In O*NET 19.0, there are 178 occupations that meet both the knowledge and education criteria for a STW designation. There are 34 more STW SOC designations in O*NET 19.0 than O*NET 25.1. There is an increase in Content Model completeness between the two versions, 136 (12%) of the occupations do not have Content Model data in O*NET 19.0, this number is 93 (9%) in O*NET 25.1.

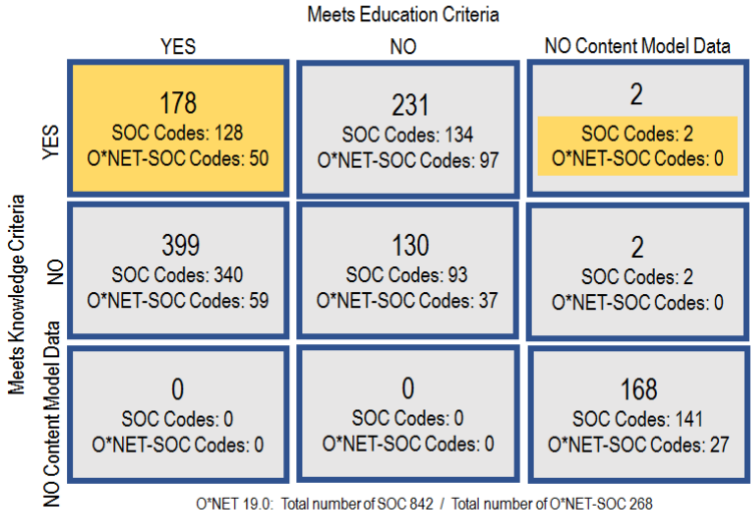
Figure 7. O*NET-SOC 2010 (O*NET 19.0) Occupations by Skilled Technical Workforce Designation



*Entry level education requirements are from the 2010 Bureau of Labor Statistics' Employment Projection Project.

Figure 8 displays the number of SOC and O*NET-SOC occupations broken down by STW education and knowledge criteria. In O*NET 19.0, there are 842 SOC and 268 O*NET-SOC occupations, whereas in O*NET 25.1, there are 867 SOC and 149 O*NET-SOC occupations (Figure 2). This shows an increase in the number of SOC occupations, a decrease in the number of O*NET-SOC occupations, and a decrease in the number of occupations overall. There are 178 occupations (128 SOC occupations and 50 O*NET-SOC occupations) that meet the education and knowledge criteria, whereas in O*NET 25.1, this decreased to 144 occupations (123 SOC occupations and 21 O*NET-SOC occupations). We also find an increase in the number of occupations with no education Content Model data, from two occupations in O*NET 19.0 to 18 in O*NET 25.1.

Figure 8. Availability of O*NET 19.0 Content Model Data for Education and Knowledge Broken Down by STW Designation and SOC and O*NET-SOC Codes



The remainder of Part III examines issues involved in constructing a STW crosswalk from one SOC release to the next.

OCCUPATION CHANGES

Changes that impact STW occupations are displayed in Tables 6 and 7; STW occupations are highlighted in orange. Table 6 displays a list of occupations that were broken out into two or more occupations in O*NET-SOC 2019:

- two STW occupations had codes changes, Web Developers and Earth Drillers, Except Oil and Gas;
- one STW occupation, Emergency Medical Technicians and Paramedics (29-2041.00), was broken into two occupations, Emergency Medical Technicians (29-2042.00) and Paramedics (29-2041.00), neither of which are in the STW;
- two nonSTW occupations, Healthcare Practitioners and Technical Workers, All Other (29-9099.00) and Production Workers, All Other (51-9199.00), were each broken into three occupations; of the six new occupations, three are in the STW, Surgical Assistants (29-9093.00), Computer Numerically Controlled Tool Operators (51-9161.00), and Computer Numerically Controlled Tool Programmers (51-9162.00).

Table 6. STW O*NET-SOC Occupations Split into Two Occupations Between O*NET-SOC 2010 and 2019

O*NET-SOC 2010		O*NET-SOC 2019	
Occupation Name	**Code**	**Occupation Name**	**Code**
Web Developers	15-1134.00	Web Developers	15-1254.00
		Web and Digital Interface Designers	15-1255.00
Emergency Medical Technicians and Paramedics	29-2041.00	Emergency Medical Technicians	29-2042.00
		Paramedics	29-2043.00
Healthcare Practitioners and Technical Workers, All Other	29-9099.00	Health Information Technologists and Medical Registrars	29-9021.00
		Surgical Assistants	29-9093.00
Earth Drillers, Except Oil and Gas	47-5021.00	Earth Drillers, Except Oil and Gas	47-5023.00
		Explosives Workers, Ordnance Handling Experts, and Blasters	47-5032.00
Production Workers, All Other	51-9199.00	Computer Numerically Controlled Tool Operators	51-9161.00
		Computer Numerically Controlled Tool Programmers	51-9162.00
		Production Workers, All Other	51-9199.00

Orange titles and codes are STW occupations.

Table 7 contains a list of occupations that were aggregated into one occupation in O*NET-SOC 2019, where at least one of the O*NET-SOC 2010 occupations being aggregated is in the STW. 42 STW and 47 nonSTW occupations were aggregated into 15 STW and 16 nonSTW occupations; of the 16 nonSTW occupations, 11 are missing education data and were classified as STW using alternative education data sources (see Table 2).

Table 7. STW O*NET-SOC Occupations Aggregated into One Occupation Between O*NET-SOC 2010 and 2019

O*NET-SOC 2010		O*NET-SOC 2019	
Occupation Name	**Code**	**Occupation Name**	**Code**
Industrial Production Managers	11-3051.00	Industrial Production Managers	11-3051.00
Methane/Landfill Gas Collection System Operators	11-3051.05		
Farmers, Ranchers, and Other Agricultural Managers	11-9013.00	Farmers, Ranchers, and Other Agricultural Managers	11-9013.00

Table 7. STW O*NET-SOC Occupations Aggregated into One Occupation Between O*NET-SOC 2010 and 2019

O*NET-SOC 2010		O*NET-SOC 2019	
Occupation Name	**Code**	**Occupation Name**	**Code**
Nursery and Greenhouse Managers	11-9013.01		
Farm and Ranch Managers	11-9013.02		
Aquacultural Managers	11-9013.03		
Appraisers and Assessors of Real Estate	13-2021.00	Appraisers and Assessors of Real Estate	13-2023.00
Assessors	13-2021.01		
Appraisers, Real Estate	13-2021.02		
Web Developers	15-1134.00	Web and Digital Interface Designers	15-1255.00
Computer Occupations, All Other	15-1199.00		
Computer Occupations, All Other	15-1199.00	Computer Occupations, All Other	15-1299.00
Computer Operators	43-9011.00		
Architectural and Civil Drafters	17-3011.00	Architectural and Civil Drafters	17-3011.00
Architectural Drafters	17-3011.01		
Civil Drafters	17-3011.02		
Electrical and Electronics Drafters	17-3012.00	Electrical and Electronics Drafters	17-3012.00
Electronic Drafters	17-3012.01		
Electrical Drafters	17-3012.02		
Electrical and Electronic Engineering Technicians	17-3023.00	Electrical and Electronic Engineering Technologists and Technicians	17-3023.00
Electronics Engineering Technicians	17-3023.01		
Electrical Engineering Technicians	17-3023.03		
Electrical Engineering Technologists	17-3029.02		
Electronics Engineering Technologists	17-3029.04		
Electro-Mechanical Technicians	17-3024.00	Electro-Mechanical and Mechatronics Technologists and Technicians	17-3024.00
Electromechanical Engineering Technologists	17-3029.03		
Industrial Engineering Technicians	17-3026.00	Industrial Engineering Technologists and Technicians	17-3026.00
Industrial Engineering Technologists	17-3029.05		
Manufacturing Engineering Technologists	17-3029.06		
Manufacturing Production Technicians	17-3029.09		
Mechanical Engineering Technicians	17-3027.00	Mechanical Engineering Technologists and Technicians	17-3027.00
Mechanical Engineering Technologists	17-3029.07		
Surveying and Mapping Technicians	17-3031.00	Surveying and Mapping Technicians	17-3031.00
Surveying Technicians	17-3031.01		
Mapping Technicians	17-3031.02		
Geological and Petroleum Technicians	19-4041.00	Geological Technicians, Except Hydrologic Technicians	19-4043.00
Geophysical Data Technicians	19-4041.01		
Geological Sample Test Technicians	19-4041.02		
Music Directors and Composers	27-2041.00	Music Directors and Composers	27-2041.00
Music Directors	27-2041.01		
Music Composers and Arrangers	27-2041.04		
Surgical Assistants	29-2099.07	Surgical Assistants	29-9093.00

Table 7. STW O*NET-SOC Occupations Aggregated into One Occupation Between O*NET-SOC 2010 and 2019

O*NET-SOC 2010		O*NET-SOC 2019	
Occupation Name	**Code**	**Occupation Name**	**Code**
Healthcare Practitioners and Technical Workers, All Other	29-9099.00		
First-Line Supervisors of Fire Fighting and Prevention Workers	33-1021.00	First-Line Supervisors of Firefighting and Prevention Workers	33-1021.00
Municipal Fire Fighting and Prevention Supervisors	33-1021.01		
Forest Fire Fighting and Prevention Supervisors	33-1021.02		
Firefighters	33-2011.00	Firefighters	33-2011.00
Municipal Firefighters	33-2011.01		
Forest Firefighters	33-2011.02		
Fire Inspectors and Investigators	33-2021.00	Fire Inspectors and Investigators	33-2021.00
Fire Inspectors	33-2021.01		
Fire Investigators	33-2021.02		
Detectives and Criminal Investigators	33-3021.00	Detectives and Criminal Investigators	33-3021.00
Police Detectives	33-3021.01		
Criminal Investigators and Special Agents	33-3021.03		
Court, Municipal, and License Clerks	43-4031.00	Court, Municipal, and License Clerks	43-4031.00
Court Clerks	43-4031.01		
Municipal Clerks	43-4031.02		
License Clerks	43-4031.03		
Credit Authorizers, Checkers, and Clerks	43-4041.00	Credit Authorizers, Checkers, and Clerks	43-4041.00
Credit Authorizers	43-4041.01		
Credit Checkers	43-4041.02		
First-Line Supervisors of Farming, Fishing, and Forestry Workers	45-1011.00	First-Line Supervisors of Farming, Fishing, and Forestry Workers	45-1011.00
First-Line Supervisors of Logging Workers	45-1011.05		
First-Line Supervisors of Aquacultural Workers	45-1011.06		
First-Line Supervisors of Agricultural Crop and Horticultural Workers	45-1011.07		
First-Line Supervisors of Animal Husbandry and Animal Care Workers	45-1011.08		
Carpenters	47-2031.00	Carpenters	47-2031.00
Construction Carpenters	47-2031.01		
Rough Carpenters	47-2031.02		
Plumbers, Pipefitters, and Steamfitters	47-2152.00	Plumbers, Pipefitters, and Steamfitters	47-2152.00
Pipe Fitters and Steamfitters	47-2152.01		
Plumbers	47-2152.02		
Earth Drillers, Except Oil and Gas	47-5021.00	Explosives Workers, Ordnance Handling Experts, and Blasters	47-5032.00
Explosives Workers, Ordnance Handling Experts, and Blasters	47-5031.00		
Loading Machine Operators, Underground Mining	53-7033.00	Loading and Moving Machine Operators, Underground Mining	47-5044.00
Mine Shuttle Car Operators	53-7111.00		

Table 7. STW O*NET-SOC Occupations Aggregated into One Occupation Between O*NET-SOC 2010 and 2019

O*NET-SOC 2010		O*NET-SOC 2019	
Occupation Name	**Code**	**Occupation Name**	**Code**
Radio, Cellular, and Tower Equipment Installers and Repairers	49-2021.00	Radio, Cellular, and Tower Equipment Installers and Repairers	49-2021.00
Radio Mechanics	49-2021.01		
Automotive Service Technicians and Mechanics	49-3023.00	Automotive Service Technicians and Mechanics	49-3023.00
Automotive Master Mechanics	49-3023.01		
Automotive Specialty Technicians	49-3023.02		
Heating, Air Conditioning, and Refrigeration Mechanics and Installers	49-9021.00	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	49-9021.00
Heating and Air Conditioning Mechanics and Installers	49-9021.01		
Refrigeration Mechanics and Installers	49-9021.02		
Computer-Controlled Machine Tool Operators, Metal and Plastic	51-4011.00	Computer Numerically Controlled Tool Operators	51-9161.00
Production Workers, All Other	51-9199.00		
Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	51-4012.00	Computer Numerically Controlled Tool Programmers	51-9162.00
Production Workers, All Other	51-9199.00		

Orange titles and codes are STW occupations.

DETAILED CHANGES IN STW OCCUPATIONS

Table 8 displays the changes in the STW designations between O*NET-SOC 2010 and 2019. There are 115 STW occupations that did not change between 2010 and 2019. Of those 115 O*NET-SOC occupations, the Content Model data were updated for 56 occupations and not updated for the other 59. There are 34 STW occupations in 2010 but not in 2019 due to not meeting either the education or knowledge criteria; there are 32 STW occupations in 2010 that in 2019 have missing education and/or knowledge data and cannot be classified. Similarly, there are 39 occupations that are new to the STW in 2019; 30 passed both the education and knowledge criteria for the first time and nine were new data-level occupations.

Table 8. Number of STW and NonSTW Occupations between O*NET-SOC 2010 and 2019

STW O*NET-SOC 2010		STW O*NET-SOC 2019		Number of Occupations
Passed both criteria		Passed both criteria 56 updated Content Model Data		115
Passed both criteria		FALSE	Failed Education / Passed Knowledge	7
			Passed Education / Failed Knowledge	27
		NA	NA Education / Failed Knowledge	9
			NA Education / Passed Knowledge	19
			NA Education / NA Knowledge	4
FALSE	Failed Education / Passed Knowledge	Passed both criteria		7
	Passed Education / Failed Knowledge			23
NA	NA Education / NA Knowledge	Passed both criteria		9

Includes O*NET occupations that were either STW in O*NET-SOC 2010 or 2019.

PROPOSED LIST OF STW OCCUPATIONS

This section summarizes the process we went through to derive our list of 133 STW occupations using O*NET-SOC 2019 occupations and Content Model data from O*NET 25.1. Based on Rothwell's metrics and criteria, out of 144 STW SOC occupations with complete data (see Figure 2):

- 117 have a one-to-one correspondence between SOC and O*NET-SOC occupations where there is no nesting (Table A1). Total employment for 114 of these occupations is 11,167,810, with no employment data for the Web Developers, Surgical Assistants, and Earth Drillers, Except Oil and Gas (OEWS Data, March 2020 https://www.bls.gov/oes/tables.htm);
- by using alternative data sources for missing education data where the occupation meets the knowledge criterion,
    - 10 out of the 18 occupations with no Content Model data for education in Figure 2 can be designated as STW SOCs (Table 2); the total employment for these 10 occupations is 2,048,660 (OEWS Data, March 2020, https://www.bls.gov/oes/tables.htm);
    - 3 out of the 18 have a one-to-one correspondence between SOC and O*NET-SOC occupations where there is nesting (Table 3), this adds 3 SOC and 3 O*NET-SOC STW occupations; there is no employment data for the three O*NET-SOC STW occupations, Solar Energy Installation Managers, Energy Auditors, and Robotics Technicians; total employment for the other three SOC STW occupations, First-Line Supervisors of Construction Trades and Extraction Workers, Construction and Building Inspectors, and Electro-Mechanical and Mechatronics Technologists and Technicians is 741,010 (OEWS Data, March 2020, https://www.bls.gov/oes/tables.htm).

Table 9 contains a list of the 16 occupations that can be added to the list of 117 STW occupations in Table A1,by using alternative data sources when there is no Content Model education data or that have a one-to-one correspondence between SOC and O*NET-SOC codes. Therefore, there are 133 SOC occupations that can be unambiguously categorized as in the STW. The total employment is greater than 13,957,480 since there is no employment data for 6 of the occupations.

Table 9. 10 SOC Occupations Added to the STW Using Alternative Education Data Sources and 3 SOC and 3 O*NET-SOC STW Occupations That Have a One-to-One Correspondence

Occupation Name	O*NET-SOC
Architectural & Civil Drafters	**17-3011.00**
Electrical & Electronics Drafters	**17-3012.00**
Electrical & Electronic Engineering Technologists & Technicians	**17-3023.00**
Electro-Mechanical and Mechatronics Technologists and Technicians	17-3024.00
Robotics Technicians	17-3024.01
Surveying & Mapping Technicians	**17-3031.00**
Nuclear Technicians	**19-4051.00**
Firefighters	33-2011.00
First-Line Supervisors of Construction Trades and Extraction Workers	47-1011.00
Solar Energy Installation Managers	47-1011.03
Carpenters	47-2031.00
Plumbers, Pipefitters, & Steamfitters	47-2152.00
Construction and Building Inspectors	47-4011.00
Energy Auditors	47-4011.01
Automotive Service Technicians & Mechanics	49-3023.00
Heating, Air Conditioning, & Refrigeration Mechanics & Installers	49-9021.00

Bolded occupations and codes are STW and STEM occupations.

Out of 21 STW O*NET-SOC occupations only three have a one-to-one correspondence with a SOC occupation (Table 2); leaving 18 that cannot be classified at the SOC level; the total employment for these 18 occupations is 2,048,660 (OEWS Data, March 2020, https://www.bls.gov/oes/tables.htm). In addition, there are 30 non-data level SOC occupations that meet the education criterion using alternative data sources but are missing knowledge data, many of these occupation titles include the words "Technologists" or "Technicians" an indication of a potential STW occupation.

RECOMMENDATIONS

The O*NET limitations addressed by Reamer in a 2015 report[3] for the National Academies Board on Science, Technology, and Economic Policy still exist today; these limitations question the usability of Content Model data to categorize STW occupations. Reamer stated, "…, O*NET is not up-to-date. As a consequence, the efficacy of the various O*NET-based tools suffers." In his report, *Information Resources to Facilitate Middle Skills Workforce Development*, the enhancement and implementation ideas he recommended for O*NET include, "… a strategy for regularly updating detail occupational descriptions, including emerging and receding occupations, changes in KSAs, and changes in educational requirements. Such a strategy may rely on some combination of methods such as greater funding of O*NET, webscraping, autocoding, crowdsourcing, and new surveys (such as the Occupational Requirements Survey)."

Since the O*NET limitations cited by Reamer have not been addressed, we do not recommend the continued use of Content Model data to categorize STW occupations. There is a disconnect between the O*NET concerns expressed in this report and by Reamer, and the use of these data to operationalize a new construct of technical work that is vital to U.S. competitiveness, security, and science and engineering research (National Science Board, 2019). In reality, the STW is a function of the nature of work which is rapidly changing due to emerging technologies, which in turn places demands for new skills. It follows that the data used to quantify the education and knowledge metrics of inclusion be constructed using labor market information that is current, reliable, and provides detailed information at the occupation level on the required technical skills.

Lack of Content Model Education Data

Since there is no single education data source that covers all occupations (see Table 3), We recommend that additional analyses be conducted to evaluate the agreement amongst the three measures of education discussed in this report: Job Zone, EP estimates, and BGT job-ad minimum education requirements. In addition, we recommend these sources be profiled for all O*NET-SOC occupation titles to evaluate how the education requirements in these data sources change with time, emerging technologies, and disruptions in the economy.

> In addition to providing information at the level of the O*NET-SOC, LMI job-ad data captures the real-time changes in employer education demands which can rapidly change with the fluctuations in the economy. Modestino et al. (2020) document employer up-skilling in response to the increase in the supply of relevant job seekers during the 2009 recession using BGT job-ad data. In contrast, down-skilling is happening in response to the pandemic (Campello et al., 2020); many occupations that required a 4-year college degree no longer do.

[3] Andrew Reamer (2015). Information Resources to Facilitate Middle Skills Workforce Development, https://atecentral.net/r33982/information_resources_to_facilitate_middle_skills_workforce_development.

In his 2015 report, Reamer advocated for the use of LMI data. He recommended that "NASWA, Direct Employers, and national human resource and industry associations should adopt a standard template for on-line job postings that would allow for more productive text analysis for the purpose of understanding occupational KSAs and educational requirements." With release of free LMI data this year, the National Labor Exchange (NLx) job-ad data[4] has the potential to supplement the O*NET data level occupations with current minimum education requirements that cover all occupations even O*NET-SOC occupations.

Lack of Content Model Knowledge Data

We recommend a new source of knowledge data tied to nondegree credentials and/or skills. O*NET provides lists of certifications, licenses, and apprenticeships that are connected with a particular O*NET-SOC occupation. This information could be supplemented with the nondegree credentials that are requested by employers in job-ads and expanded to include the technical skills employers request in order to build networks that align technical skills with nondegree credentials and occupations.

One idea for a new knowledge data source is to use the nondegree credentials, skills, or a combination of the two to define the education/training as STW or not. Whereas STEM is defined for both educational programs using the Classification of Instructional Programs (CIP codes) and occupations using the SOC code descriptions, at present this is not an option available for categorizing STW occupations and therefore the reliance on O*NET Content Model knowledge data.

Perhaps a nondegree credential classification system similar to CIP codes could be used to categorize nondegree credentials as STW or not. Aligning nondegree credentials with skills acquisition is a major topic of discussion in the nondegree credential community. To accomplish this would be an onerous task due to the number of nondegree credentials (Credential Engine (US), 2019), but the benefit to the nondegree credential community would be immeasurable. Not only could this be used to help define and categorize education and training programs, it would provide sufficient information to categorize credentials as STW or not, help employers request credentials based on the skill acquisition the credential represents, and give leaners a better idea of what nondegree credentials could lead to a technical occupation. Also, since the landscape on nondegree credentials is ever increasing and changing, using LMI data to link skills and credentials would provide a knowledge assessment that is more relevant and current.

Lack of One-to-One Correspondence

We recommend that DOL provide survey data, such as the number of employed, for all 8-digit O*NET-SOC occupations. This way, if the only available information about an occupation is the SOC level a percentage of individuals employed in STW occupations nested under the SOC level could be estimated.

The lack of a one-to-one correspondence cannot be resolved with alternative or proxy data sources without setting additional criteria. This raises some difficulties when counting the number of STW jobs and the counts are only available at the SOC level. How would you split the number of jobs of the parent SOC among the nested STW and nonSTW O*NET-SOC occupations? BLS does not provide survey data on education requirements or the number of employed at the O*NET-SOC level. The lack of data at the O*NET-SOC level poses a challenge to constructing STW metrics that can be tracked over time and provide data that is comparable across federal agencies and organizations studying the STW for the purpose of policy making.

[4] National Labor Exchange NLx Research Hub About the Data: https://nlxresearchhub.org/about-the-data

STEM occupations are only defined at the SOC level but this is not an option for STW occupations since they are often new and emerging occupations developed in response to changes in technology.

One idea that we have not evaluated, would use LMI data to get an estimate of the employment numbers for 8-digit O*NET-SOC occupations. The numbers of employed in the parent SOC would come from federal survey data which could then be distributed using the percentage of job-ads to all the 8-digit O*NET-SOC occupations nested under it.

Variability of the Content Model Estimates

If the Content Model data will continue to be used to classify STW occupations, it is recommended the variability of the estimate be incorporated in the decision process; this will allow for greater consistency between SOC releases and provides a statistically defensible metric. We also recommend that additional analyses be conducted that compares the criteria for all occupations in both O*NET-SOC 2010 and O*NET-SOC 2019 using a confidence interval across all occupations over time, with emphasis on the stability of these metrics over time and how they change with emerging technologies and disruptions in the economy.

Part I highlights the ambiguity in setting a discrete cut-off when metrics are measured with error. An occupation with a 4.5 technical domain score receives the designation in one O*NET Content Model release but loses the designation in the next when the score is 4.4. despite the fact there is no statistical difference between the two estimates when the variability of the estimates is taken into account. In this proof of concept, there are approximately 18 additional occupations that would be classified as STW if a confidence interval was used to evaluate the education and knowledge criteria. For twelve of these occupations the total employment is 714,250 (OEWS Data, March 2020, https://www.bls.gov/oes/tables.htm); the other six are O*NET-SOC occupations and therefore have no employment data. There may be additional occupations that fall in this grey zone, but this report only looked at STW occupations in 2010 and how they were categorized in 2019.

CONCLUSIONS

If the goal is to provide a definition that can be used to compare metrics across statistical agencies and organizations over time and to guide the development of evidence-based policies, this report finds the current STW metrics to be lacking and recommends that it be re-examined. The SOC Policy Committee[5] defines STEM occupations using the SOC structure and the Classification Principles and Coding Guidelines[6] for STEM designations. Each SOC release incorporates the lessons learned from the challenges of applying the STEM framework by members of a workgroup from relevant federal centers, commissions, departments, and bureaus. The takeaway for the STW is that the STEM definition is constructed by a workgroup of discipline experts and the STEM occupations are defined only at the SOC level. This provides the data needed for the "comparability of data across statistical agencies and organizations studying the STEM workforce for policymaking purposes, including educational and workforce planners."[3] Applying the same process for STW would remove the reliance on O*NET Content Model data that may or may not be available for an occupation and does not measure the constantly changing technical education and labor market environments that impact STW occupations. In testimony before the House Higher Education and Workforce

[5] Bureau of Labor Statistics. (June 2019). Options for defining STEM (Science, Technology, Engineering, and Mathematics) occupations under the 2018 Standard Occupational Classification (SOC). system https://www.bls.gov/soc/attachment_a_stem_2018.pdf.
[6] Classification Principles and Coding Guidelines. (November 2017). U.S. Bureau of Labor Statistics On behalf of the Office of Management and Budget (OMB) and the Standard Occupational Classification Policy Committee (SOCPC). https://www.bls.gov/soc/2018/soc_2018_class_prin_cod_guide.pdf

Investment Subcommittee and reauthorizing the Workforce Innovation and Opportunity Act, BGT CEO[7] stated that "Jobs and skills are changing faster than traditional labor information's ability to measure them. Current government data sources provide essential macroeconomic data, but cannot provide the granular, microeconomic data needed to respond to skill gaps and offer targeted, effective learning programs."

There is also the issue of overlap between some STW and STEM occupations. Some STEM occupations that do not require a four year degree are also classified as STW and some are not. The occupations classified as both STEM and STW (2018 SOC) are grouped by SOC minor groups in Table A2. All 20 STW occupations in the major occupation groups, Computer and Mathematics (15); Architecture and Engineering (17); Life, Physical, and Social Science (19); and Healthcare Practitioners and Technical (29); are also classified as STEM. Are these STEM or STW occupations? In which group should they be counted? It does make a difference. For example, immigration policies provide for a separate allocation of visas based on STEM degrees and post-secondary education funding is often tied to the STEM classification of instructional program codes which only exist for college programs, creating a bias against career technical education (Kim, 2019). The education-to-employment pathways of the skilled technical workforce are left out even though there is an increasing recognition among researchers of their importance to the future of the U.S. economy (NSB, 2019; NAS, 2017). In contrast, there are 18 STEM occupations that do not require a four year degree that are not in the STW. These include ten occupations in the broad occupation category Healthcare Practitioners and Technical Occupations (29); three in Life, Physical, and Social Science Occupations (19); four in Architecture and Engineering Occupations (17); and one in Computer and Mathematics (15). The reasons vary: for three occupations there is no content model data; for four occupations they pass the knowledge criteria but fail the education which does not agree with the BLS Employment Projection entry-level requirement education of an associate's degree; six occupations would be included in STW if an interval metric was used; and the remainder do not pass the knowledge criterion.

Like STEM occupations, there are two parts to defining the STW that need to be clearly understood before suitable metrics and pathways can be developed, the technical education and training that lead to a job whose tasks and activities employ these technical skills. The education and training part is so vast (see Credential Engine, 2021), not only in the number and types of nondegree credentials but also in the number of entities providing them: profit and not-for-profit colleges, universities, community colleges, and high schools; bootcamps; unions; industries; industry associations; profit and not-for-profit massive open online courses; federal and state governments; and non-governmental organizations. The occupation end of the equation is well defined by federal government surveys at the six-digit SOC code, what is not well defined or understood is the link between the two -- one can think of this as the majority of education and training providers are off the grid (Credential Engine, 2021) and the occupations are not. For example, certification education can be completed at a community college, but the certification examination is at the certifying organization, and often the results are not reported back to the community college.

Perhaps the best way to make progress is to start with employers demands for skills and nondegree credentials (using LMI data) and work backwards toward the nondegree credentials that provide the skills the employer is demanding. After all -- the value of a nondegree credential is tied to obtaining employment, so it follows that the demands of the employer should be taken into account when it comes to education and training. Without this integration of administrative and opportunity data sources to connect stakeholders, the persistent disconnect

[7] Getting Workforce Investment Right: House Testimony on WIOA (June 2, 2021) Matthew Sigelman htttps://www.burning-glass.com/getting-workforce-investment-right-house-testimony-wioa/

between the supply of and demand for skilled workers will continue to hamper effective local, regional, and national responses to the fast changing labor market.

Any attempt to define the boundaries of STW education, training, and employment is subjective and has consequences outside the academic exercises of defining models of technical education, training, and employment. In reality, the concept of STW is a function of the nature of work and the demands of employers which are rapidly changing due to emerging technologies which in turn places demands for new education and training programs, occupation titles and descriptions, which are all driven by the skills that employers value and need. Any definition of STW must take this into account.

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Appendix

Table A1. 117 STW SOC Level Occupations with No Detailed O*NET-SOC Occupations Nested Under Them (orange); 10 STW SOC Level Occupations Added Using Additional Data Sources (black); 3 STW SOC and 3 STW O*NET-SOC Level Occupations with a One-to-One Correspondence (black)

Occupation Name	SOC 2019	O*NET-SOC Version 25.1
Management Occupations (N=1, 0.75%)		
*Postmasters and Mail Superintendents	11-9131	11-9131.00
Business and Financial Operations Occupations (N=1, 0.75%)		
*Tax Examiners and Collectors, and Revenue Agents	13-2081	13-2081.00
Computer and Mathematical Occupations (N=2, 1.50%)		
*Computer User Support Specialists	**15-1232**	15-1232.00
*Web Developers	**15-1254**	15-1254.00
Architecture and Engineering Occupations (N=10, 7.52%)		
*Cartographers and Photogrammetrists	**17-1021**	17-1021.00
*Architectural & Civil Drafters	**17-3011**	17-3011.00
*Electrical & Electronics Drafters	**17-3012**	17-3012.00
*Mechanical Drafters	**17-3013**	17-3013.00
*Aerospace Engineering and Operations Technologists and Technicians	**17-3021**	17-3021.00
*Civil Engineering Technologists and Technicians	**17-3022**	17-3022.00
*Electrical & Electronic Engineering Technologists & Technicians	**17-3023**	17-3023.00
*Electro-Mechanical and Mechatronics Technologists and Technicians	**17-3024**	17-3024.00
*Robotics Technicians	**17-3024**	17-3024.01
*Surveying & Mapping Technicians	**17-3031**	17-3031.00
Life, Physical, and Social Science Occupations (N=2, 1.50%)		
*Chemical Technicians	**19-4031**	19-4031.00
*Nuclear Technicians	**19-4051**	19-4051.00
Art, Design, Entertainment, Sports, And Media Occupations (N=7, 5.26%)		
*Fine Artists, Including Painters, Sculptors, and Illustrators	27-1013	27-1013.00
*Technical Writers	27-3042	27-3042.00
*Court Reporters and Simultaneous Captioners	27-3092	27-3092.00
*Audio and Video Technicians	27-4011	27-4011.00
*Broadcast Technicians	27-4012	27-4012.00
*Sound Engineering Technicians	27-4014	27-4014.00
*Photographers	27-4021	27-4021.00
Healthcare Practitioners and Technical Occupations (N=5, 3.76%)		
*Respiratory Therapists	**29-1126**	29-1126.00
*Dental Hygienists	**29-1292**	29-1292.00
*Surgical Technologists	**29-2055**	29-2055.00
*Veterinary Technologists and Technicians	**29-2056**	29-2056.00
*Surgical Assistants	**29-9093**	29-9093.00
Protective Service Occupations (N=1, 0.75%)		
*Firefighters	33-2011	33-2011.00
Food Preparations and Serving Relations Occupations (N=1, 0.75%)		
*Chefs and Head Cooks	35-1011	35-1011.00
Office and Administrative Support Occupations (N=2, 1.50%)		
*Secretaries and Administrative Assistants, Except Legal, Medical, & Executive	43-6014	43-6014.00
*Desktop Publishers	43-9031	43-9031.00
Farming, Fishing, and Forestry Occupations (N=1, 0.75%)		
*Logging Equipment Operators	45-4022	45-4022.00
Construction and Extraction Occupations (N=31, 23.31%)		
*First-Line Supervisors of Construction Trades and Extraction Workers	47-1011	47-1011.00
*Solar Energy Installation Managers	47-1011	47-1011.03

Table A1. 117 STW SOC Level Occupations with No Detailed O*NET-SOC Occupations Nested Under Them (orange); 10 STW SOC Level Occupations Added Using Additional Data Sources (black); 3 STW SOC and 3 STW O*NET-SOC Level Occupations with a One-to-One Correspondence (black)

Occupation Name	SOC 2019	O*NET-SOC Version 25.1
*Boilermakers	47-2011	47-2011.00
*Brickmasons and Blockmasons	47-2021	47-2021.00
*Stonemasons	47-2022	47-2022.00
*Carpenters	47-2031	47-2031.00
*Construction Laborers	47-2061	47-2061.00
*Paving, Surfacing, and Tamping Equipment Operators	47-2071	47-2071.00
Pile Driver Operators	47-2072	47-2072.00
*Drywall and Ceiling Tile Installers	47-2081	47-2081.00
*Electricians	47-2111	47-2111.00
*Glaziers	47-2121	47-2121.00
*Pipelayers	47-2151	47-2151.00
*Plumbers, Pipefitters, & Steamfitters	47-2152	47-2152.00
*Reinforcing Iron and Rebar Workers	47-2171	47-2171.00
*Roofers	47-2181	47-2181.00
*Structural Iron and Steel Workers	47-2221	47-2221.00
*Solar Photovoltaic Installers	47-2231	47-2231.00
*Helpers-Brickmasons, Blockmasons, Stonemasons, and Tile & Marble Setters	47-3011	47-3011.00
*Helpers-Carpenters	47-3012	47-3012.00
*Helpers-Electricians	47-3013	47-3013.00
*Helpers-Pipelayers, Plumbers, Pipefitters, and Steamfitters	47-3015	47-3015.00
*Construction and Building Inspectors	47-4011	47-4011.00
*Energy Auditors	47-4011	47-4011.01
*Elevator and Escalator Installers and Repairers	47-4021	47-4021.00
*Derrick Operators, Oil and Gas	47-5011	47-5011.00
*Rotary Drill Operators, Oil and Gas	47-5012	47-5012.00
*Service Unit Operators, Oil and Gas	47-5013	47-5013.00
*Earth Drillers, Except Oil and Gas	47-5023	47-5023.00
*Continuous Mining Machine Operators	47-5041	47-5041.00
*Loading and Moving Machine Operators, Underground Mining	47-5044	47-5044.00
Installation, Maintenance, and Repair Occupations (N=40, 30.07%)		
*First-Line Supervisors of Mechanics, Installers, and Repairers	49-1011	49-1011.00
*Computer, Automated Teller, and Office Machine Repairers	49-2011	49-2011.00
*Radio, Cellular, and Tower Equipment Installers and Repairers	49-2021	49-2021.00
*Telecommunications Equipment Installers and Repairers, Except Line Installers	49-2022	49-2022.00
*Avionics Technicians	49-2091	49-2091.00
*Electric Motor, Power Tool, and Related Repairers	49-2092	49-2092.00
*Electrical and Electronics Installers and Repairers, Transportation Equipment	49-2093	49-2093.00
*Electrical and Electronics Repairers, Commercial and Industrial Equipment	49-2094	49-2094.00
*Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	49-2095	49-2095.00
*Electronic Equipment Installers and Repairers, Motor Vehicles	49-2096	49-2096.00
*Audiovisual Equipment Installers and Repairers	49-2097	49-2097.00
*Security and Fire Alarm Systems Installers	49-2098	49-2098.00
*Aircraft Mechanics and Service Technicians	49-3011	49-3011.00
*Automotive Service Technicians & Mechanics	49-3023	49-3023.00
*Bus and Truck Mechanics and Diesel Engine Specialists	49-3031	49-3031.00
*Farm Equipment Mechanics and Service Technicians	49-3041	49-3041.00
*Mobile Heavy Equipment Mechanics, Except Engines	49-3042	49-3042.00
*Rail Car Repairers	49-3043	49-3043.00
*Motorboat Mechanics and Service Technicians	49-3051	49-3051.00

Table A1. 117 STW SOC Level Occupations with No Detailed O*NET-SOC Occupations Nested Under Them (orange); 10 STW SOC Level Occupations Added Using Additional Data Sources (black); 3 STW SOC and 3 STW O*NET-SOC Level Occupations with a One-to-One Correspondence (black)

Occupation Name	SOC 2019	O*NET-SOC Version 25.1
*Motorcycle Mechanics	49-3052	49-3052.00
*Outdoor Power Equipment and Other Small Engine Mechanics	49-3053	49-3053.00
*Bicycle Repairers	49-3091	49-3091.00
*Recreational Vehicle Service Technicians	49-3092	49-3092.00
*Mechanical Door Repairers	49-9011	49-9011.00
*Control and Valve Installers and Repairers, Except Mechanical Door	49-9012	49-9012.00
*Heating, Air Conditioning, & Refrigeration Mechanics & Installers	49-9021	49-9021.00
*Industrial Machinery Mechanics	49-9041	49-9041.00
*Maintenance Workers, Machinery	49-9043	49-9043.00
*Millwrights	49-9044	49-9044.00
*Telecommunications Line Installers and Repairers	49-9052	49-9052.00
*Camera and Photographic Equipment Repairers	49-9061	49-9061.00
*Medical Equipment Repairers	49-9062	49-9062.00
*Watch and Clock Repairers	49-9064	49-9064.00
*Maintenance and Repair Workers, General	49-9071	49-9071.00
*Wind Turbine Service Technicians	49-9081	49-9081.00
*Commercial Divers	49-9092	49-9092.00
*Locksmiths and Safe Repairers	49-9094	49-9094.00
*Manufactured Building and Mobile Home Installers	49-9095	49-9095.00
*Signal and Track Switch Repairers	49-9097	49-9097.00
*Helpers-Installation, Maintenance, and Repair Workers	49-9098	49-9098.00
Production Occupations (N=24, 18.04%)		
*Engine and Other Machine Assemblers	51-2031	51-2031.00
*Structural Metal Fabricators and Fitters	51-2041	51-2041.00
*Timing Device Assemblers and Adjusters	51-2061	51-2061.00
*Meat, Poultry, and Fish Cutters and Trimmers	51-3022	51-3022.00
*Rolling Machine Setters, Operators, and Tenders, Metal and Plastic	51-4023	51-4023.00
*Patternmakers, Metal and Plastic	51-4062	51-4062.00
*Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	51-4081	51-4081.00
*Tool and Die Makers	51-4111	51-4111.00
*Layout Workers, Metal and Plastic	51-4192	51-4192.00
*Plating Machine Setters, Operators, and Tenders, Metal and Plastic	51-4193	51-4193.00
*Prepress Technicians and Workers	51-5111	51-5111.00
*Textile Winding, Twisting, & Drawing Out Machine Setters, Operators, & Tenders	51-6064	51-6064.00
*Model Makers, Wood	51-7031	51-7031.00
*Patternmakers, Wood	51-7032	51-7032.00
*Nuclear Power Reactor Operators	51-8011	51-8011.00
*Stationary Engineers and Boiler Operators	51-8021	51-8021.00
*Water and Wastewater Treatment Plant and System Operators	51-8031	51-8031.00
*Gas Plant Operators	51-8092	51-8092.00
*Chemical Equipment Operators and Tenders	51-9011	51-9011.00
*Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders	51-9021	51-9021.00
*Dental Laboratory Technicians	51-9081	51-9081.00
*Computer Numerically Controlled Tool Operators	51-9161	51-9161.00
*Computer Numerically Controlled Tool Programmers	51-9162	51-9162.00
*Etchers and Engravers	51-9194	51-9194.00
Transportation and Material Moving Occupations (N=5, 3.76%)		
*Ship Engineers	53-5031	53-5031.00
*Traffic Technicians	53-6041	53-6041.00

Table A1. 117 STW SOC Level Occupations with No Detailed O*NET-SOC Occupations Nested Under Them (orange); 10 STW SOC Level Occupations Added Using Additional Data Sources (black); 3 STW SOC and 3 STW O*NET-SOC Level Occupations with a One-to-One Correspondence (black)

Occupation Name	SOC 2019	O*NET-SOC Version 25.1
*Dredge Operators	53-7031	53-7031.00
*Gas Compressor and Gas Pumping Station Operators	53-7071	53-7071.00
*Pump Operators, Except Wellhead Pumpers	53-7072	53-7072.00

Bolded codes are both STEM and STW occupations.
*Occupations with 2019 job-ads Burning Glass Technologies.

Table A2. Number of STEM and STW Designations by 2018 SOC Minor Groups

SOC Code	SOC Occupation Name	STEM	STW	BOTH
11-0000 Management Occupations				
11-3000	Operations Specialties Managers	1		
11-9000	Other Management Operations	3	1	
13-0000 Business and Financial Operations				
13-2000	Financial Specialist		1	
15-0000 Computer and Mathematics				
15-1200	Computer	15	2	2
15-2000	Mathematical Science	6		
17-0000 Architecture and Engineering				
17-1000	Architects, Surveyors, and Cartographers	4	1	1
17-2000	Engineers	18		
17-3000	Drafters, Engineering Technicians, and Mapping Technicians	14	9	8
19-00004 Life, Physical, and Social Science				
19-1000	Life Scientists	12		
19-2000	Physical Scientists	9		
19-3000	Social Scientists and Related Work	12		
19-4000	Life, Physical, and Social Science Technicians	12	2	2
25-0000 Education Instruction and Library				
25-1000	Postsecondary Teachers	21		
27-0000 Art and Design Work				
27-1000	Art and Design Workers		1	
27-3000	Media and Communication Workers		2	
27-4000	Media and Communication Equipment Workers		4	
29-0000 Healthcare Practitioners and Technical				
29-1000	Healthcare Diagnosing or Treating Practitioners	45	2	2
29-2000	Health Technologists and Technicians	22	2	2
29-9000	Other Healthcare Practitioners and Technical Occupations	5	1	1
33-0000 Protective Service Operations				
33-2000	Firefighters		1	
35-0000 Food Preparation and Serving Related				
35-1000	Supervisors of Food Preparation and Serving Workers		1	
41-0000 Sales and Related				
41-4000	Sales Representatives, Wholesale and Manufacturing	1		
41-9000	Other Sales and Related Workers	1		
43-0000 Office and Administrative Support				
43-6000	Secretaries and Administrative Assistants		1	
43-9000	Other Office and Administrative Support Workers		1	
45-0000 Farming, Fishing, and Forestry				
45-4000	Forest Conservation, and Logging Workers		1	
47-0000 Construction and Extraction				
47-1000	Supervisors of Construction and Extraction Workers		1	
47-2000	Construction Trades Workers		16	
47-3000	Helpers, Construction Trades		4	
47-4000	Other Construction and Related Workers		4	
47-5000	Extraction Workers		6	
49-0000 Installation, Maintenance, and Repair				
49-1000	Supervisor of Installation, Maintenance, and Repair Workers		1	
49-2000	Electrical and Electronic Equipment Mechanics, Installers, Repairers		11	
49-3000	Vehicle and Mobile Equipment Mechanics, Installers, Repairers		11	
49-9000	Other Installation, Maintenance, and Repair		18	
51-0000 Production				
51-2000	Assemblers and Fabricators		3	

Table A2. Number of STEM and STW Designations by 2018 SOC Minor Groups

SOC Code	SOC Occupation Name	STEM	STW	BOTH
51-3000	Food Processing Workers		1	
51-4000	Metal Workers and Plastic Workers		6	
51-5000	Printing Workers		1	
51-6000	Textile, Apparel, and Furnishing Workers		1	
51-7000	Woodworkers		2	
51-8000	Plant and System Operators		4	
51-9000	Other Production Occupations		6	
53-0000 Transportation and Material Moving				
53-5000	Water Transportation Workers		1	
53-6000	Other Transportation Workers		1	
53-7000	Material Moving Workers		3	