



EDUCATION AND LABOR

Supporting Middle-Skills STEM Workforce Development

Analysis of Workplace Skills in Demand and Education Institutions' Curricular Offerings in the Oil and Gas Sector

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Preface

Employers are struggling to find skilled workers who can contribute to their companies' growth and success, especially in “middle-skills” job fields involving science, technology, engineering, and mathematics (STEM). While the overall shortage of such workers is clear, little is known about the shortage's extent or its root causes. One possible cause is education and workforce systems' inability to keep pace with the changing needs of the economy; employers' skill demands are not aligned with the curricula and programming of education institutions that produce the labor pool for the sub-baccalaureate STEM labor market.

Understanding the relationship between sub-baccalaureate programs' curricula and the needs of employers is crucial for both education policy research and for understanding how local colleges and employers can jointly improve the economic prospects of the labor force that does not seek four-year degrees. To better understand the relationship between sub-baccalaureate programs' curricula and the needs of employers, RAND Corporation researchers in 2017 administered a survey to instructors who taught applied technical and industrial courses in STEM fields in five purposefully selected community and technical colleges in Ohio, Pennsylvania, and West Virginia. Our findings of a lack of alignment highlight the need for industry and college leadership to commit resources to align instruction to employer needs.

This study was undertaken by RAND Education and Labor, a division of the RAND Corporation that conducts research on early childhood through postsecondary education programs, workforce development, and programs and policies affecting workers, entrepreneurship, financial literacy, and decisionmaking. This research was generously supported by a grant from the National Science Foundation (NSF #1535322).

More information about RAND can be found at www.rand.org. Questions about this report should be directed to the lead author Gabriella C. Gonzalez at ggonzal@rand.org, and questions about RAND Education and Labor should be directed to educationandlabor@rand.org.

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Summary

“Middle-skills” jobs require more education and training than that provided by a high school diploma but less education and training than a four-year college degree. Workers with middle-skills jobs include carpenters, machinists, mechanics, electricians, production workers, computer support specialists, computer systems analysts, and drafters. The middle-skills job sector is the fastest-growing job market in the U.S. economy (Landivar, 2013; Graf, Fry, and Funk, 2018). However, employers reportedly struggle to find workers with the needed combination of knowledge and skills—especially in science, technology, engineering, and mathematics (STEM)—for these positions (Gonzalez et al., 2015). This search for workers is particularly pertinent to the tri-state region of Pennsylvania, Ohio, and West Virginia, where the boom from new oil and natural gas extraction technologies has propelled the region economically.

Little rigorous research has been devoted to measuring how well education and workforce systems, both in the tri-state region and across the United States, are keeping pace with the changing needs of the economy. Policymakers and employers lack a full understanding of the problem and therefore lack possible solutions that could support a well-functioning, agile, and efficient workforce development system. One key part of understanding the problem is to document the alignment between employers’ skill demands and the curricula and programming of education institutions focused on producing the labor pool needed for the middle-skills STEM labor market. It is also important to understand the knowledge, skills, and abilities (KSAs) that students in sub-baccalaureate programs find most challenging.

Objectives of This Study and Research Questions

This report, produced by the RAND Corporation with support from the National Science Foundation, builds on analyses of a 2016 survey of oil and gas employers and providers of education and training in the tri-state region (Bozick et al., 2017). Researchers documented the KSAs required by employers in the oil and natural gas industry, assessed the extent to which colleges were positioned to provide employers in the oil and natural gas industry with workers who had appropriate knowledge and skills for high-priority occupations, and identified collaborative strategies and practices in place that connected employers in the oil and natural gas industry with educators. Bozick et al. found some gaps in the demands of oil and gas industry employers and the *general* programming offered by the education providers in the region. However, this survey was not able to probe specific curricular offerings or challenges that students might have with specific KSAs. The analyses documented in this report fill those gaps by exploring and describing what knowledge areas and skill areas instructors deemed important in their courses, both *in practice* and as *intended*, within a purposefully selected set of

community and technical colleges in the tri-state region.¹ These colleges were selected because they have been part of a consortium of public education and training providers and private oil and gas corporations (a sector-based public-private partnership called ShaleNET). Researchers administered a survey to instructors in the sample of colleges in the tri-state region in 2017.

Our analyses answered two questions:

1. How well aligned were the content, skills, and workplace learning opportunities in the tri-state region's college courses with the needs that the region's STEM employers reported?
2. What content areas were most challenging for students and thus may be areas in which students require more support?

Data and Methods

College Sample Selection

We selected five colleges in the tri-state region that had training partnerships with oil and gas industry companies. These colleges were part of a tri-state broad-based public-private partnership called ShaleNET, which involved in-depth collaboration among key regional employers in the oil and gas industry, nonprofit oil and gas employer member associations, and colleges. The five colleges included in this study were

- Beaver County Community College (Pennsylvania)
- Pennsylvania College of Technology (Pennsylvania)
- Pierpont College (West Virginia)
- Stark State College (Ohio)
- Westmoreland Community and Technical College (Pennsylvania).

Two characteristics distinguished these colleges from other sub-baccalaureate STEM training programs, making them ideal sites to explore the alignment between curricular offerings and the demands of middle-skills STEM oil and gas jobs. First was their degree of industry alignment; the designers of the ShaleNET training program specifically crafted curricula to meet the skill sets needed in high-demand occupations, with the goal of creating a more direct and reliable pathway to middle-skills STEM jobs. Second, these colleges employed a unique curricular model that offered “stackable credentials.” With a standardized curriculum for ten programs and three tiers of training, students had the option of multiple entry and exit points depending on their desired credentials, and training could be completed at any of the colleges, with easy transfer of credits across colleges (Dunham et al., 2016).

¹ A growing body of literature indicates that *intended* curriculum can change considerably when that curriculum is *enacted* by teachers in their classrooms (Huntley and Chval, 2010; Stein and Kauffman, 2010; Remillard, 2000).

TRI-STATE Workforce Preparation Survey and Course Syllabi

To probe specific course curricula and syllabi both *in practice* and as *intended* within the sample colleges, we relied on two sources of data: (1) a survey (referred to as the TRI-STATE Workforce Preparation Survey) fielded in the spring and fall of 2017 to instructors at the selected colleges and (2) instructors' course syllabi.

Survey design. We developed the TRI-STATE Workforce Preparation Survey to gather data regarding instructors' perspectives on key knowledge and skills emphasized in courses they taught. We used the U.S. Department of Labor's Employment and Training Administration's conceptualization of knowledge and skills, in which *knowledge* represents the "acquisition of facts and principles about a domain of information," and *skills* are the "procedures to work with given knowledge" (Reeder and Tsacoumis, 2017a, 2017b). We selected the KSAs included in the 2016 survey to oil and gas employers and education providers (Bozick et al., 2017). We identified high-priority occupations in the oil and gas industry sector and then used a repository of occupational information and analysis maintained by the U.S. Department of Labor Employment and Training Administration to identify KSAs and other characteristics necessary for those occupations.²

Knowledge areas we inquired about in both surveys were:

- Automation (e.g., programmable logic controllers, electronics)
- Blueprint reading
- Building and construction
- Design and computer-assisted design (CAD)
- Commercial driver's license and driver training
- Chemistry or chemistry-related materials
- Computer science (e.g., software, computer programming classes)
- Corrosion
- Oil and gas drilling, including drilling technology
- Electrical (e.g., electric circuits, machinery)
- Energy systems (including solar technology)
- Engineering and technology
- English (e.g. reading, writing)
- Geology
- Heating, ventilation, and air conditioning
- Hydraulic and pneumatic systems (e.g., gas and fluids compression, flow)
- Manufacturing, production and processing, including assembly
- Safety (e.g., Occupational Safety and Health Administration regulations and compliance)
- Industrial Instrumentation and sensors (e.g., measurement, mechatronics, process controls)
- Mathematics (e.g., algebra, applied math)
- Mechanics and motors (e.g., mechanics, mechanical drive components)
- Oil and gas industry (e.g., "about the oil and gas industry" courses)
- Pipelines and pipeline operation
- Well-pad/gas and oil lease operations, including well servicing
- Physics, including statics and strength of materials)
- Power plant and power systems
- Rigging
- Pumping (e.g., sucker rod pumping, free plunger lift)
- Soft skills (e.g. leadership skills, interpersonal communication)
- Welding
- Other

² See Bozick, et al., 2017, for more details on how researchers identified the set of skills.

Skill areas we inquired about were:

- Administration and management
- Applying new learning
- Active listening
- Complex problem-solving
- Coordinating actions
- Critical thinking
- Equipment maintenance
- Equipment selection
- Machine or equipment installation
- Instructing others
- Judgment and decisionmaking
- Use of learning and study strategies
- Management of financial resources
- Management of material resources
- Management of personnel
- Monitoring performance of self and others
- Negotiation with others
- Operation of equipment or systems
- Operation monitoring (monitoring gauges, dials or other indicators)
- Operations analysis (needs analysis to create a design)
- Persuasion
- Quality control analysis
- Repairing machines or systems
- Service orientation
- Social perceptiveness
- Speaking to others
- Systems analysis and evaluation
- Design of technology
- Time management
- Troubleshooting
- Other skills

Instructor sample selection, survey administration, and syllabi collection. Our survey sample included instructors in gas/oil and applied industrial programs of study at each of the five participating institutions. In total, we identified 42 programs across the five institutions with instructors teaching relevant courses. Altogether, we identified 180 instructors (in four institutions) to whom we sent our spring 2017 survey, and 181 instructors (in five institutions) to whom we sent our fall 2017 survey.³ In addition to responding to the survey, we asked instructors to upload the course syllabus for each course about which they responded. Of the 72 instructors who responded in spring or fall 2017, 11 responded in both the spring and fall waves and 17 responded about two courses they taught, which provided us with a total of 100 responses about specific courses. This provided us with a 27-percent survey response rate for spring 2017 and 18-percent response rate for fall 2017. Of those instructors, 38 uploaded a syllabus with their responses to their courses in either spring or fall 2017.

Analytic Approach

To describe which participating college's applied technical courses convey KSAs required of employers in the sub-baccalaureate STEM labor market, we compared the reported needs of each states' employers in terms of KSA requirements (as determined from the analysis in Bozick et al., 2017) with a content review of the *intended curriculum* and the *enacted curriculum* for all ShaleNET and adjacent programs. To document the KSAs for each course, we conducted basic descriptive analyses of instructors' responses to the survey. We also conducted regression analyses to explore whether responses varied by instructors' self-reported collaboration with industry and whether instructors were full or part time.

We grouped the knowledge areas into five categories:

³ Instructors at the Beaver County Community College were only surveyed in fall 2017 because their participation in the ShaleNET/TEAM consortium did not begin until the 2017–2018 school-year.

- **Academic** encompassed subjects traditionally taught in colleges and universities that serve as the theoretical underpinning of many other classes (i.e., mathematics, engineering, or English).
- **Specific to the oil and gas industry** captured the technical knowledge areas that are specific to that field, including oil and gas leasing, oil and gas drilling, or pumping.
- **Technical** included all other technical knowledge areas that could be applied to the oil and gas industry or to other adjacent technical fields.
- **Safety** included classroom and occupational safety.
- **Soft skills** captured all the nonacademic knowledge areas valued by employers.⁴

We grouped the skill areas into four categories:

- **Cognitive skills** included skills that enhanced a student’s ability to understand and digest material, such as critical thinking, active listening, and applying new knowledge.
- **Operations and analysis skills** captured those skills needed on the job to perform operations and duties, such as equipment maintenance and operations analysis.
- **Management skills** encompassed skills related to personnel management and leadership, such as monitoring performance of self and others.
- **Interpersonal skills** included skills related to a students’ ability to relate and communicate with others, such as social perceptiveness.⁵

We also conducted qualitative analyses of the 36 syllabi uploaded by instructors for the courses they taught in order to gain additional insights on which topics and skills were formally *intended* to be taught in their courses. Syllabi were coded for the specific knowledge and skills that they addressed, using the knowledge and skill lists that were part of the instructor survey. In addition, themes in regard to specific soft skills addressed in syllabi were documented to determine any trends in skills addressed within syllabi. To establish reliability in our coding, four researchers coded six syllabi together and established decision rules for specific areas where codes were not applied consistently. Then, two researchers coded the remaining syllabi together, periodically meeting to come to consensus on any codes that were different for each syllabus that had been coded.

⁴ The research team engaged in an iterative process in creating the categories with the goal of balancing the categories’ specificity and number. We include soft skills as a general knowledge area to encompass all the areas of knowledge an instructor could address in his or her courses, as well as to illustrate the extent to which instructors perceived themselves as addressing soft skills more generally in relation to other knowledge areas.

⁵ To create the four categories, the research team made the following decisions: renaming the basic skills category the cognitive category, eliminating the systems skills category by moving judgement and decisionmaking skills to the cognitive category and systems analysis skills to the technical category, eliminating the complex problem-solving category by moving complex problem-solving skills to the cognitive category, moving troubleshooting skills from the technical to the cognitive category, renaming the social skills category the interpersonal category, moving speaking to other from the cognitive category to the interpersonal category, moving monitoring performance of self and others from the cognitive to the management category, and moving instructing other and coordinating actions from the interpersonal to the management category.

Summary of Key Findings

- **Instructors reported that they emphasized cross-cutting knowledge areas—those that are applicable to a variety of different courses and fields—more than occupation-specific areas.** This is not particularly surprising, as many of these courses integrate both academic and technical concepts by design and focus on occupational applications that do not always directly map onto a single academic discipline or approach. Moreover, increasing attention has been paid to ensuring that occupationally focused programs convey general job skills so as to prepare students for a wide variety of jobs after graduation (Stone and Lewis, 2012).
- **“Safety” was the most-emphasized knowledge area (65 percent of courses),** which may stem from the fact that safety is a critical component of almost all jobs and tasks in technical fields, including the oil and gas industry, and must therefore be reinforced in each class.
- **“Soft skills” knowledge (workplace competencies, such as being able to work in a team) was the second most-emphasized area (28 percent of courses).** This relatively strong emphasis on soft skills, compared with other knowledge areas we surveyed, is in keeping with employers’ increasing demand for workers who have proficiency in this area. It is a knowledge area applicable to a variety of jobs and contexts.

In addition to asking about the knowledge areas they emphasized, the survey asked instructors how much emphasis they placed on each of a list of individual skill areas. The list mirrored the skills inquired about in the employer survey fielded in 2016 and reported in Bozick et al. (2017) to probe whether there was an alignment between the skills employers sought and the skills instructors emphasized. We found the following:

- **Instructors emphasized cognitive skills more than interpersonal skills in their courses.** Cognitive skills were overall the most-emphasized skills by instructors, with an average of 64 percent of courses including an emphasis on cognitive skills. About three-quarters of courses emphasized critical thinking, active listening, and applying new learning in many or all of their classes, and about two-thirds of courses emphasized complex problem-solving, judgement and decisionmaking, and troubleshooting. These six skills were the most emphasized of all the skills in any category. The high level of emphasis suggests that instructors were attempting to impart habits of mind and approaches to situations and problems that can be applied across jobs in the oil and gas industry and even in other sectors.
- **Syllabi often matched the knowledge areas and skills that instructors stated they emphasized.** The top knowledge areas that came up in more than one-third of syllabi were similar to the most commonly emphasized knowledge areas in the instructor survey: safety, electrical, computer science, math, English, and instrumentation/sensors. The two top skills that came up in more than one-third of syllabi were operation of systems or equipment (36 percent of syllabi) and troubleshooting (33 percent of syllabi). Those two skills were also two of the top skills emphasized in survey reports, although higher percentages of instructors indicated emphasizing those skills in their courses (52 percent emphasized operation of systems or equipment, and 60 percent emphasized troubleshooting).
- **However, several knowledge areas and skills commonly emphasized in the survey were less frequently addressed in syllabi,** including engineering (emphasized by 49

percent of instructors in the survey but in only 14 percent of syllabi) and manufacturing (emphasized by 35 percent of instructors in the survey versus 22 percent of syllabi). Instructors might have a broader definition of engineering and manufacturing than those who coded the syllabi, or perhaps engineering and manufacturing topics naturally came up in the course of teaching core course content without being named in syllabi as teaching topics. Many skills emphasized by over half of instructors in the survey were rarely if ever mentioned in syllabi, including judgment and decisionmaking (no syllabi), complex problem-solving (11 percent of syllabi), active listening (11 percent of syllabi), applying new learning (6 percent of syllabi), and critical thinking (8 percent of syllabi). Syllabi might be written to note key knowledge, rather than skills.

- **A greater percentage of employers sought nontechnical skills in interpersonal and management knowledge areas compared with the percentage of courses that emphasized them.** The results from the Bozick et al. (2017) survey indicated that employers' most-wanted skills were critical thinking, judgement and decisionmaking, and complex problem-solving. Strikingly, none of the skills most sought after by employers, as determined in Bozick et al., fall in the technical category. Three of the skills (speaking, negotiation, and social perceptiveness) are interpersonal skills, the category of skills *least* emphasized by instructors in the survey. Another three skills emphasized by employers (management of personnel resources, time management, and coordination) were management skills, the second least emphasized category of skills by instructors. These patterns support the notion that these skills are high demand, but that instructors may be undervaluing them in the classroom.
- **A greater percentage of instructors reported emphasizing technical and cognitive skills than the percentage of employers who reported seeking such skills.** Of the five skills with the greatest discrepancy between instructors' and employers' responses on the surveys, three were technical (operation and control, equipment selection, and technology design) and two were cognitive (troubleshooting and learning strategies). These results do not necessarily suggest that instructors should emphasize these skills to a lesser degree; indeed, employers' responses regarding which skills their high-demand jobs required could be influenced by the lack of supply of workers with those skills. That is, they may have been less likely to indicate cognitive and technical skills were required if workers were graduating from programs with those skills.
- **Instructors partnering with industry were more likely to emphasize skills that were more valued by employers.** Instructors may have recognized this need for management skills as they collaborated with their industry peers. In addition, while the oil and gas industry knowledge area category were the least emphasized among instructors, partnerships with industry were related to more emphasis on oil and gas, which may be highly aligned to the pool of potential jobs.
- **Part-time instructors composed the majority of the survey sample.** Fifty-seven percent of respondents indicated that they were part-time instructors. While we do not have evidence to suggest that full-time instructors are more effective than part-time instructors (or vice versa), this substantial number of part-time instructors in our sample highlights the importance of a deeper understanding of the instructor labor market, the supply of full-time and part-time instructors available to local colleges, and pros and cons of each group.

To answer the second research question, we examined which knowledge areas and skills were particularly challenging for students to learn, according to their instructors, and which resources instructors wished they had greater access to. We found the following:

- **Instructors reported that students had the most difficulty with technical and academic knowledge areas in their courses.** This was particularly the case for math, which was a knowledge area that instructors both emphasized “to a strong degree” and therefore warranted particular attention.

The knowledge area “soft skills” was another area in which instructors reported their students had difficulty.

- **Although instructors reported that students struggled with multiple skills, cognitive and management skills reportedly posed the greatest difficulty for students.** Given that cognitive skills were among the most-emphasized skills by employers, as documented in Bozick et al. (2017) and by instructors, it may be that more resources are needed to support students’ learning these skills. Management skills, which are also in high demand by employers, may be another area that warrants further attention.
- While the mix of barriers depends on the types of knowledge area the instructor endeavored to teach, **respondents reported that money and time were the greatest barriers in conveying the knowledge and skills to students.** The varied perceptions of resource needs by instructional focus indicates that optimal allocation of resources should consider the specialized nature, and therefore needs, of classes instructors teach.
- **There is a clear and positive association between instructors reporting that they needed more resources and also reporting more student difficulty.** Though more research needs to be done to understand whether a resource deficit is hurting student acquisition of knowledge or skills, our findings underscore the fact that classrooms and instructors need to be well-resourced if students are to learn abstract and specialized forms of knowledge.

Conclusions

Understanding the relationship between sub-baccalaureate programs’ curricula and the needs of employers is crucial for both education policy research and for the broader consideration of how local colleges and employers can jointly improve the economic prospects of the labor force that does not seek four-year degrees. Our findings highlight the need for industry and college leadership to consider committing resources to align instruction to employer needs. Although we purposefully selected colleges that had designed programs in tandem with industry leaders, disconnects between curriculum and industry demands in knowledge areas and skills evidently remained. The inability to coordinate has left the door open for some mismatches between the skills sought after by employers and the skills taught by instructors. This suggests that further effort by employers, colleges, and third-party interest groups to bridge this gap and encourage dialogue between instructors and employers could result in more aligned curricula.

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Abbreviations

CAD	computer-assisted design
ETA	Employment and Training Administration
HVAC	heating, ventilation, and air conditioning
KSA	knowledge, skills, and abilities
O*NET	Occupational Information Network Data Collect Program
OLS	ordinary least squared
STEM	science, technology, engineering, and mathematics
TEAM	Tri-State Energy and Advanced Manufacturing Consortium

1. Introduction

As of 2016, 17.3 million workers ages 25 and older—13 percent of the 131.3 million people in the U.S. workforce—were employed in jobs that required science, technology, engineering, and mathematics (STEM) skills and training (Graf, Fry, and Funk, 2018). Growth of STEM employment has markedly outpaced the growth of overall employment in the United States: Between 1990 and 2016, STEM employment grew 79 percent, whereas overall employment grew only 34 percent (Graf, Fry, and Funk, 2018).¹ As the STEM economy grows, business leaders are pressuring—and in some cases, investing in—schools to emphasize STEM skills that are directly required on the job (Tai, 2012).

This is particularly the case for “middle-skills” STEM jobs. Middle-skills workers—such as carpenters, machinists, mechanics, electricians, production workers, computer support specialists, computer systems analysts, and drafters—require more education and training than a high school diploma but less than a four-year college degree (Landivar, 2013; Graf, Fry, and Funk, 2018). A 2013 report by the Brookings Institution refers to this sub-baccalaureate segment of the STEM labor market as the “second STEM” economy (Rothwell, 2013). While STEM workers tend to be highly educated, roughly 6 percent of the STEM workforce has not attended college, 14 percent has some college but no degree, and 15 percent has an associate’s degree only. While middle-skills workers can be in non-STEM fields, they are more prevalent in STEM field occupations, such as health care practitioner and technician, computer worker, and engineer (Graf, Fry, and Funk, 2018).

For workers with only a high school diploma or associate degree, wages for STEM jobs are substantially higher than wages in other fields (Carnevale, Smith, and Melton, 2011). However, the supply of workers to fill middle-skills STEM jobs is not meeting the demand: According to analyses of the May 2015 Bureau of Labor Statistics Occupational Employment Statistics, conducted by the National Skills Coalition, 53 percent of all U.S. jobs were middle-skills jobs, yet only 43 percent of employees possessed the necessary skills to meet middle-skills role demands. Moreover, estimates project that between 2014 and 2024, 48 percent of job openings will be for middle-skills jobs (National Skills Coalition, undated). The lack of a properly skilled workforce is hindering the ability of U.S. businesses to compete globally (Accenture, Burning Glass, and Harvard Business School, 2014); it also hampers U.S. workers from earning more and

¹ There is no standard definition of a *STEM job*. A methodology developed by the Brookings Institution, with the support of the U.S. Department of Labor’s Employment and Training Administration, defines STEM jobs based on Occupational Information Network Data Collect Program (O*NET) codes for 736 occupations; the degree of knowledge in STEM was qualitatively assessed by workers in those occupations (for more details, see Rothwell, 2013; and Baird, Bozick, and Harris, 2017). Another methodology utilizes the occupational classification scheme developed by the U.S. Census, which groups occupations into 468 categories, of which 74 are defined as STEM occupations (IPUMS, undated). This methodology has been used in recent Pew Research Center studies (see Graf, Fry, and Funk, 2018).

improving their living standards. Millions of job postings go unfilled even as millions of people remain unemployed or underemployed (Accenture, Burning Glass, and Harvard Business School, 2014). The demand for middle-skills STEM positions should only grow, as members of a rapidly aging workforce retire (Gonzalez et al., 2015).

The expansion of the middle-skills STEM job market is particularly striking in Ohio, Pennsylvania, and West Virginia (hereafter referred to as *the tri-state region*). Improvements in horizontal drilling and hydraulic fracturing technologies allowed unconventional oil and natural gas production in the tri-state region's Utica and Marcellus Shale plays. Since 2011, this region has experienced an increase in the number of middle-skills STEM job openings in the oil and natural gas industry (Pickenpaugh and Adder, 2018). Following a steady decline in well-paid, blue-collar factory jobs, the oil and natural gas industry has emerged as the new nexus of entry-level and midlevel STEM jobs in the tri-state region. Employment in the core occupations of the gas industry increased 130 percent—more than 15,000 jobs—from 2009 to 2013, with average wages reaching \$90,000 per year (Center for Workforce Information and Analysis, 2014). However, the rapid growth of the industry has outpaced the workforce. A 2012 report by Development Dimensions International highlighted difficult-to-fill occupations with high-volume hiring projected through 2020 in the tri-state region; most of these positions were middle-skills STEM jobs (Kauffman and Fisher, 2012). Two studies on the tri-state region's workforce reinforce this forecast:

- The region is estimated to experience a shortfall of 80,000 workers by 2025, based on baby boomer retirements, modest job growth, and a talent pipeline not large enough to fill these openings.
- The fastest growing sub-baccalaureate occupations are in STEM fields, such as health care, production/maintenance, data science, and information security.
- New business investments (e.g., autonomous vehicles, additive manufacturing, robotics, the ethane cracker) in the tri-state region could add new job demands, particularly for mechanical, electrical, and software engineers and for maintenance technicians. However, the region's high school career and technical education programs are underenrolled for these occupations.
- Traditional industries are being disrupted by technological advances, and employers and talent are not keeping pace (Burning Glass Technologies, The Council for Adult and Experiential Learning, and Allegheny Conference on Community Development, 2016; Allegheny Conference on Community Development, undated).

To create a workforce development system that is adaptable and sufficiently agile to support the flexibility needed for U.S. STEM industries in general, and in the tri-state region specifically, stakeholders must better understand how to align postsecondary education and training for STEM middle-skills jobs with workforce demands. Employers are struggling to find skilled workers who can contribute to their companies' growth and success. Yet little is known about how the curricula and programming of the educational institutions that provide this training align with employers' skill demands. We also do not know what aspects of curricula are most challenging for students and areas for possibly more focus and support for students.

A workforce development system includes a variety of secondary (career and technical education) and postsecondary education and training opportunities and institutions. These include credit-bearing and workforce development noncredit-bearing programs through community colleges and colleges; private training centers that offer short-term courses and licensing; and vocational and trade programs offered through unions (Gonzalez et al., 2015). These institutions and initiatives provide a range of programming that could potentially fill the education and training needs of the STEM labor market.

Two-year colleges and trade schools are a central component of the broad workforce development system. They play an integral role in STEM professional workforce development: Over 40 percent of bachelor's and master's degree recipients attended community college at some point in their studies (Mooney and Foley, 2011). Students rely on two-year colleges and trade schools because of their low tuition and fees, proximity to jobs and family, and open admissions (Tsapogas, 2004). Because groups underrepresented in STEM fields are a significant portion of students at two-year schools, STEM workforce development programming at these schools offers an added opportunity to increase diversity and broaden participation in STEM.

Two-year colleges and trade schools are especially important to local labor markets. Non-college-bound youth often remain in their hometowns after high school graduation and use two-year colleges and trade schools as their primary method of entry into sub-baccalaureate jobs, including STEM jobs. These jobs, unlike high-skill STEM jobs that require bachelor's degrees, are geographically dispersed and available in nearly every major metropolitan region (Rothwell, 2013). Therefore, investments in workforce development for the "second STEM economy" will likely require strategies that build on the curricula and programming in community colleges.

The importance of studying STEM curricula and training in two-year schools is even more urgent given the lower retention rates for two-year schools and programs compared with four-year programs (National Student Clearinghouse Research Center, 2017). Researchers have specifically called for more studies to understand teaching and learning at two-year higher education institutions, particularly in STEM programs (Labov, 2012; National Science Board, 2010; Perin, 2001). Such studies are particularly needed given that the majority of students attending two-year institutions of higher education are enrolled in elementary, noncredit, and remedial courses that are likely not preparing them for STEM occupations (Goldrick-Rab, 2010). We need a better understanding of both the instruction that students receive and the main learning challenges they face in order to support and improve STEM preparation offered within two-year programs.

Objectives of This Study

This report, produced with support from the National Science Foundation, builds on analyses of a 2016 survey of STEM employers (specifically in the oil and natural gas industries) and education and training providers in the tri-state region (Bozick et al., 2017). That report documented the knowledge, skills, and abilities (KSAs) required by these employers, assessed the extent to which regional colleges are positioned to provide employers in the region with

workers who have appropriate knowledge and skills for high-priority STEM middle-skills occupations, and identified collaborative strategies and practices in place that connect STEM employers in the region with educators. Bozick et al. provides a descriptive portrait of the alignment between regional employers' KSAs and regional educational offerings, but it does not illuminate how well STEM education and training providers are providing the appropriate and needed KSAs to their students *in practice*.

In this report, based on surveys administered in spring and fall 2017 and analysis of syllabi of courses taught in technical industrial programs, we closely examine the coursework and curricular offerings of a purposefully selected set of community and technical colleges in the tri-state region to provide a descriptive portrait of the extent to which offerings aligned with the reported demands of tri-state region employers who participated in the 2016 survey. Our analyses focus on general applied technical fields, as well as oil- and gas-specific fields, to capture how well postsecondary institutions offer broadly applicable knowledge and skills. Our findings and recommendations are intended to apply to a variety of applied industrial fields, including engineering-related and other advanced manufacturing or technical occupations.

Specifically, we sought to answer two questions:

1. How well aligned were the content, skills, and workplace learning opportunities in the tri-state region's college courses with the needs that the region's STEM employers reported?
2. What content areas were most challenging for students and thus may be areas where students require more support?

To address the first question, we provide descriptive evidence on the types of knowledge areas and skills that instructors emphasized in their courses, identifying overarching themes in the findings. We then compare the degree to which employers demand a skill to the degree to which instructors emphasized the skill to highlight possible areas of alignment and mismatch between supply and demand. Because the partnering of instructors with industry can be an important mechanism by which the demand and supply of skills are aligned, we employ ordinary least squared (OLS) regression to understand how instructors' emphasis in skills and knowledge areas differed among instructors who partnered with industry and those who did not. Furthermore, we probe the types of activities instructors engaged in when they reported partnering with industry.

To address the second question, we report descriptive results on a set of questions that asked instructors to identify knowledge and skills with which students had difficulty understanding. We identified overarching patterns in which the degree to which skills and knowledge areas emphasized were related to the degree to which instructors reported students' having difficulty. Because resource constraints may be a barrier to effective teaching and a contributing factor to student difficulty, we analyzed the types of resources instructors reported needing and how they varied by knowledge area. Finally, we used OLS regressions to understand the degree to which the number and types of resources requested were related to the degree of students' having difficulty with a knowledge or skill area, as reported by the instructor.

Together, this report and Bozick et al. contribute new knowledge to our understanding of the role that sub-baccalaureate programs play in providing potential middle-skills workers with the skills and training necessary to succeed in the oil and natural gas industry and in the broader STEM labor market. Understanding the relationship between sub-baccalaureate programs' curricula and employers' needs is crucial for both education policy research and for the consideration of how local colleges and employers can jointly improve the economic prospects of the labor force that does not seek four-year degrees. In turn, this information is vital for supporting an agile and effective workforce development system for the second STEM economy.

In the subsequent sections of this chapter we explain the process for selecting the colleges in our study and provide a roadmap for the remainder of this report.

College Sample Selection

To answer this study's research questions, we purposefully selected five colleges in the tri-state region that had exemplar public-private partnerships (collaborations between public education institutions and private business entities) in place that targeted training for high-demand occupations in the oil and gas industry.

The five colleges included in this study were:

- Beaver County Community College (Pennsylvania)
- Pennsylvania College of Technology (Pennsylvania)
- Pierpont College (West Virginia)
- Stark State College (Ohio)
- Westmoreland Community and Technical College (Pennsylvania).

These colleges were purposefully selected because of their history of working collaboratively in a tri-state public-private partnership, known as ShaleNET, since 2010. Three of the colleges (Pennsylvania College of Technology, Stark State College, and Westmoreland Community and Technical College) were the original members of ShaleNET, which was funded by a 2010 and a 2014 grant from the U.S. Department of Labor's Employment and Training Administration. Pierpont Community and Technical College was included in the ShaleNET consortium in 2014. Beaver County Community College joined the consortium in 2016, when the 2014 grant ended; it is now the "hub" college under the consortium's new name, Tri-State Energy and Advanced Manufacturing (TEAM) Consortium. More information about ShaleNET and TEAM are available in Appendix A.

Two features distinguish ShaleNET (and its successor, TEAM) from more traditional sub-baccalaureate STEM training programs, which made these colleges ideal sites to explore the alignment between curricular offerings and the demands in middle-skills STEM oil and gas jobs. First was the degree of industry alignment; ShaleNET training programs were specifically targeted to high-demand occupations, with the goal of creating a more direct and reliable pathway to middle-skills STEM jobs. This industry alignment was the result of a broad-based public-private partnership, with collaboration among key regional employers in the oil and gas

industry, nonprofit oil and gas employer member associations (the Pennsylvania Independent Oil and Gas Association, the Independent Oil and Gas Association of West Virginia, the Ohio Oil and Gas Association, and the Allegheny Conference on Community Development), and regional post-secondary education and training institutions.

The second unique feature of ShaleNET was the “stackable credential model.” With a standardized curriculum for ten programs and three tiers of training, students had the option of multiple entry and exit points depending on the desired credentials. Training could be completed at any of the ShaleNET schools, with easy transfer of credits across schools. This tiered training model provided a unique opportunity to study the returns on educational investments for different levels of sub-baccalaureate training. This tiered model could be replicated in other sectors and regions, where employers and stakeholders are considering which degree programs could be minimally necessary to sustain a productive workforce (Dunham et al., 2016).

Limitations of Analyses

It is important to highlight that these analyses are descriptive in nature; the associations we found are intended to provide a portrait of the curricular offerings at the sub-baccalaureate level and how those offerings compare to employer needs. We were not able to infer causality or assess the alignment of curricular offerings with industry demands as compared with other partnerships; one would hope that a strong sector-based, public-private partnership would approach complete alignment.

While the analyses reported here cannot elucidate causal relationships, they do provide a critical starting point in our understanding of sub-baccalaureate level workforce training. These findings are intended to be useful for various stakeholders and could be applicable to any industry grappling with rapid innovative changes and emerging technologies. The high-level, descriptive findings may guide researchers to engage in more research with a larger, more representative sample of instructors.

Organization of This Report

Chapter Two describes the data and methodology employed to answer the study’s two research questions. Chapter Three addresses the first question; Chapter Four addresses the second. Chapter Five summarizes the study’s key findings and offers some recommendations for the tri-state region in supporting a workforce development system for middle-skills STEM occupations. Appendix A describes the ShaleNET and TEAM consortia in more detail. Appendix B provides a list of the knowledge and skill areas used in our instructor survey. Appendix C provides technical details of our analyses.

2. Data, Methods, and Analytic Approach

We relied on two sources of data to address this study’s research questions: a survey (called the TRI-STATE Workforce Preparation Survey) administered in the spring and fall of 2017 to instructors in the five participating colleges described in Chapter One and course syllabi provided by the instructors who responded to the survey. The targeted population for survey respondents included instructors in programs that specifically focused on preparation for the oil and gas industry (such as the Oil and Gas Technologies programs of study at Stark State), as well as those teaching in adjacent programs intended to provide similar or broader preparation for jobs in applied industrial fields, such as the Technology, Advanced Manufacturing and Engineering Science programs of study at Westmoreland Community College (hereafter referred to as applied industrial programs). Thus, the targeted population of instructors was not limited to only those who taught within ShaleNET-specific oil and gas courses, but rather a broader population of instructors who taught in programs of study that could lead to a certificate (e.g., National Institute of Metalworking Skills certificate), an associate’s degree, and/or a bachelor’s degree in a range of STEM fields.¹

In this chapter, we provide details on the methods for developing the survey, selecting our instructor sample, survey administration procedures, and analytic methods for analyzing the survey data, and the course syllabi.

TRI-STATE Workforce Preparation Survey Content

We developed the TRI-STATE Workforce Preparation Survey to gather data regarding instructors’ perspectives on their courses’ key knowledge and skills. We identified no other survey instruments addressing the precise information we wished to gather in our survey. In particular, we could not identify any other surveys intended to gather information about what was taught and learned in preparation programs for employment in industrial or oil and gas occupations. We therefore developed most survey items ourselves. To guide the development of our survey, we visited three ShaleNET programs during the 2015–2016 academic year and interviewed the program leads of each program and five instructors to learn what was taught and learned in those programs. We also gathered documentation regarding programs of study at each institution (e.g., program overviews, course descriptions, sample syllabi). We also piloted the survey with one lead instructor or department head in each of three ShaleNET institutions; these three individuals completed our survey and participated in an interview to discuss survey items

¹ The only institution we studied that offered bachelor’s degrees was Pennsylvania College of Technology; the other institutions offered certificates and associate’s degrees, although some institutions had partnerships with other institutions that could allow students to pursue a bachelor’s degree.

that were unclear or could be revised to capture more clear information. The survey was then revised based on pilot feedback.

Core foci for the survey were (1) the knowledge areas that instructors emphasized within their courses and (2) the skills emphasized in their courses. We used the U.S. Department of Labor’s Employment and Training Administration’s conceptualization of knowledge and skills: *knowledge* is defined as the “acquisition of facts and principles about a domain of information,” while *skills* are the “procedures to work with given knowledge” (Reeder and Tsacoumis, 2017a, 2017b). We developed a list of 30 knowledge areas we asked about in the survey using data from our documentation and interviews to ensure that we included all knowledge areas emphasized across ShaleNET programs. For the list of skill areas, we included the 30 skill areas sought by employers for high-priority occupations in the oil and gas industry, as developed for the RAND SHALE (Skills for a Healthy Agile Local Economy and Workforce) survey (Bozick et al., 2017). This list of skill areas was developed by first identifying high-priority occupations in the oil and gas industry sector and then using a repository of occupational information and analysis maintained by the U.S. Department of Labor Employment and Training Administration to identify skills and other characteristics necessary for those occupations.² Appendix B provides a list of the knowledge and skill areas used in the TRI-STATE Workforce Preparation Survey.

The TRI-STATE Workforce Preparation Survey asked instructors to name one course they taught that was most closely related to preparation for oil and gas occupations; the survey then asked about the knowledge and skills respondents emphasized in that course. Instructors had the opportunity to respond about a second course they also taught. We asked instructors about specific courses because instruction and skills emphasized can differ from course to course; in addition, survey research suggests that respondents provide more accurate responses about events and experiences that are more specific and less general (Tourangeau, Rips, and Rasinski, 2000; Ross and Sicoly, 1979).

Beyond asking instructors about the degree to which they emphasized specific knowledge and skill areas, the TRI-STATE Workforce Preparation Survey asked instructors about students’ difficulty with each area and the resources needed to support those areas. The survey also included more general questions for each course about which an instructor responded (e.g., credit hours for the course, how frequently it was taught, how many times the instructor had taught it), as well as their instructional approaches and how they interacted with students. The survey also inquired about the extent to which respondents partnered with others in industrial occupations for any aspects of their course. We also asked instructors to complete demographic questions about their years of experience teaching, education, and full-time or part-time status at their institutions. Finally, we asked instructors to upload the syllabus they used for each course about which they responded in the survey.

² See Bozick, et al., 2017, for more details on how the set of skills was identified.

Instructor Sample

Our survey sample included instructors in gas/oil and applied industrial programs of study at each of five institutions that participated in the study: Beaver County Community College in Beaver, Pennsylvania; Pierpont Community and Technical College in Fairmont, West Virginia; Pennsylvania College of Technology in Williamsport, Pennsylvania; Stark State College in Canton, Ohio; and Westmoreland County Community College in Youngwood, Pennsylvania. These colleges ranged in size. At the time of our study, Pierpont was the smallest college (with 40 associate’s degree, diploma, and certificate programs serving about 1,400 students) and Stark State was the largest (with 230 associate’s degree, diploma, and certificate programs serving about 15,000 students). Westmoreland Community College and Pennsylvania College of Technology served about 5,100 and 5,300 students, respectively, whereas Beaver County Community College served about 2,300 students.

We identified instructors eligible to participate in the study by selecting the key oil and gas programs at each institution, as well as adjacent applied industrial programs that emphasized knowledge and skills also targeted by ShaleNET programs. As noted earlier, we developed a list of key knowledge and skill areas emphasized in ShaleNET programs. Using that list, we identified all programs of study at each institution that could potentially emphasize the knowledge and skills also emphasized by ShaleNET programs. These programs were all intended to prepare students for careers in the oil and gas industry, although some also included generally applicable knowledge and skills related to industrial and process technology and engineering. In total, we identified more than 40 relevant programs across the five institutions. We sent our spring 2017 survey to 180 instructors across four institutions, and sent our fall 2017 survey to 181 instructors across five institutions (instructors at Beaver County Community College were only surveyed in fall 2017 because the college’s participation in the ShaleNET/TEAM consortium began in the 2017–2018 school year).

For each program we identified, we reviewed program course requirements using all documents available online (e.g., course catalogs and academic program descriptions) to determine whether our focal knowledge areas were target areas for courses in those programs. After identifying programs that addressed these target areas, we worked with each institution to gather the list of instructors who taught courses within those programs in both spring and fall 2017 and invited the group of instructors to participate in the survey. Table 2.1 lists the main programs of study from each institution for which we identified and surveyed instructors.

Table 2.1. Main Academic School or Program of Surveyed Instructors in Each Institution

Institution	Programs of Study	Total Number of Programs Included	Available Degrees
Beaver County Community College	<ul style="list-style-type: none"> • Process Technology 	1	<ul style="list-style-type: none"> • Associate’s degree
Pierpont Community and Technical College	<ul style="list-style-type: none"> • Applied Process Technology • Electric Utility Technology • Petroleum Technology 	3	<ul style="list-style-type: none"> • Associate’s degree • Certificate

Institution	Programs of Study	Total Number of Programs Included	Available Degrees
Pennsylvania College of Technology	<ul style="list-style-type: none"> Industrial, Computing and Engineering Technologies (e.g., Applied Technology Studies, Automated Manufacturing and Machining) 	8	<ul style="list-style-type: none"> Bachelor's degree Associate's degree Certificate
Stark State College	<ul style="list-style-type: none"> Engineering Technologies (e.g., Design Engineering Technology, Electric Power Utility Technology) Industrial Technologies (e.g., Automation and Robotic Technology, Industrial Technology) Oil and Gas Technologies (e.g., Industrial Process Operation Technology, Petroleum Technology) 	17	<ul style="list-style-type: none"> Associate's degree Certificate
Westmoreland County Community College	<ul style="list-style-type: none"> Technology, Advanced Manufacturing and Engineering Science (e.g., Advanced Manufacturing and Robotics, Applied Industrial Technology) 	14	<ul style="list-style-type: none"> Associate's degree Certificate

At every institution but Pennsylvania Technical College, we surveyed all or nearly all the instructors in the major academic programs listed. In response to Institutional Review Board requirements at Pennsylvania Technical College, we reached out to a smaller number of Pennsylvania Technical College instructors teaching content closely related to applied industrial occupation, but we also included instructors teaching in content areas similar to those in other institutions.

Administration Procedures

In both spring and fall 2017, we sent our targeted instructors an email invitation to complete an online survey using a link provided within the email. We sent several reminders to nonrespondents. For every institution but Stark State College, we were able to offer a \$25 gift card honorarium for those who completed the survey; in fall 2017, we also offered an additional \$10 gift card honorarium for those who completed the survey for two courses they taught. At Stark State College, we contributed \$25 to a Stark State scholarship fund on behalf of each instructor who completed the survey because gift card honoraria were not allowable per the directives of Stark State College's Institutional Review Board. In addition to responding to the survey, instructors could upload a course syllabus for each course about which they responded.

Of the 72 instructors who responded in the spring or fall 2017, 11 responded in both the spring and fall waves and 17 responded about two courses they taught, which provided us with a total of 100 responses about specific courses. Of those instructors, 38 uploaded a syllabus with

their responses to their courses in either spring or fall 2017. Table 2.2 provides details on respondents and response rates.

Table 2.2. Respondents and Survey Response Rates

Institution	Spring 2017		Fall 2017		Instructors Responding in Spring and Fall
	Targeted Instructors	Responses/Response Rate (%)	Targeted Instructors	Responses/Response Rate (%)	
Beaver County Community College	N/A	N/A	12	4 (33%)	0
Pierpont Community and Technical College	8	4 (50%)	9	6 (67%)	3
Pennsylvania College of Technology	33	5 (15%)	35	9 (26%)	0
Stark State College	118	15 (13%)	111	23 (21%)	5
Westmoreland County Community College	21	11 (52%)	12	6 (50%)	3
Total	180	35 (19%)	181	48 (27%)	11

The bulk of respondents were from Stark State, which has a much stronger focus on programs related to both gas/oil and other applied industrial occupations. In contrast, Pierpont has fewer programs that focus on those areas. Response rates were relatively low, particularly at Stark State College. One reason for the low response rate could have been the lack of a monetary incentive at Stark State, as well as a lack of knowledge about the study among instructors in adjacent programs, as we had less communication with them than with the instructors and department heads in petroleum-specific programs.³

Analytic Approach

To assess the extent to which oil and gas industry-specific credential programs convey KSAs required of employers in the sub-baccalaureate STEM labor market, we compared the reported needs of each states' employers in terms of KSA requirements (as determined from the analysis in Bozick et al., 2017) with a content review of the *intended curriculum* and the *enacted curriculum* for all ShaleNET and adjacent programs.⁴ To date, little guidance exists on how to conduct a curriculum review for postsecondary courses. Paulsen and Peseau (1991) and Ellibee and Mason (1997) have suggested frameworks for assessing postsecondary curriculum that include systematic reviews of knowledge bases for a given course or curriculum and the

³ In addition, we have some evidence that our email invitations were diverted to recipients' junk or spam mail folders, although we alerted our contacts at each institution when we discovered that this may have been happening, and they—in turn—alerted instructors to check their junk mail folders.

⁴ A growing body of literature indicates that *intended curriculum* can change considerably when that curriculum is *enacted* by teachers in their classrooms (Huntley and Chval, 2010; Stein and Kaufman, 2010; Remillard, 2000).

subsequent development of standards for assessing content and instruction as part of a curriculum review, which we adopted in this study.

To document the KSAs for each course, we conducted based descriptive analyses of instructors' responses to the survey. We also conducted regression analyses in order to determine whether instructor responses varied by their self-reported collaboration with industry companies or by instructors' being part or full time. We explored these variations to see whether more collaborations with industry or an instructor's being more attached to the college resulted in different types of knowledge and skill areas being emphasized. These analyses were also descriptive in nature, as we were not guided by a specific hypothesis to test. Regression analyses are described in more detail in Appendix C.

We also conducted qualitative analyses of the 36 syllabi uploaded by instructors for the courses they taught in order to gain additional insights on which topics and skills were formally *intended* to be taught in their courses. Syllabi were coded for the specific knowledge and skills that they addressed, using the knowledge and skill lists that were part of the instructor survey. In addition, themes in regard to specific soft skills addressed in syllabi were documented to determine any trends in skills addressed within syllabi. To establish reliability in our coding, four researchers coded six syllabi together and established decision rules for specific areas where codes were not applied consistently. Then, two researchers coded the remaining syllabi together, periodically meeting to come to consensus on any codes that were different for each syllabus that had been coded.

3. What Do Instructors of Middle-Skills Technical Programs Teach?

The demands of 21st-century jobs require that workers exhibit proficiency in a variety of technical, social, and managerial domains (Carnevale and Hanson, 2015). These requirements cut across industrial and even technical fields, where workers must have nontechnical knowledge and skills, such as interpersonal and administrative skills, as well as technical expertise. While many technical and nontechnical skills are learned on the job, educational settings remain a principal avenue through which future workers obtain and hone knowledge and skills (Carnevale and Hanson, 2015).

As described in Chapter Two, we surveyed instructors of technical courses in five colleges in Ohio, Pennsylvania, and West Virginia to understand the types of knowledge and skills they emphasized in their classes. Through two waves of surveys, we obtained responses from 72 instructors on 100 courses they taught in applied industrial programs, including courses taught in the departments that might be expected to impart some of the same general knowledge and skills.

Courses that were taught by instructors included introductory and more-advanced courses in the following areas: heating, ventilation, and air conditioning (HVAC); AutoCAD; blueprint reading; electrical and electronic systems; energy and industrial technologies; instrumentation/mechatronics; industrial safety; machining and machine tools; manufacturing; petroleum industry; pipelines and pipeline operations; rigging; robotics; technical support; and welding.

We provide results at the individual knowledge area and skill level, as well as aggregate items by category. In addition to presenting descriptive trends in instructors' responses, we contextualized the results in two ways. First, we compared the skills instructors emphasized to skills employers in the oil and gas industry reported seeking among those they hire. In prior research (Bozick et al., 2017), we surveyed employers of the oil and gas industry in the tri-state region to understand the knowledge and skills they seek in the employees they hire. The instructor surveys allow us to compare the alignment between the skills employers seek in their applicants with the skills that instructors emphasize in their classes. An alignment along this dimension could be beneficial for employers and workers because it could mean that workers leaving colleges and entering the workforce will be equipped with employable skills and could increase the probability of finding employment. For employers, this alignment could increase the pool of qualified applicants for their open positions. Yet, we do not know the extent of this alignment or how much instructor reports of what they teach vary from school to school and program to program.

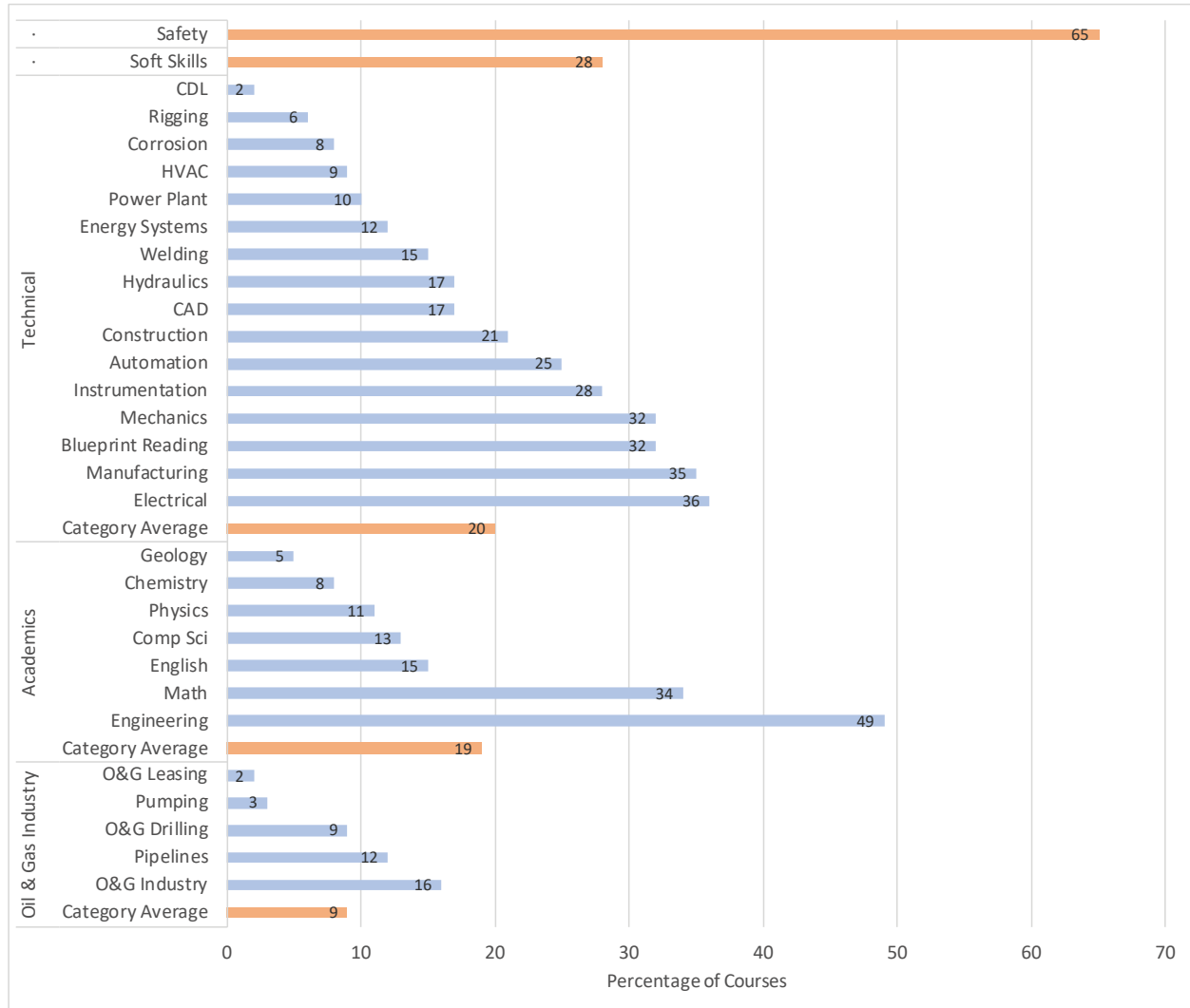
Second, Bozick et al. (2017) surveyed college administrators and employers to understand the degree to which they collaborated to align the education and work opportunities of employers. In this report, we extended that analysis to understand what proportion of responding

instructors partnered with industry to inform their instruction and the relationship between instructors partnering with industry and the types of knowledge and skills the instructor emphasizes. We also examined the role of instructor employment status (part time versus full time), highlighting the considerations when hiring each type of instructor.

Instructors Emphasized Cross-Cutting Knowledge Areas More Than Occupation-Specific Areas

To understand which knowledge areas instructors emphasized in their courses, we asked the following question: “How much emphasis is placed on the following knowledge areas within [course]?” Response options included: “not taught in the course,” “emphasis in a few classes,” “emphasis in several or many classes,” and “emphasis in every or almost every class.” As discussed Chapter Two, we presented instructors with a list of 30 knowledge areas we derived from set of that are typically emphasized in courses intended to prepare students to work in the oil and gas industry. Figure 3.1 illustrates the percentage of courses in which a particular knowledge area was emphasized in “several or many” or “every or almost every” classes.

Figure 3.1. Percentage of Courses Where Knowledge Area Was Emphasized in “Several or Many” or “Every or Almost Every” Class



NOTES: Category labels are displayed in orange. Each blue bar represents the percentage of courses in which each individual knowledge area within the category was emphasized. Averages of the individual blue bars for each category are presented in orange. CDL = commercial driver’s license; Comp Sci = computer science; O&G = oil and gas.

We grouped the knowledge areas into five categories: academic, specific to the oil and gas industry, technical, safety, and soft skills knowledge. The research team engaged in an iterative process in creating the categories with the goal of balancing the specificity and number of categories. In the end, the team grouped the knowledge areas in the five categories presented in Table 3.1.

Table 3.1. Knowledge Area Categories

Category	Category Description	Knowledge Areas in Category
Safety	Includes classroom and occupational safety knowledge	Safety
Soft skills knowledge	All the nonacademic knowledge areas that are reportedly valued by employers	Soft skills ^a
Oil and gas industry	Technical knowledge areas specific to the oil and gas industry field	Oil and gas leasing, pumping, oil and gas drilling, pipelines, general oil and gas industry knowledge.
Technical	All technical knowledge areas that could be applied to the oil and gas industry or to other adjacent technical fields	Commercial driver's license, rigging, corrosion, HVAC, power plant, energy systems, welding, hydraulics, CAD, construction, automation, instrumentation, mechanics, blueprint reading, manufacturing, electrical
Academic	Subjects traditionally taught in colleges and universities that serve as the theoretical underpinning of many other classes (i.e., mathematics, engineering, English)	Geology, chemistry, physics, computer science, English, math, engineering

^a We also asked instructors about the extent to which they emphasized specific skills in a separate survey item, but we included soft skills as a more general knowledge area to comprehend all the areas of knowledge an instructor could address, as well as to be able to illustrate the extent to which instructors perceived themselves as addressing soft skills more generally in relation to other knowledge areas.

Looking at the category averages, *safety* was the most-emphasized category (65 percent of courses), followed by *soft skills knowledge* (28 percent), *technical* knowledge (20 percent), *academics* (19 percent), and knowledge areas specific to the *oil and gas industry* (9 percent).¹

These results suggest that cross-cutting knowledge areas—those that are applicable to a variety of different courses and fields—were emphasized, both overall and within category. This is not particularly surprising, given that many of these courses integrated both academic and technical concepts by design and focused on occupational applications that do not always directly map onto a single academic discipline or approach. Moreover, there has been increasing attention paid to ensuring that occupationally focused programs convey general job skills to prepare students for a wide variety of jobs (Stone and Lewis, 2012).

Safety may be the most-emphasized knowledge area because it is a critical component of almost all jobs and tasks in technical fields, including the oil and gas industry, and must therefore be reinforced in each class. In addition, programs were generally intended to provide students with industry-based credentials, which typically include safety course requirements. The relatively strong emphasis on soft skills, compared with other knowledge areas, is in keeping with the increasing demand for proficiency in this area; employers want workers who have technical knowledge *and* can interact with their colleagues and function as part of a team (Bozick et al., 2017).

As mentioned earlier, within categories, the greater emphasis on cross-cutting knowledge areas emerged. In the *academic* category, engineering and math were the most-emphasized

¹ All results reported are statistically significantly different. See Appendix C for results of tests of significance.

knowledge areas. These subjects were more widely applicable across contexts than geology and chemistry, which were the least emphasized. Within the *oil and gas* category, specific aspects of the industry, such as leasing and pumping, were the least emphasized.²

Cognitive Skills More Emphasized Than Interpersonal Skills

In addition to asking about the knowledge areas they emphasized, we asked instructors how much emphasis they placed on each of a list of individual skill areas with the following question: “How much emphasis is placed on the following skills in [course]?” Response options included: “not taught in the course,” “emphasis in a few classes,” “emphasis in several or many classes,” and “emphasis in every or almost every class.”

We used the same skill areas that Bozick et al. (2017) used in their surveys of employers in the oil and gas industry. In creating the list of skills, the authors drew on the U.S. Department of Labor Employment and Training Administration’s Occupational Information Network Data Collect Program (O*NET) Resource Center. O*NET contains a repository of KSAs and other characteristics derived from surveys of workers and employers. The skill areas were the O*NET skills most relevant to the oil and gas industry (Bozick et al., 2017).

We performed a parallel analysis on the skills, in which we analyzed the percentages of courses in which instructors emphasized each individual category and then calculated category averages. In grouping skills into categories, we used O*NET categories as a template and made minor modifications to create four broad categories: cognitive skills, analysis and operations skills, management skills, and interpersonal skills.³ Modifications were made iteratively in team meetings in which researchers once again balanced category specificity with the number of categories. Table 3.2 presents the categories and the skills contained in each category.

² This difference is marginally significant ($p = 0.0527$).

³ Research teams’ decisions in grouping the skills categories include: renaming the basic skills category the cognitive category, eliminating the systems skills category by moving judgement and decisionmaking skills to the cognitive category and systems analysis skills to the technical category, eliminating the complex problem solving category by moving complex problem solving skills to the cognitive category, moving troubleshooting skills from the technical to the cognitive category, renaming the social skills category the interpersonal category, moving speaking to other from the cognitive category to the interpersonal category, moving monitoring performance of self and others from the cognitive to the management category, and moving instructing other and coordinating actions from the interpersonal to the management category.

Table 3.2. Skills Categories

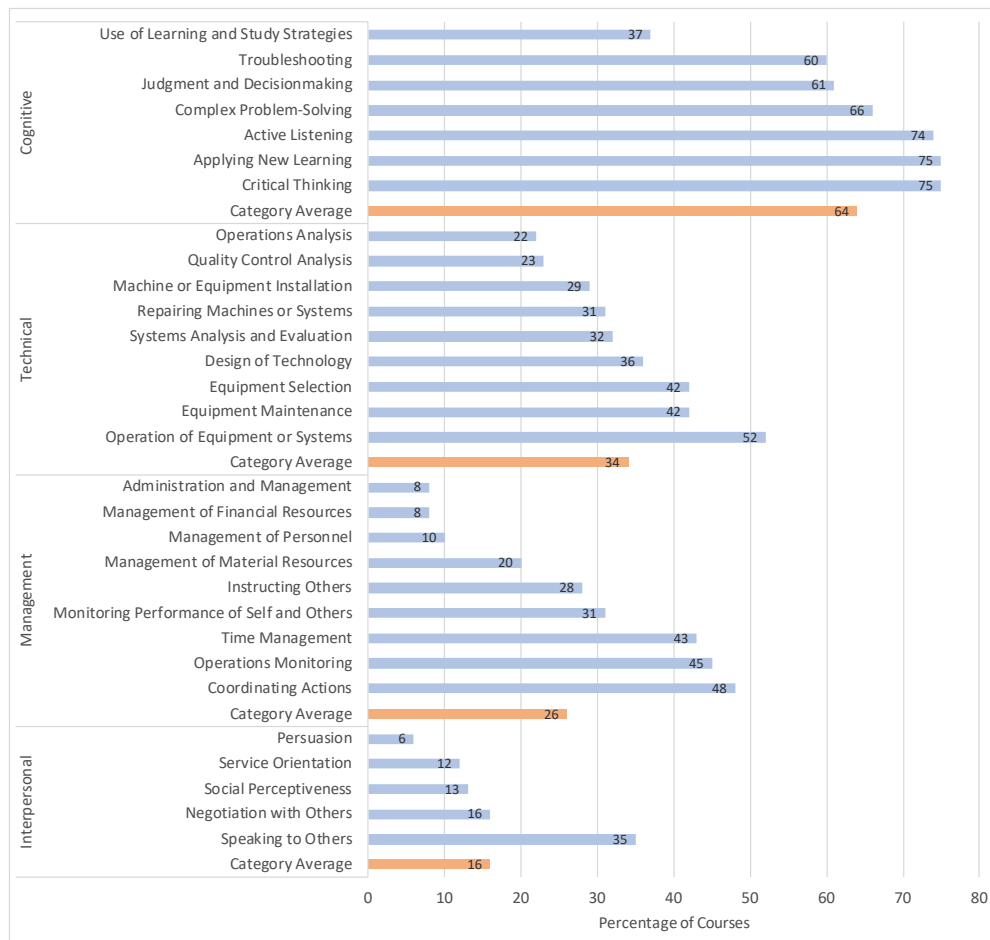
Category	Category Description	Skills in Category
Cognitive	Skills that involve abstract thinking and decisionmaking; includes classroom and occupational safety knowledge	Use of learning and study strategies, troubleshooting, judgement and decisionmaking, complex problem solving, active listening, applying new learning, critical thinking
Soft skills	All the nonacademic knowledge areas that are reportedly valued by employers	Soft skills ^a
Analysis and operations	Skills needed to install, maintain, and analyze equipment and systems; technical knowledge areas specific to the oil and gas industry field	Operations analysis, quality control analysis, machine or equipment installation, repairing machines or systems, systems analysis and evaluation, design of technology, equipment selection equipment maintenance, operation of equipment or systems; oil and gas leasing, pumping, oil and gas drilling, pipelines, general oil and gas industry knowledge
Technical	All technical knowledge areas that could be applied to the oil and gas industry or to other adjacent technical fields	Commercial driver's license, rigging, corrosion, HVAC, power plant, energy systems, welding, hydraulics, CAD, construction, automation, instrumentation, mechanics, blueprint reading, manufacturing, electrical knowledge
Management academic	Skill pertaining to the management of material, financial, and human capital resources; subjects traditionally taught in colleges and universities that serve as the theoretical underpinning of many other classes (i.e. mathematics, engineering, or English).	Administration and management, management of financial resources, management of personnel, management of material resources, instructing others, monitoring performance of self and others, time management, operations monitoring, coordinating actions, geology, chemistry, physics, computer science, English, math, engineering
Interpersonal	Skills pertaining to the effective teamwork and communication with others	Persuasion, service orientation, social perceptiveness, negotiation with others, speaking to others

^a We also asked instructors about the extent to which they emphasized specific skills in a separate survey item, but we included soft skills as a more general knowledge area to comprehend all the areas of knowledge an instructor could address, as well as to be able to illustrate the extent to which instructors perceived themselves as addressing soft skills more generally in relation to other knowledge areas.

Figure 3.2 presents the results. Cognitive skills were very much the most-emphasized skills in courses, with an average of 64 percent. *Critical thinking*, *active listening*, and *applying new learning* were emphasized in about three-quarters of courses, and *complex problem-solving*, *judgement and decisionmaking*, and *troubleshooting* were emphasized in about two-thirds of courses. These skills run the gamut of abstract thought processes—gathering information from several sources, synthesizing information and ideas, and weighing all options to finally come to

a decision. This high level of emphasis suggests that instructors were attempting to impart habits of mind and approaches to situations and problems that can be applied in all job fields.

Figure 3.2. Percentage of Courses Where Skills Were Emphasized in “Several or Many” or “Every or Almost Every” Class



NOTE: Category labels are in orange and orange bars represent category averages. Individual skills within categories are represented by blue bars.

Analysis and operations and *management* skills ranked second and third by emphasis. Within the *analysis and operations* skills category, skills that revolve around the lifecycle of equipment (selection, operation, and maintenance) were the most emphasized. In the *management* category, the most-emphasized skills were managing people (coordinating others’ actions, monitoring operations, and time management).

The *interpersonal* category was least emphasized by the instructors we surveyed. As the name of the category suggests, these are skills that workers need to interact with others, such as speaking and negotiating with others, persuasion, service orientation, and social perceptiveness. The category contains many skills considered to be “soft” or “noncognitive” skills. With the exception of the ability to speak to others, these skills were only emphasized in 16 percent of the

courses or less. This lower level of emphasis is striking, considering the important role interpersonal skills, and soft skills more broadly, play in worker success (Duncan and Dunifon, 2012). This result also conflicts with the growing demand for soft skills from employers, particularly in the oil and natural gas industry, as well as the findings reported in the previous section of this chapter that a core knowledge area emphasized by instructors were *soft skills knowledge*.

Knowledge and Skills Emphasized in Syllabi Were Similar to Survey Reports

We also examined instructors' syllabi for the knowledge and skill areas asked about in the survey. While we would expect the knowledge and skills emphasized most in the survey to come up in instructors' syllabi, we might also see differences between survey reports and syllabi. For example, while syllabi provide a record of topics and knowledge intended to be taught, what instructors actually emphasized could be different because they could not cover all syllabi topics or weaved in skills or knowledge that were not highlighted in the syllabi. At any rate, a fair match between knowledge and skills addressed in syllabi and survey reports could serve to triangulate our results and confirm both intended and actual course content, although readers should keep in mind that instructors uploaded syllabi for just one-third of the courses they reported about in the survey.⁴

Syllabi results echoed survey findings in several knowledge and skill areas. The top knowledge areas that came up in more than one-third of syllabi were similar to the most commonly emphasized knowledge areas in the survey: safety, electrical, computer science, math, English, and instrumentation/sensors. On the other hand, several commonly emphasized knowledge areas reported in the survey were less frequently addressed in syllabi, including engineering (emphasized in 49 percent of the courses in the survey but in only 14 percent of syllabi) and manufacturing (emphasized in 35 percent of courses in the survey versus 22 percent of syllabi). It could be that instructors had a broader definition of engineering and manufacturing than the researchers who coded the syllabi, or that engineering and manufacturing topics

⁴ We investigated whether the characteristics of courses and instructors differed by whether a syllabus was uploaded to investigate selection bias in the syllabi analysis. We performed two-tailed t-tests of the following course and instructor characteristics: number of courses the instructor taught, number of sections the instructor taught, number of times the instructor taught the course, whether the instructor partnered with industry, years of experience as an instructor, part-time status of instructor, whether the instructor responded to two courses in the survey, course length, credit hours for the course, hours per week for the course, lab hours per week for the course, and whether the response came in the fall wave of the survey. Instructors who uploaded the surveys taught more sections (3.87 versus 3.05; $p = 0.0631$), taught longer courses (14.89 weeks versus 12.62 week; $p = 0.0035$), more likely to partner with industry (0.43 versus 0.23; $p = 0.0389$), less likely to be part time (0.38 versus 0.67; $p = 0.0010$), and taught courses with fewer hours per week (3.38 hours versus 4.17 hours; $p = 0.0770$) and fewer lab hours per week (2.34 versus 3.54; $p = 0.0261$). The remainder of the characteristics had no significant difference by the propensity to upload syllabi. These differences indicate that results should be interpreted with caution and may not be representative of the full sample.

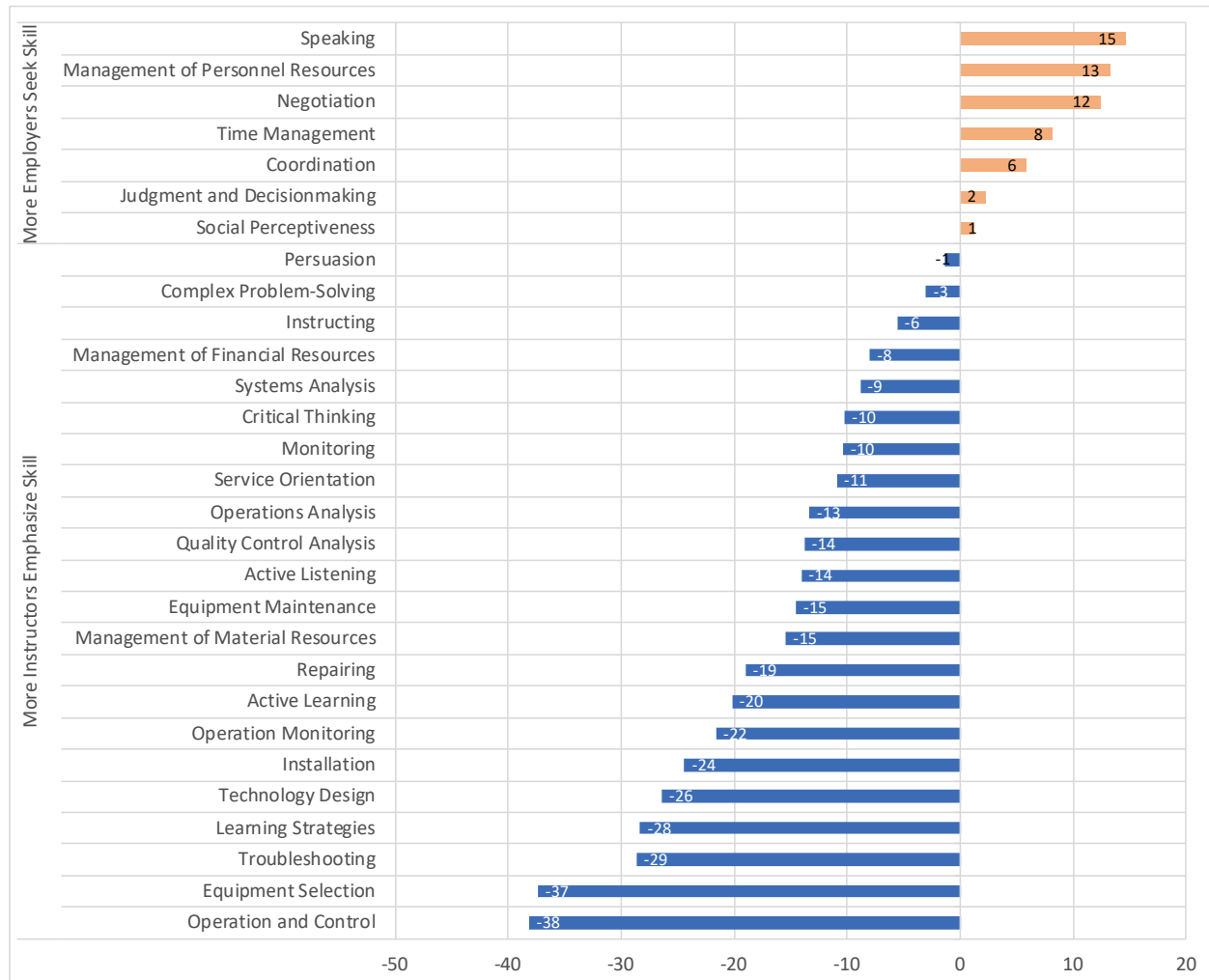
naturally came up in the course of teaching core course content, although they were not explicitly named in syllabi as teaching topics.

Generally, while more than half of the courses were reported to emphasize many skills, including a number of cognitive skills, those skills were less often explicitly mentioned in syllabi. The two top skills that came up in more than one-third of syllabi were operation of systems or equipment (36 percent of syllabi) and troubleshooting (33 percent of syllabi). Those two skills were also two of the top skills emphasized in survey reports, although higher percentages of instructors indicated emphasizing those skills in their courses (52 percent of courses emphasized operation of systems or equipment, and 60 percent emphasized troubleshooting). However, many other skills emphasized in over half of courses in the survey were rarely if ever mentioned in syllabi, including judgment and decisionmaking (no syllabi), complex problem-solving (11 percent of syllabi), active listening (11 percent of syllabi), applying new learning (6 percent of syllabi), and critical thinking (8 percent of syllabi). It may be that syllabi were written to note key knowledge, rather than skills. However, given the skills gap identified as a potential issue for hiring, as explained in Chapter One, such skills may bear more explicit attention in syllabi as areas that instructors should be expected to address.

More Employers Sought Interpersonal, Management Skills Than Courses Emphasized Them

As indicated earlier in the chapter, we previously surveyed employers of the oil and gas industry in the tri-state region to understand the knowledge and skills they seek in the employees they hire (Bozick et al., 2017). The results indicated that the top three sought-after skills by employers were critical thinking, judgement and decisionmaking, and complex problem-solving. In this section we formally probe whether there was an alignment between the skills employers sought and the skills instructors emphasized by comparing the percentage of employers reporting a particular skill as necessary for in demand jobs with the percentage of instructors emphasizing that skill in many or most classes. Figure 3.3 reports these results.

Figure 3.3. Difference in Percentage of Employers Seeking Skill and Percentage of Courses Emphasizing Skill



NOTE: Skills at the top of the graph, in orange, have a greater percentage of *employers* seeking those skills, and skills at the bottom of the graph, in blue, have a greater percentage of *instructors* emphasizing those skills.

Strikingly, none of the seven skills more sought after by employers, as determined in Bozick et al. (2017), fall in the *analysis and operations* category. Three of the seven skills (speaking, negotiation, and social perceptiveness) are *interpersonal* skills, the category of skills *least* emphasized in courses in the TRI-STATE Workplace Preparation Survey. Another three skills emphasized by employers (management of personnel resources, time management, and coordination) were *management* skills, the second least emphasized category of skills in courses. These patterns support the notion that these skills were in high demand, but that instructors may be undervaluing them in the classroom. It is important to note that the differential between employer and instructor responses were quite small in some cases, though the three skills with the greatest differential belong to the interpersonal or management categories.

The greatest discrepancies in responses of employers and instructors were in the *analysis and operations* and *cognitive* skill categories. Instructors indicated emphasizing skills in these areas to a much greater degree compared with employers who indicated seeking those skills. For example, of the five skills emphasized in more than a quarter of courses, three were *analysis and operations skills* (operation and control, equipment selection, and technology design) and two were *cognitive* (troubleshooting and learning strategies) skills.

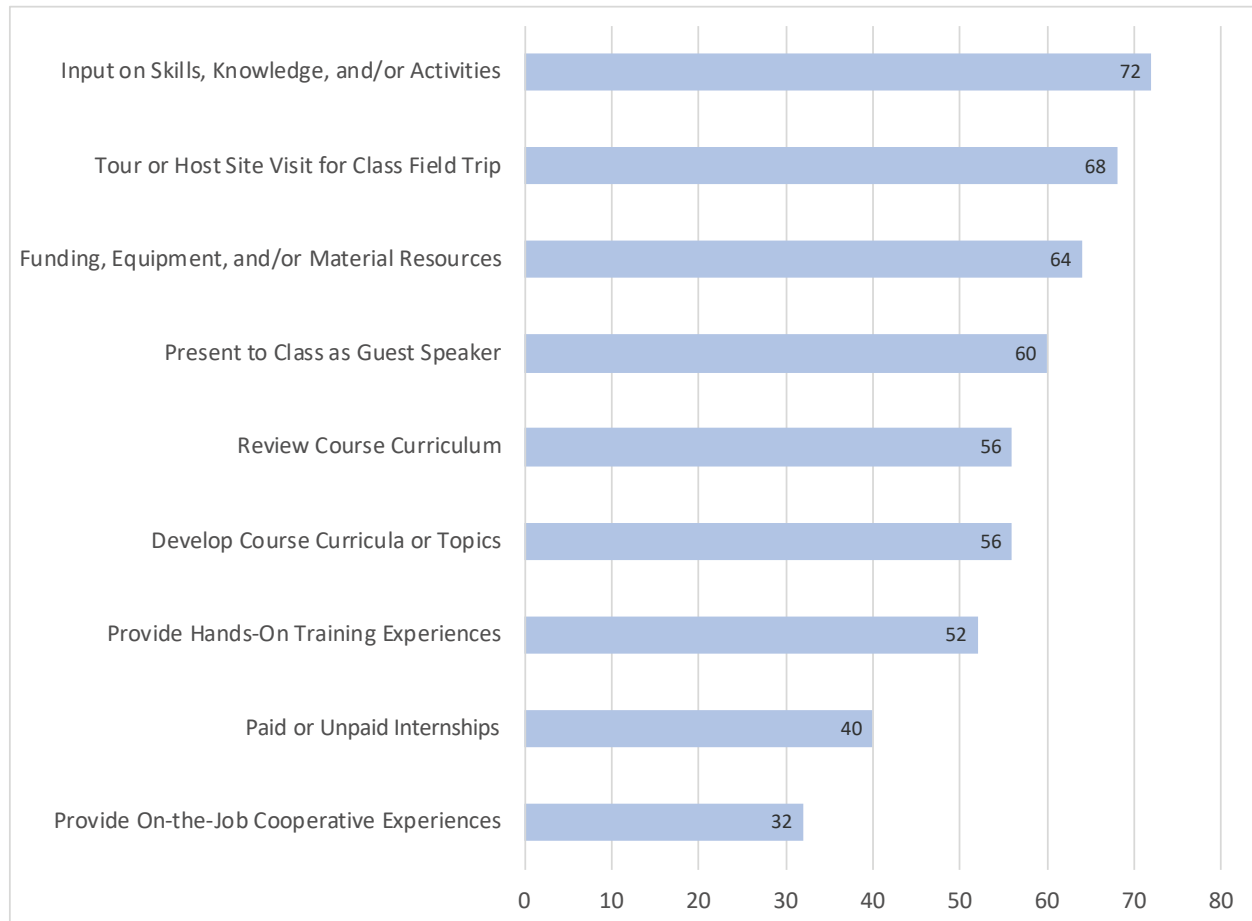
These results do not necessarily suggest that instructors should emphasize these skills to a lesser degree; indeed, the top three skills sought after by employers were all *cognitive* skills. Though we asked employers which skills were required for high-demand jobs, their responses could be influenced by the supply of workers with those skills. That is, they may have been less likely to indicate cognitive and technical skills were required if workers were graduating from programs with those skills. Instead, the results suggest that in addition to emphasizing cognitive and technical skills, instructors who also emphasized interpersonal and management skills may have taught courses that were better aligned with employer needs.

Instructors Partnering with Industry Emphasized Skills More Valued by Employers

Bozick et al. (2017) found that that approximately half of oil and gas employers and postsecondary education providers in the tri-state region collaborated with one another around workforce planning issues. Only 41 percent of employer respondents in that survey indicated they undertook workforce planning activities with colleges, and 56 percent of college administrator respondents reported collaborating with employers (Bozick et al., 2017). This study's instructor survey further shows low levels of collaboration between postsecondary institutions and employers: Only 35 percent of instructors who responded to our survey indicated that they collaborated with industry. These low levels of collaboration can be cause for concern. As noted by the National Academy of Sciences, Engineering, and Medicine (2016), collaboration can benefit student outcomes by allowing integration of relevant skills into coursework, provision of material support and equipment for classes, and opportunities for students to obtain field work experiences. While there is not an empirically informed consensus on the optimal level of employer-college collaboration to support robust local workforce development, our findings here do suggest there is room for improvement.

When instructors did partner with industry, 72 percent sought input on KSAs to emphasize in their course, and 64 percent obtained funding, equipment, or other material resources to use in their classroom. Instructors also established pathways for students to interact with potential employers either through tours and field trips (68 percent), class presenters (60 percent), internships (40 percent), hands-on experiences (52 percent), or on-the-job cooperative experiences (32 percent).

Figure 3.4. Percentage of Respondents Reporting Types of Industry Collaboration, Conditional on Reporting Industry Collaboration

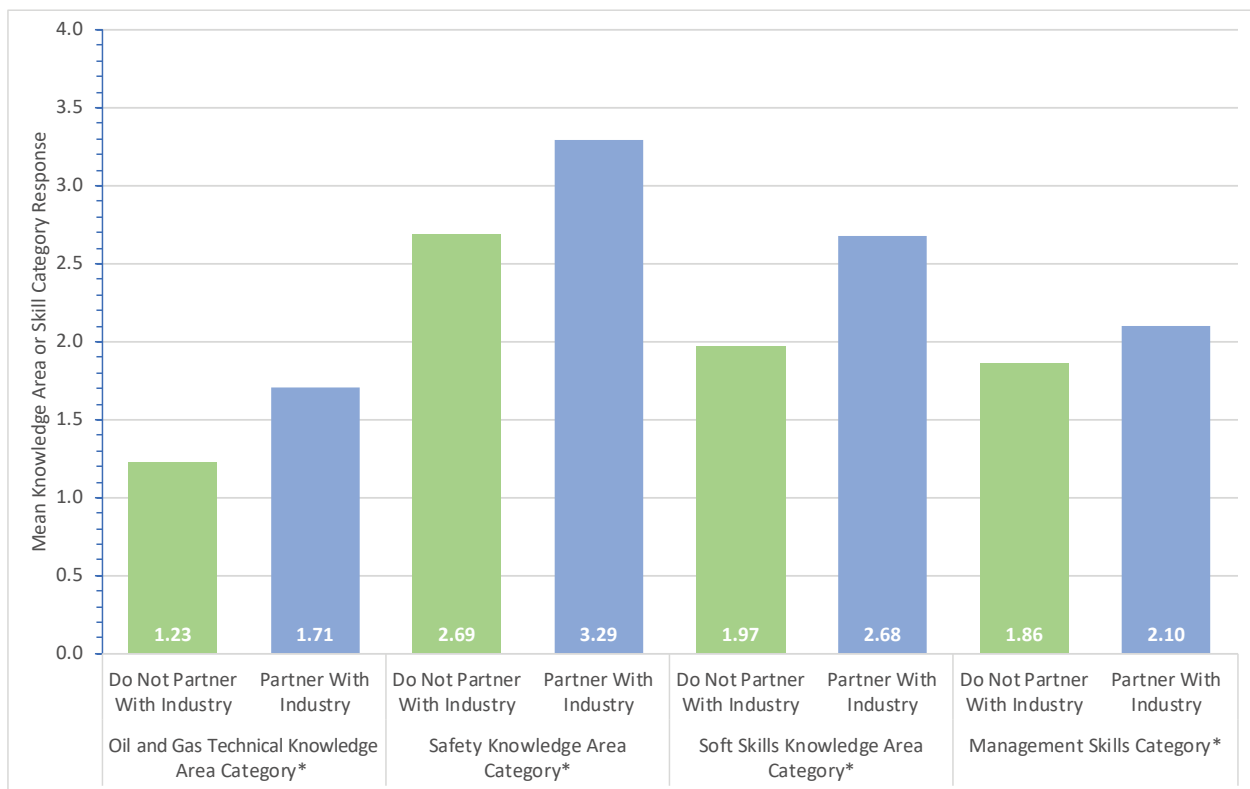


NOTES: This figure includes only the 35 percent of respondents ($n = 25$) who indicated they partnered with industry. A test of the null hypothesis that all estimates are equal to each other is rejected: $\chi^2_8 = 31.35, p = 0.0001$.

In addition, we found that instructors who partnered with industry tended to emphasize different categories of skills and knowledge areas. To explore this relationship, we first took each instructor’s Likert scale response (1 through 4) indicating how much they emphasized each knowledge area or skill in a course and calculated their average response for each knowledge area and skill category. If an instructor indicated that they did not teach any knowledge areas or skills in a category, they would have responded to each question with a 1 and the category average would be 1. Conversely, if they emphasized each item in a category in every or almost every class, they would have rated each item a 4 and the category average would be a 4. The averages could take on values between 1 and 4 if they rated each question differently. We then looked for differences in category averages among instructors who indicated they partnered with

industry and those who did not.⁵ Figure 3.5 shows that instructors who partnered with industry were statistically significantly more likely ($p < 0.05$) to emphasize the *oil and gas technical*, *academics*, *safety*, and *soft skills* knowledge area categories, and the *management* skills category to a greater extent. For all other categories but one, partnering with industry was associated with a greater emphasis, but the estimates were not statistically significant. For the cognitive skills category, partnering with industry was associated with less emphasis, but again the estimate was not statistically significant.

Figure 3.5. Mean Knowledge Area and Skill Category Responses, by Indicator for Partnering with Industry



NOTE: * Results are statistically significant at the 5-percent level. On the y-axis, 1 = not taught in class/the course, 4 = emphasized in every or almost every class.

⁵ Tests of statistical significance are derived from a regression model where each category average was regressed on an indicator for having indicated a respondent partnered with industry, and indicator for being a part-time instructor, a vector of covariates that includes the length of the course, the number of credit hours of the course, the number of times the instructor has taught the course, years of experience of the instructor, and indicator for having worked outside of teaching in the past, the number of course hours per week, the number of lab hours per week for the course, an indicator for the fall wave of the survey, and an indicator if this was the second course an instructor responded to in the survey. Models also include college fixed effects and a random effect to account for instructors who took surveys in the fall and spring. See Appendix C for more technical details.

These differences may be consequential for students. For example, instructors may not have emphasized management skills enough relative to employers' need for those skills. However, instructors who partnered with industry emphasized those skills more. Thus, instructors may have recognized this need for management skills as they collaborated with their industry peers. In addition, while the oil and gas industry knowledge area category were the least emphasized among instructors, partnerships with industry were related to more emphasis on oil and gas, which may be highly aligned to the pool of potential jobs. Similarly, some research has illustrated that employers demand proficiency in a variety of soft skills and reward workers that can demonstrate such proficiency (Kuhn and Weinberger, 2005; Lindqvist and Vestman, 2011; Nyhus and Pons, 2005). Our survey findings suggest that instructors may have received this message through their industry collaborations. Finally, as the safety knowledge area underpins many of the courses and skills needed in the oil and gas industry, partnering with industry may help provide instructors with the tools and knowledge needed to teach this area more effectively. Our results do not tell us whether partnering with industry *caused* instructors to emphasize these knowledge area and skill categories to a greater extent; it could be the case that instructors who emphasize the knowledge and skills needed in the oil and gas industry may also be more likely to partner with the industry. Nevertheless, these associations support the notion that more collaboration with industry is associated with potentially more aligned coursework.

Part-Time Instructors Composed the Majority of the Sample

Local colleges often rely on a mix of part-time and full-time instructors to meet their instructional needs. Full-time instructors may have more time to concentrate on developing curriculum and hone their pedagogical techniques. However, being in the classroom full time poses the risk of losing contact with practitioners. Therefore, full-time instructors must make a conscious effort to remain current with the advances in the field should they want their lessons and coursework to remain relevant. Part-time instructors, on the other hand, may be doing other work that is closely related to the areas of their instruction; this potential alignment between the courses taught and their work could give them a first-hand knowledge of the needs and challenges of the jobs in the field. However, they potentially could have less time to hone their pedagogical skills. Our survey results suggest that part-time instructors make up a significant portion of the instructor pool, as 57 percent of respondents indicated that they are part-time instructors. While we do not have evidence to suggest that full-time instructors are more effective than part-time instructors (or vice versa), this substantial number of part-time instructors suggests that a deeper understanding of the pros and cons of each group is important, as well as a deeper understanding of the instructor labor market and the supply of full-time and part-time instructors available to local colleges.

Conclusion

Overall, our surveys shed critical light on the types of knowledge areas and skills instructors of technical courses emphasize in their classes and how they compare with the skills employers indicated they seek in their applicants. We found that instructors emphasized cross-cutting knowledge areas, such as safety and soft skills, over specific knowledge areas, such as knowledge about the oil and gas industry and technical knowledge. Instructors also heavily emphasized cognitive skills, while they focused on interpersonal and management skills to a much lesser degree.

In many ways, instructors and employers were aligned in terms of the skills they taught and the skills they demanded, respectively. Cognitive skills topped the list of skills demanded by employers and emphasized by instructors, and instructors are emphasizing technical skills at rates that are on par or greater than what employers are demanding. Instructors, however, were less likely to have emphasized interpersonal and managerial skills, and more employers were seeking those skills than instructors were emphasizing them. Only recently have researchers uncovered the importance of these skills and the demand for these skills from the workforce, perhaps leaving preparation programs to catch up with this trend. Interestingly, we also found that syllabi—the formal record of knowledge and skills to be addressed in courses—mentioned many skills, and particularly cognitive skills, at a lower rate than instructors indicated emphasizing them in their instruction.

One key area of variation in instructors is the degree to which they were partnering with industry. Only 35 percent of instructors indicated that they partnered with industry. This low-level of collaboration is in line with results seen from surveys of employers and school administrators (Bozick et al., 2017) but may be affecting the types and quality of instruction experienced by students. When instructors did partner with industry they engaged in many activities thought to be beneficial to students such as obtaining input on classroom instruction, organizing tours and field trips to industry site, obtaining funding or needed equipment, develop curricula, and provide internships or on-the-job cooperative experiences. Furthermore, instructors who partnered with industry were more likely to emphasize critical knowledge areas and skills, such as knowledge of the oil and gas industry and safety, academic knowledge, soft skills, and management skills. Each of these areas have important returns in the workplace.

Finally, our results highlight a key variation along another dimension: part-time employment status. A majority of our sample (57 percent) were part-time instructors. While part-time and full-time instructors each have potential advantages and disadvantages, the number of part-time instructors indicates that more research needs to be done to understand how employment arrangements could affect the teaching and learning occurring in the classroom. At minimum, our results highlight the many considerations that department managers consider when attracting faculty and instructors and emphasize the importance of studying the instructor labor market to a greater degree to further understand the supply of each type of instructor.

4. What Are Possible Barriers to Success for Students in Middle-Skills Technical Programs?

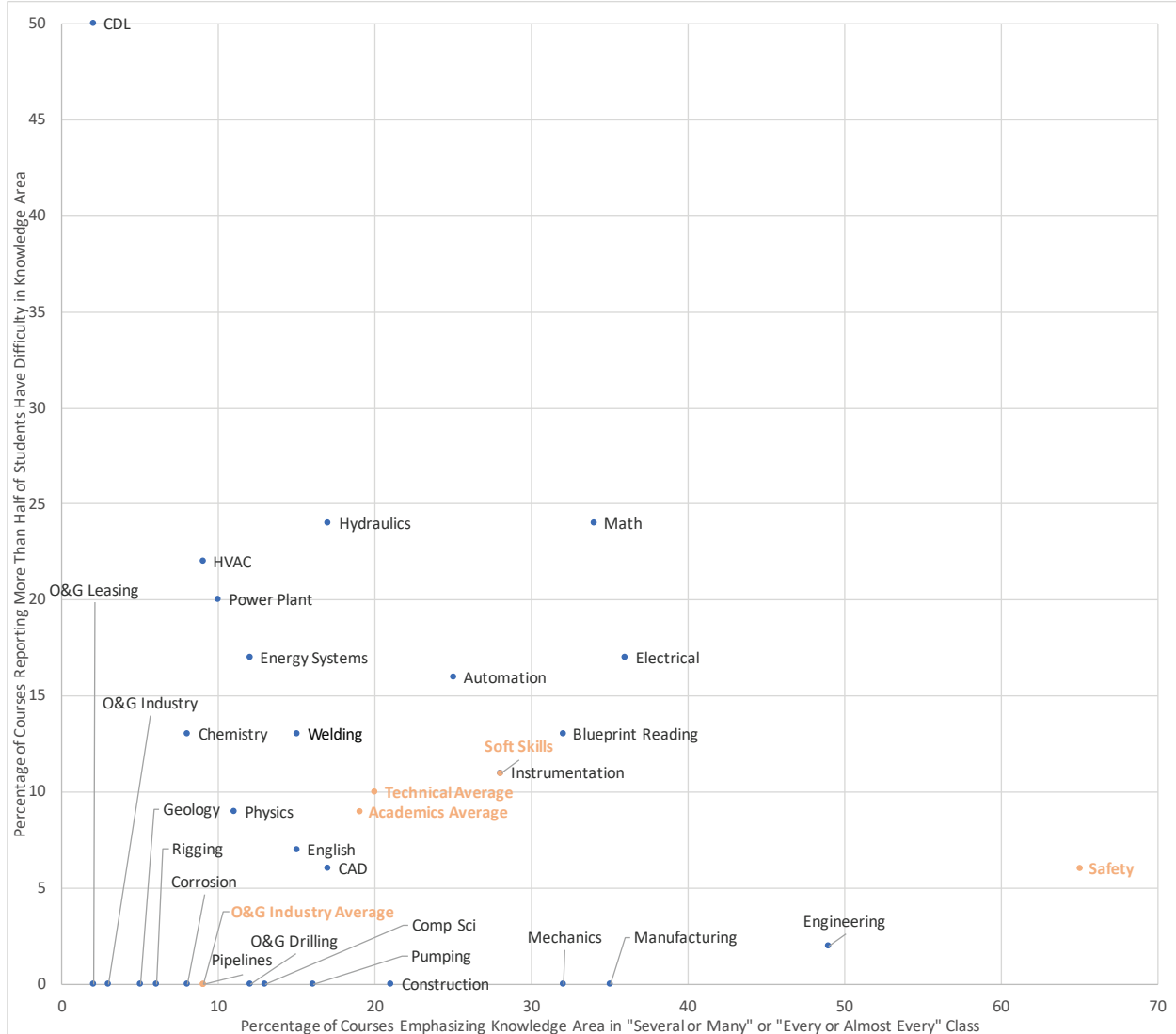
While the alignment between employer demand and what is taught in applied industrial programs may be necessary to improve job placement, simply aligning demands and teaching is insufficient. Students must be supported to overcome difficulties in learning more challenging material, and instructors must have the resources and support to address that material. In this chapter, we address both the knowledge and skill areas that most challenge students and the resources instructors need to effectively teach middle-skills technical programs material. As our selected colleges had established partnerships with oil and gas industry employers, we expected that these colleges would have programming to support students struggling with knowledge areas and skills most in demand. We hope that these results can guide colleges, employers, and other members of the oil and gas industry on where to target support to aid the instruction of critical skills needed for a prepared workforce.

Technical and Academic Knowledge Areas Posed Greatest Difficulty, Soft Skills Also Challenging

In Chapter Three, we shared findings regarding which areas of knowledge and skills instructors emphasized most. For each of the knowledge and skill areas that instructors indicated emphasizing, we also asked instructors to indicate the proportion of students who had considerable difficulty learning key content in that area (response options included few or no students, less than half my students, or more than half my students). Typically, colleges offer remedial courses for students who struggle in foundational subject areas like reading, writing, and mathematics (Attewell et al., 2006). According to a 2016 report, 68 percent of those starting at public two-year institutions took at least one remedial course between 2003 and 2009, with 59 percent taking remedial math courses and 28 percent taking remedial English courses (Chen and Simone, 2016). However, we have little idea of the extent to which students are challenged by specific technical subjects.

Figure 4.1 compares the percentage of courses in which a knowledge area was emphasized (*x*-axis) with the percentage of courses where instructors indicated that more than half of their students experienced considerable difficulty in each area (*y*-axis). We included the knowledge area categories defined in Chapter Three: technical knowledge areas, academic knowledge areas, areas more specifically related to the oil and gas industry, safety, and soft skills.

Figure 4.1. Emphasized Knowledge Areas and Student Difficulty



NOTE: Individual knowledge areas are represented by blue markers, and category averages are represented by orange markers. CDL = commercial driver's license.

Looking at the y-axis, the item-level results revealed wide variation in the knowledge areas that posed challenges to students. In courses in which commercial driver's licenses were emphasized, 50 percent of instructors reported that a majority of students were having considerable difficulty with key content in that area (however, only two instructors emphasized commercial driver's licenses, and only one instructor indicated that students were having considerable difficulty). Mathematics, hydraulics, and HVAC followed, with 20 to 24 percent of instructors having indicated that more than half their students had difficulty in those areas. On the other side of the spectrum, no instructor indicated that a majority of students had difficulty learning in 13 of the 30 knowledge areas we asked about in our survey—including all six knowledge areas contained in the oil and gas industry category.

This variation indicates that a heavy emphasis on a knowledge area did not necessarily translate to a high degree of difficulty in learning that knowledge. Knowledge areas toward the bottom right-hand portion of the graph were heavily emphasized in courses, but instructors did not report a high degree of student difficulty. For example, engineering was the second most-emphasized knowledge area (49 percent of courses), but in only 2 percent of courses was it indicated that a majority of students had difficulty acquiring this knowledge. Similarly, manufacturing and mechanics were also emphasized in a considerable number of courses, but in no one reported that a majority of his or her students were having difficulty with these areas. Importantly, some knowledge areas in the upper right-hand quadrant, such as mathematics, were both emphasized by instructors and posed a significant challenge to students.

The muted correlation between knowledge area emphasis and student difficulty in a knowledge area has implications for where stakeholders might want to target their resources. Heavily emphasized knowledge areas in which a considerable number of students struggle, such as mathematics, are prime targets for additional resources. As a cross-cutting knowledge area that serves as a foundation to many careers in applied areas (not just oil and gas), student difficulties in math can spill over and negatively affect tasks and operations performed at work. While the importance of (and student difficulties in) math is known to pertain to academic achievement, our analysis indicates that these issues are also central to occupationally focused courses.

Heavily emphasized knowledge areas in which few students struggle, such as manufacturing, may also need continued support because of the importance of providing quality instruction in these industry-relevant domains. However, stakeholders should not ignore knowledge areas simply because they are not as heavily emphasized. Although such areas as HVAC, energy systems, and power plants are less emphasized, student difficulty was reported in a considerable proportion of the courses. Learning these knowledge areas could be just as important for the success of students in specialized industry, and supporting their learning should also be a priority for both colleges and employers with which colleges partner. Partnerships between employers and colleges might enable colleges to offer more expert guidance and hands-on opportunities in these content areas.

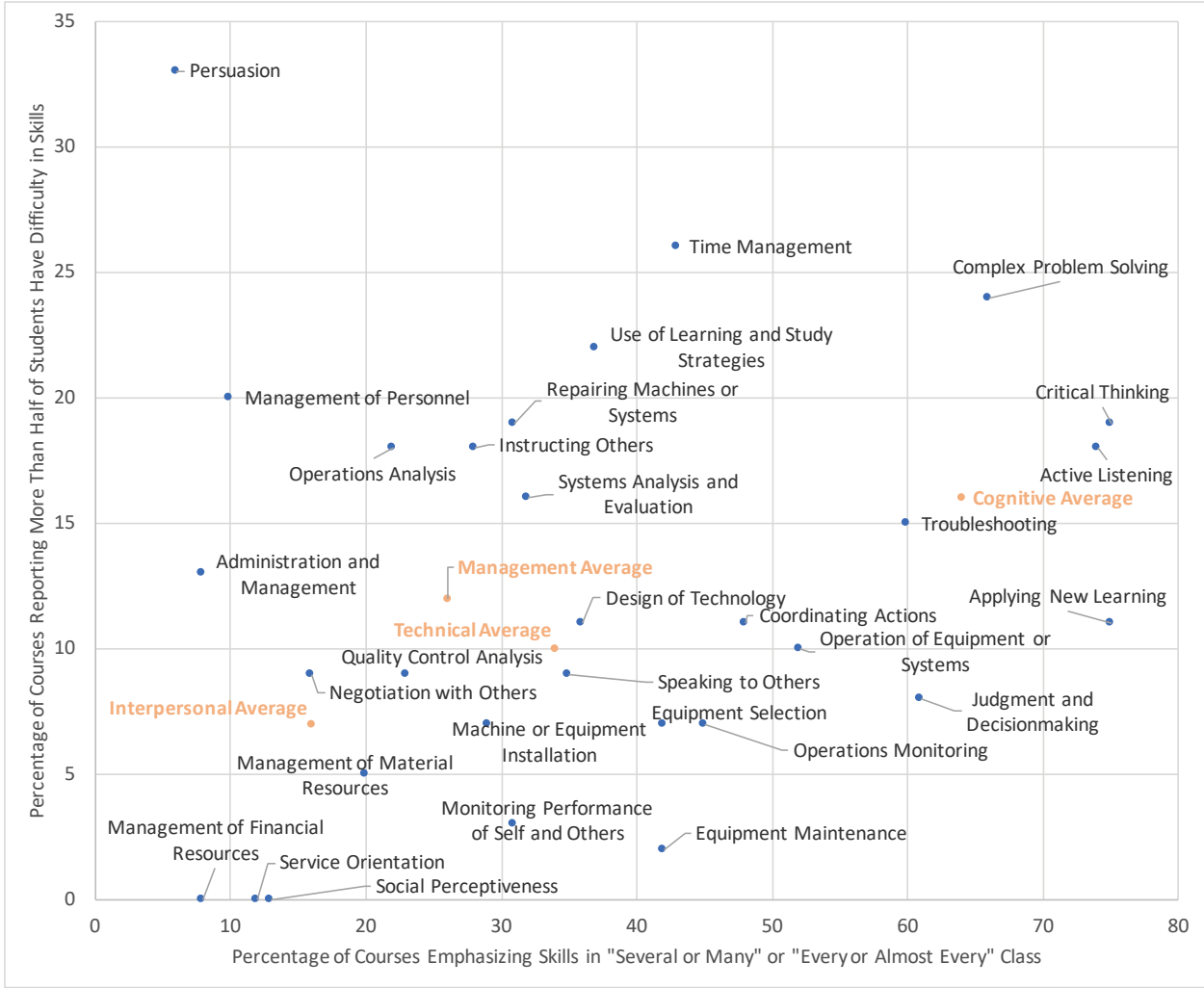
Instructors indicated that students were having difficulty in courses where such knowledge areas as soft skills knowledge and safety were emphasized. Instructors indicated that their students struggled with soft skills and safety in 11 and 6 percent of courses, respectively. While these were not the largest numbers in terms of percentages, both areas were highly emphasized. These results highlight that students need support in both the traditional cognitive and technical domains, as well as the equally important nonacademic areas. Supporting the development of these nonacademic skills may become more important as researchers further understand the benefits of developing these nonacademic areas.

Cognitive and Management Skills Posed the Greatest Difficulty for Students

The surveys inquired about the extent to which instructors' students experienced considerable difficulty in learning the skills they emphasized in their class (response scale: "few or no students," "less than half my students," or "more than half my students").

Figure 4.2 compares the proportion of courses in which a skill was emphasized in "several or many" or "every or almost every class" with the proportion of courses in which instructors reported that more than half of their students experienced difficulty learning an emphasized skill. Results are also presented by the skill categories discussed in Chapter Three: cognitive, management, technical, and interpersonal.

Figure 4.2. Emphasized Skills and Student Difficulty



NOTE: Skill categories are labeled in orange and individual skills are represented by blue markers.

Instructors indicated their students experienced difficulty with a wide swath of skills that spanned all skill categories. The most difficult skills were persuasion, time management, and complex problem-solving, which spanned the interpersonal, management, and cognitive categories, respectively. Technical skills also presented a challenge for students. For example, in 19 percent of courses that emphasized repairing machines or systems, instructors reported a majority of their students had difficulty understanding the skill. The breadth of skills with which students experience difficulty is in contrast to the knowledge area analysis. Whereas instructors reported 13 of 30 knowledge areas (43 percent) posed no challenge for a majority of their students in their courses, only three of 30 skills (10 percent) posed no such challenge.

Overall, instructors reported that students had the most difficulty with cognitive skills, which were also the most-emphasized skills. In combination, these results indicate that a large number of students struggled with these skills, underscoring the need for support. The cognitive skills category is followed in difficulty by management, technical, and interpersonal skills. Colleges could partner with employers to develop curricula that specifically target these skill areas and emphasize them across programs. In addition, training for instructors in two-year programs might provide additional guidance on how to support students in these areas.

The fact that a significant number of instructors reported student difficulty in learning management skills is particularly salient given employers' demands for these skills. As noted in Chapter Three, employers sought management skills—specifically, management of personnel resources, time management, and coordinating actions—to a greater degree than what instructors emphasized. Figure 4.2 shows instructors reported a majority of their students had difficulty with those skills (20 percent, 26 percent, and 11 percent, respectively). If instructors and programs further emphasize these management skill areas to align themselves with the demands of employers, they will need to reflect carefully upon best approaches for teaching these skills in ways that students can understand their relevance and utility in occupational settings.

Money and Time Pose the Biggest Barriers for Instructors, Though Barrier Types Depend on Knowledge Areas Emphasized

For each knowledge area they emphasized in their instruction, we asked instructors to identify those resources that they wished they had in greater quantity or quality to support student learning. Instructors could indicate a need for: money, time, noncomputer equipment, computer software/hardware equipment, tutors, help using the computer, or no needs.

Table 4.1 summarizes the results by category. Money was the most commonly requested support, with an average of 34 percent of instructors, on average across knowledge areas, indicating that they desired more “money for materials.” Time and noncomputer equipment were the second most-common resource needs. Notably, an average of 30 percent of instructors indicated that they did not need any of the resources we asked about in our survey, suggesting that additional resources are not universally needed for all knowledge areas.

Table 4.1. Percentage of Respondents Indicating Support Needed, by Knowledge Area Category

	All Knowledge Areas	Technical	Oil and Gas Industry	Academic	Safety	Soft Skills
Money for materials	34	38	55	22	34	14
More time to support students	24	27	7	23	22	21
Noncomputer equipment	22	29	24	11	17	0
Computer software/hardware	18	20	5	21	11	11
Tutors or teaching assistants	18	21	7	21	11	18
Help using a computer or other equipment	7	8	2	7	2	4
None	30	25	26	34	38	46

NOTE: Percentages are calculated by summing the instances professors indicated they would like a resource and dividing that sum into the number of emphasized knowledge areas.

Requested supports, however, varied significantly based on the type of knowledge areas instructors emphasized. In the technical and oil- and gas-based knowledge categories, for example, money remained the greatest needed resource, and the need for money dwarfed all other resources for oil- and gas-related knowledge areas. In both categories, noncomputer equipment was the second most-requested support. The greater emphasis on money and equipment for technical and oil and gas knowledge areas may not be surprising given that this knowledge may require expensive instructional materials, including equipment for hands-on learning. While we cannot directly extrapolate these findings to all occupational programs, they highlight the importance of physical resources that parallel those of the workplace. In contrast, in knowledge categories related to academics, safety, and soft skills, a smaller percentage of instructors requested noncomputer equipment. For safety, the emphasis once again turned to money and time, while instructors who emphasized soft skills additionally needed tutors.

Those emphasizing academic knowledge indicated needing a broader set of supports, including money, time, computer software and hardware, and tutors. These academic knowledge areas likely require less-specialized industrial equipment, but perhaps more specialized computer software and support in the form of tutors.

Finally, between one-third and one-half of instructors indicated needing no supports for knowledge areas related to academic, safety, and soft skills areas, whereas only one-quarter of instructors indicated needing no support for knowledge areas in the technical and oil and gas categories. These findings suggest that those teaching more technical subjects might need slightly more support in general.

Instructors Who Reported Needing More Resources Also Reported More Student Difficulty

While the two barriers each pose a different type of challenge to imparting the knowledge that workers need to be competitive in the oil and gas industry job market, they can also be related. A lack of resources in teaching a knowledge area could lead to suboptimal instruction and more student difficulty in learning that knowledge area. Providing instructors with the proper resources to teach a knowledge area is one way to better support student learning and potentially decrease the degree to which students have difficulty understanding the concepts.

We found that instructors who reported needing more resources in a knowledge area also reported greater student difficulty in that knowledge area. We used the following model to estimate the relationship between reported resources needed and reported student difficulty:

$$Y_{ick} = \beta_0 + \beta_1 Resources_{ick} + \alpha_k + \gamma_{ic} + \varepsilon_{ick}$$

Y_{ick} represents the degree of student difficulty that instructor (i) reported in course (c) for emphasized knowledge area (k). $Resources_{ick}$ represents the number of resources the instructor reported needing in that course for that emphasized knowledge area. α_k represents a knowledge area fixed effect, γ_{ic} are instructor-by-course fixed effects, and ε_{ick} is a stochastic error term.

This model allowed us to examine instructors of a specific course and compare the degree of student difficulty reported by the instructor in a certain knowledge area (using the original scale of: “few or no students,” “less than half my students,” or “more than half my students”) with the number of supports the instructor indicated he or she needed in that knowledge area (ranging from zero supports to all six possible supports). The knowledge area fixed effects allowed us to control for average differences among knowledge areas.

Results indicated that for every extra support requested by an instructor in a knowledge area, instructors were 56 percent more likely to indicate that a greater proportion of students in their class was having difficulty in that knowledge area ($p < 0.05$). To probe this finding more deeply, we redefined $Resources_{ick}$ above to be indicators for each type of support instead of the total number of supports needed. Results indicate that the need for noncomputer equipment is driving the result. Estimates on some other types of support are large, but they are not significant.¹

We cannot say with certainty that the lack of resources—noncomputer equipment in particular—caused more difficulty in student learning, as perceived by the instructors. Different types of students likely enrolled in different courses, and those student characteristics were likely related to the degree to which instructors perceived the need for supports and the degree to which instructors perceived student difficulty. However, the relationship highlights the multiple inputs that produce student learning and the importance of a well-resourced classroom to optimize student learning. Furthermore, the specialized technical nature of many of these classes make the

¹ See Appendix C for all models and point estimates.

relationship between noncomputer equipment and student difficulty intuitive. Ensuring that instructors have the resources needed to teach should not be overlooked in conversations among stakeholders. A tighter cooperation among colleges, employers, and third-party stakeholders could ensure that instructors have all the resources they need, including specialized equipment.

Conclusion

In this chapter, we analyzed two barriers to successfully equipping a workforce with the knowledge and skills necessary for the modern oil and gas industry job market: (1) which knowledge areas and skills were particularly challenging for students to learn according to their instructors, and (2) which resources instructors wished they had greater access to in terms of quality or quantity to help them teach the emphasized knowledge and skills. Overall, we found that the two barriers were related: Instructors who perceived a need for more resources also reported a greater degree of students' difficulty with learning the content.

Our results demonstrated that the correlation between emphasizing knowledge areas and student difficulty in a knowledge area was muted, indicating more nuance must be considered when allocating more resources to help struggling students. Some areas, such as math, were both emphasized to a strong degree and posed challenges to students, and therefore they warrant particular attention. Looking at skills, students had particular difficulty with cognitive and management skills. Recall that cognitive skills are among the most-emphasized skills by employers and instructors, indicating more resources may be needed to support students in learning these important skills. Management skills may also warrant further attention.

From the resource perspective, time and money were consistently in short supply. Noncomputer equipment was a particular need among those emphasizing technical and oil and gas knowledge areas, whereas needs were more evenly spread among those emphasizing academic areas. The shifting perceptions of resource needs by instructional focus indicates that optimal allocation of resources will consider the specialized nature, and therefore needs, of classes instructors teach. These perceived needs for resources could have consequences for students, as instructors who required more resources also reported a greater degree of student difficulty. Though more research needs to be done to understand whether a resource deficit is hurting student acquisition of knowledge or skills, our findings underscored the fact that classrooms and instructors need to be well resourced if students are to learn abstract and specialized forms of knowledge.

5. Summary of Key Findings and Conclusions

The analyses in this report provide a descriptive portrait of the alignment between course offerings and demands of employers in the oil and gas industry in the tri-state region. We asked two questions:

1. How well aligned were the content, skills, and workplace learning opportunities in the tri-state region's college courses with the needs that the region's STEM employers reported?
2. What content areas were most challenging for students and thus may be areas where students require more support?

In this chapter, we summarize our key findings from the analysis of surveys of instructors in five purposefully selected technical colleges in the tri-state region and an analysis of the curricula of those instructors' course offerings. We purposefully selected these five colleges in the tri-state region because they had specifically designed partnerships with industry leaders in the hopes to meet the demands of the growing and evolving oil and gas industry. Therefore, these colleges provided a best-case example of a sector-based partnership: They had been working collaboratively with oil and gas employers on curriculum and training options and thus we hypothesized they would provide a strong descriptive portrait of aligned programming. We fielded the survey in spring and fall 2017.

We end this report with concluding thoughts on how the tri-state region can improve its efforts to align workforce education and training with the knowledge and skill demands in the oil and gas industry to support middle-skills STEM careers more broadly. Our hope is that the descriptive portrait provided in this report can further inform the direction of collaborations so that they can effectively use the relationship and resources already in place to stand up effective and comprehensive sector-based public-private partnerships that supports a workforce development system that best meets middle-skills STEM labor market needs. It should be of interest to oil and gas employers, education providers, and stakeholders who are embedded in collaborative efforts under way in the region and across the United States.

Key Findings

We start with a summary of analyses of what types of knowledge areas and skills were emphasized in courses specific to the oil and gas industry and other technical courses generally related to middle-skills STEM occupations, alongside our analyses of the syllabi for these courses. This allowed us to explore what instructors deemed important in their courses, both *in practice* and as *intended*, which we compared with oil and gas employers' responses on a survey administered in 2016 as part of a previous report (Bozick et al., 2017).

We found the following:

- **Instructors reported that they emphasized cross-cutting knowledge areas—those that are applicable to a variety of different courses and fields—more than occupation-specific areas.** This is not particularly surprising, as many of these courses integrate both academic and technical concepts by design and focus on occupational applications that do not always directly map onto a single academic discipline or approach. Moreover, there has been increasing attention paid to ensuring that occupationally focused programs convey general job skills so as to prepare students for a wide variety of jobs after graduation (Stone and Lewis, 2012).
- **“Safety” was the most-emphasized knowledge area (65 percent of courses),** which may stem from the fact that safety is a critical component of almost all jobs and tasks in technical fields, including the oil and gas industry, and must therefore be reinforced in each class.
- **“Soft skills knowledge” (workplace competencies, such as being able to work in a team) was the second most-emphasized area (28 percent of courses).** This relatively strong emphasis on soft skills, compared with other knowledge areas we surveyed, is in keeping with employers’ increasing demand for workers who have proficiency in this area. It is a knowledge area applicable to a variety of jobs and contexts.
- **Instructors emphasized cognitive skills more than interpersonal skills in their courses.** Cognitive skills were overall the most-emphasized skills by instructors, with an average of 64 percent of courses including an emphasis on cognitive skills. About three-quarters of courses emphasized critical thinking, active listening, and applying new learning in many or all of their classes, and about two-thirds of courses emphasized complex problem-solving, judgement and decisionmaking, and troubleshooting. These six skills were the most emphasized of all the skills in any category. The high level of emphasis suggests that instructors were attempting to impart habits of mind and approaches to situations and problems that can be applied across jobs in the oil and gas industry and even in other sectors.
- **Syllabi often matched the knowledge areas and skills that instructors stated they emphasized.** The top knowledge areas that came up in more than one-third of syllabi were similar to the most commonly emphasized knowledge areas in the instructor survey: safety, electrical, computer science, math, English, and instrumentation/sensors. The two top skills that came up in more than one-third of syllabi were operation of systems or equipment (36 percent of syllabi) and troubleshooting (33 percent of syllabi). Those two skills were also two of the top skills emphasized in survey reports, although higher percentages of instructors indicated emphasizing those skills in their courses (52 percent emphasized operation of systems or equipment, and 60 percent emphasized troubleshooting).
- **However, several knowledge areas and skills commonly emphasized in the survey were less frequently addressed in syllabi,** including engineering (emphasized by 49 percent of instructors in the survey but in only 14 percent of syllabi) and manufacturing (emphasized by 35 percent of instructors in the survey versus 22 percent of syllabi). Instructors might have a broader definition of engineering and manufacturing than those who coded the syllabi, or perhaps engineering and manufacturing topics naturally came up in the course of teaching core course content without being named in syllabi as teaching topics. Many skills emphasized by over half of instructors in the survey were rarely if ever mentioned in syllabi, including judgment and decisionmaking (no syllabi), complex problem-solving (11 percent of syllabi), active listening (11 percent of syllabi),

applying new learning (6 percent of syllabi), and critical thinking (8 percent of syllabi). Syllabi might be written to note key knowledge, rather than skills.

- **A greater percentage of employers sought nontechnical skills in interpersonal and management knowledge areas compared with the percentage of courses that emphasized them.** The results from the Bozick et al. (2017) survey indicated that employers' most-wanted skills were critical thinking, judgement and decisionmaking, and complex problem-solving. Strikingly, none of the skills most sought after by employers, as determined in Bozick et al. (2017), fall in the technical category. Three of the skills (speaking, negotiation, and social perceptiveness) are interpersonal skills, the category of skills *least* emphasized by instructors in the survey. Another three skills emphasized by employers (management of personnel resources, time management, and coordination) were management skills, the second least emphasized category of skills by instructors. These patterns support the notion that these skills are high demand, but that instructors may be undervaluing them in the classroom.
- **A greater percentage of instructors reported emphasizing technical and cognitive skills than the percentage of employers who reported seeking such skills.** Of the five skills with the greatest discrepancy between instructors' and employers' responses on the surveys, three were technical (operation and control, equipment selection, and technology design) and two were cognitive (troubleshooting and learning strategies). These results do not necessarily suggest that instructors should emphasize these skills to a lesser degree; indeed, employers' responses regarding which skills their high-demand jobs required could be influenced by the lack of supply of workers with those skills. That is, they may have been less likely to indicate cognitive and technical skills were required if workers were graduating from programs with those skills.
- **Instructors partnering with industry were more likely to emphasize skills that were more valued by employers.** Thus, instructors may have recognized this need for management skills as they collaborated with their industry peers. In addition, while the oil and gas industry knowledge area category were the least emphasized among instructors, partnerships with industry were related to more emphasis on oil and gas, which may be highly aligned to the pool of potential jobs.
- **Part-time instructors composed the majority of the survey sample.** Fifty-seven percent of respondents indicated that they were part-time instructors. While we do not have evidence to suggest that full-time instructors are more effective than part-time instructors (or vice versa), this substantial number of part-time instructors in our sample highlights the importance of a deeper understanding of the instructor labor market, the supply of full-time and part-time instructors available to local colleges, and pros and cons of each group.

In Chapter Four, we examined which knowledge areas and skills were particularly challenging for students to learn according to their instructors and to which resources instructors wished they had greater access to help them teach the emphasized knowledge and skills. We found the following:

- **Instructors reported that students had the most difficulty with technical and academic knowledge areas in their courses.** This was particularly the case for math, which was a knowledge area that instructors both emphasized “to a strong degree” and therefore warranted particular attention.

The knowledge area “soft skills” was another area in which students had difficulty.

- **Although instructors reported that students struggled with multiple skills, cognitive and management skills reportedly posed the greatest difficulty for students.** Given that cognitive skills were among the most-emphasized skills by employers, as documented in Bozick et al. (2017) and by instructors, it may be that more resources are needed to support students' learning these skills. Management skills, which are also in high demand by employers, may be another area that warrants further attention.
- While the mix of barriers depends on the types of knowledge area the instructor endeavored to teach, **respondents reported that money and time were the greatest barriers in conveying the knowledge and skills to students.** The shifting perceptions of resource needs by instructional focus indicates that optimal allocation of resources should consider the specialized nature, and therefore needs, of classes instructors teach.
- **There is a clear and positive association between instructors reporting that they needed more resources and also reporting more student difficulty.** Though more research needs to be done to understand whether a resource deficit is hurting student acquisition of knowledge or skills, our findings underscore the fact that classrooms and instructors need to be well-resourced if students are to learn abstract and specialized forms of knowledge.

Concluding Remarks

The results presented in this report contribute new knowledge to our understanding of the role that sub-baccalaureate programs play in providing potential middle-skills STEM workers with the skills and training necessary to succeed in the labor market specific to the oil and natural gas industry. Understanding the relationship between sub-baccalaureate programs' curricula and the needs of employers is crucial for both education policy research and for more broadly considering how local colleges and employers can jointly improve the economic prospects of the labor force that does not seek four-year degrees. In turn, this information is vital for supporting an agile and effective workforce development system for the second STEM economy. Our analyses of instructor surveys and their course syllabi provided an in-depth understanding of the types of knowledge areas and skills that education providers emphasized at the time of our study, spring and fall 2017.

The findings summarized earlier in this chapter suggest that industry and college leadership consider committing resources to align instruction to employer needs. Although we purposefully selected colleges that had designed programs in tandem with industry leaders, it was evident that disconnects between curriculum and industry demands in knowledge areas and skills still existed. Previous research has highlighted that each side (education providers and industry leaders) was eager to collaborate but relied on the other entity to initiate outreach. Furthermore, each side cited institutional constraints that tended to hinder outreach efforts (Bozick et al., 2017). Our findings corroborate this disconnect: The inability to coordinate has left the door open for some mismatches between the skills sought after by employers and the skills taught by instructors. This suggests that further effort by employers, colleges, and third-party interest groups to bridge this gap and encourage dialogue between instructors and employers could result in more aligned curriculum and benefit all stakeholders.

Appendix A. Description of ShaleNET and TEAM Consortia

ShaleNET was a unique partnership between employers in the energy sector and a consortium of colleges in Ohio, Pennsylvania, Texas, and West Virginia. Through this partnership, local employers collaborated with community colleges to design sub-baccalaureate credentialing programs that aimed to teach critical, occupation-specific STEM skills to students set to take high-demand semiskilled STEM jobs in the expanding energy sector across the tri-state region and in Texas. Given the direct participation of industry and the focus on the cultivation of occupation-specific STEM skills, ShaleNET was a potential model for other sectors and regions on how to develop public-private partnerships that could efficiently prepare workers for employment in the sub-baccalaureate STEM labor market.

ShaleNET's goals were to (1) train a skilled local workforce to support the needs of the growing natural gas industry; and (2) help traditionally vulnerable groups (e.g., rural students or veterans) find family-supporting jobs in the STEM labor market. In 2010, the U.S. Department of Labor's Employment and Training Administration (ETA) provided a grant to Westmoreland County Community College, the central hub of ShaleNET at that time, to establish ShaleNET. In the 2010 grant, the initial focus of ShaleNET was on four entry-level certification programs, which were administered by 20 training providers in the Marcellus Shale region. From 2010 to 2013, more than 950 ShaleNET participants received entry-level (or "Tier 2") certification. A follow-on grant from the U.S. Department of Labor's ETA in 2012 allowed ShaleNET to operate from 2012 to 2016, with Pennsylvania College of Technology as the hub. At this point, the consortium included Westmoreland County Community College, Pennsylvania; Pennsylvania College of Technology; Stark State College, Ohio; Pierpont Community and Technical College West Virginia; and Navarro College, Texas. For the follow-on grant, ShaleNET offered 11 programs across three tiers of entry- and career-level training, as detailed in Table A.1.

Table A.1. ShaleNET Program Offerings

Tier	Programs
Tier 2: Entry-level certification ^a	Roustabout Floorhand Completion Technician Welder Helper
Tier 3: Industry certificates	Production Technician Pipeline Technician Process Technician Instrumentation and Electronics Technician
Tier 4: Associate's degrees	Petroleum Technology Mechatronics Industrial Maintenance Technology

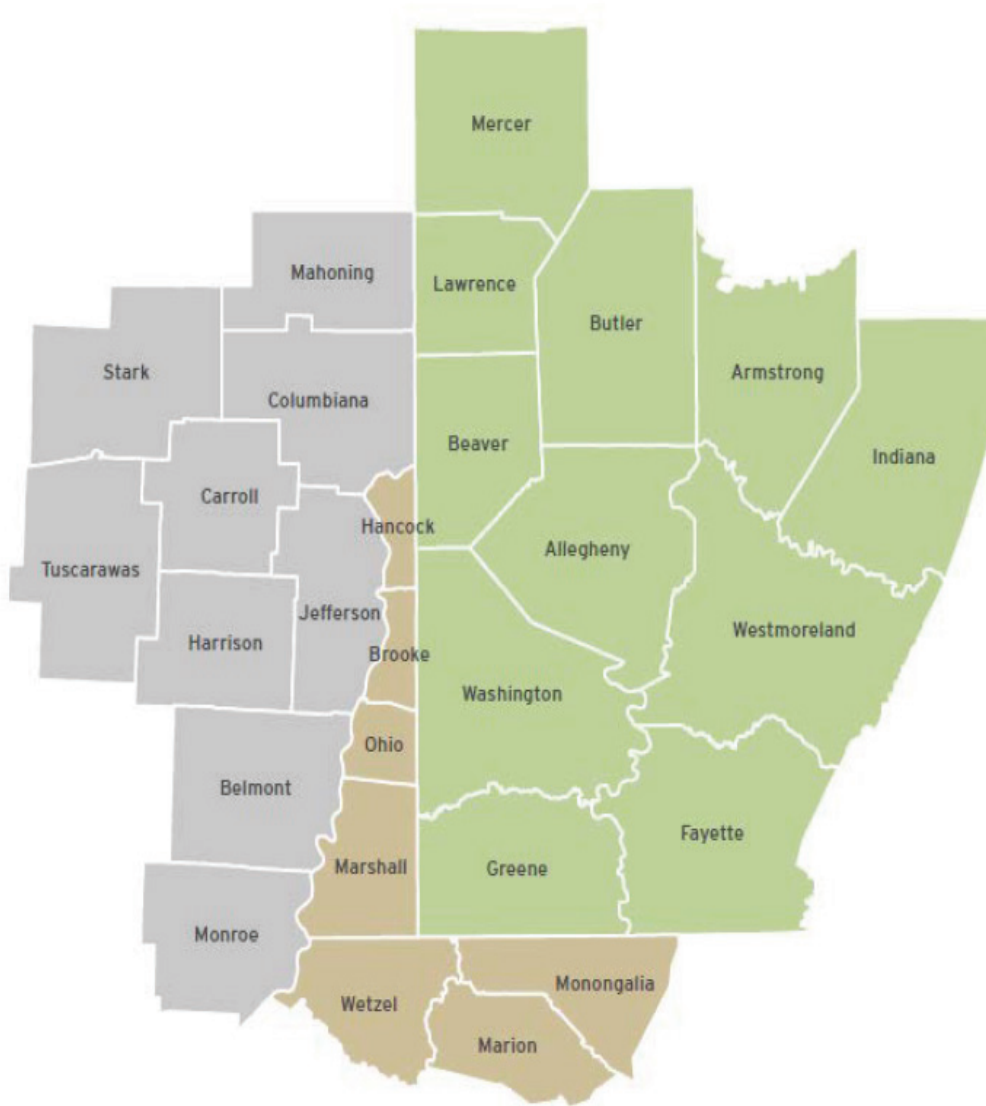
^a Tier 1 of ShaleNET is "Foundational Skills," which is incorporated into all training programs.

ShaleNET offered the entry-level certification programs (Tier 2), and industry certificates and associate's degree programs (Tiers 3 and 4) were added with an initial cohort of 393 students in the fall of 2013. ShaleNET's tiered training model provides a unique opportunity to understand the return on educational investments for different levels of sub-baccalaureate training. Entry-level certification programs could be completed in as little as three weeks, while industry certificates required at least a semester at a community college, and associate's degrees typically take two years as a full-time student. While these three tiers of training provide different depth of study, they were consistent in their focus on high-demand STEM occupations in the oil and gas industry.

When the ETA grant ended in 2016, the presidents of each of the tri-state colleges endeavored to continue the collaboration and founded the TEAM Consortium. TEAM Consortium is co-chaired by the Community College of Beaver County and Chevron Corporation, and is financially supported by Chevron, the Appalachian Regional Commission, and the Claude Worthington Benedum Foundation. The college "hub" was moved to Beaver Community and Technical College and a staff member was hired to lead TEAM. Beaver Community and Technical College was selected as the hub because of its centralized location in the region and because Royal Dutch Shell is building a \$6 billion ethane cracker plant in Beaver County, Pennsylvania. At the inception of TEAM, Shell was collaborating with Beaver College to develop various degrees and certifications for employment in the plant.

The TEAM Consortium encompasses 27 counties across the tri-state region, as illustrated in Figure A.1.

Figure A.1. Counties in Ohio, Pennsylvania, and West Virginia that Compose the TEAM Consortium Footprint



This wave of new economic activity has been anticipated by visionary leaders across the tri-state area, and efforts are being coordinated across state lines to respond to the need for a properly trained workforce.

Appendix B. Instructor Survey Items Addressing Knowledge and Skills

The instructor survey included questions about the knowledge and skills that instructors addressed in one course they taught. Instructors could answer the same questions for a second course they taught, if they chose to do so. The specific knowledge and skill areas we asked about in the survey, along with the question wording, is included below.

How much emphasis is placed on the following knowledge areas [within COURSE A and/or within COURSE B]? (Scale: “not taught in the course,” “emphasis in some or a few classes,” “emphasis in many or most classes,” “emphasis in every class”)

- Automation (e.g., programmable logic controllers, electronics)
- Blueprint reading
- Building and construction
- Design and computer-assisted design (CAD)
- Commercial driver’s license and driver training
- Chemistry or chemistry-related materials
- Computer science (e.g., software, computer programming classes)
- Corrosion
- Oil and gas drilling, including drilling technology
- Electrical (e.g., electric circuits, machinery)
- Energy systems (including solar technology)
- Engineering and Technology
- English (e.g., reading, writing)
- Geology
- Heating, ventilation, and air conditioning (HVAC)
- Hydraulic and pneumatic systems (e.g., gas and fluids compression, flow)
- Manufacturing, production and processing, including assembly
- Safety (e.g., [Occupational Safety and Health Administration] regulations and compliance)
- Industrial Instrumentation and Sensors (e.g., measurement, mechatronics, process controls)
- Mathematics (e.g., algebra, applied math)
- Mechanics and motors (e.g., mechanics, mechanical drive components)
- Oil and gas industry (e.g. “about the oil and gas industry” courses)
- Pipelines and pipeline operation
- Well-pad/gas and oil lease operations, including well servicing
- Physics, including statics and strength of materials)
- Power plant and power systems
- Rigging
- Pumping (e.g., sucker rod pumping, free plunger lift)

Soft Skills (e.g. leadership skills, interpersonal communication)

Welding

Other [Please describe: _____]

How much emphasis is placed on the following skills [in COURSE A and/or COURSE B]?
(Scale: Not taught in the course; Emphasis in some or a few classes; Emphasis in many or most classes; Emphasis in every class; Unsure)

Administration and Management

Applying New Learning

Active Listening

Complex Problem-Solving

Coordinating Actions

Critical Thinking

Equipment Maintenance

Equipment Selection

Machine or Equipment Installation

Instructing Others

Judgment and Decisionmaking

Use of Learning and Study Strategies

Management of Financial Resources

Management of Material Resources

Management of Personnel

Monitoring Performance of Self and Others

Negotiation with Others

Operation of Equipment or Systems

Operation Monitoring (monitoring gauges, dials or other indicators)

Operations Analysis (needs analysis to create a design)

Persuasion

Quality Control Analysis

Repairing Machines or Systems

Service Orientation

Social Perceptiveness

Speaking to Others

Systems Analysis and Evaluation

Design of Technology

Time Management

Troubleshooting

Other Skills [Please describe: _____]

Appendix C. Technical Appendix

This appendix describes the methodologies for the regression analyses conducted in Chapters Three and Four.

Instructor Responses to Emphasized Knowledge Areas and Skills

Instructors were asked to what extent they emphasized 30 knowledge areas and 30 skills. Each item was judged on a 4-point Likert scale: (1) not taught in the course; (2) emphasis in a few classes; (3) emphasis in several or many classes; and (4) emphasis in every or almost every class. An instructor was deemed to emphasize the knowledge area or skill if he or she responded with a 3 or 4. The percentage of respondents emphasizing a knowledge area or skill is therefore the proportion of respondents that indicated a 3 or 4 for that item. The category average is the average proportion of all items in the category.

Only statistically significant differences are discussed in the report narrative. Table C.1 displays the results of the tests of significance.

Table C.1. Tests of Significance in Instructor Responses to Emphasized Knowledge Areas and Skills

Null Hypothesis	Chi Squared	P-Value
Panel A: Knowledge Areas		
Safety, soft skills, technical, academics, and oil and gas industry averages are equal	$\chi^2_4 = 136.43$	$p < 0.001$
Safety average is equal to soft skills average, the category emphasized by the next largest number of instructors	$\chi^2_1 = 40.69$	$p < 0.001$
Engineering average is equal to math average, the two knowledge areas most emphasized by instructors	$\chi^2_1 = 4.96$	$p = 0.0206$
Math average is equal to English average, the knowledge area emphasized by the next largest number of instructors	$\chi^2_1 = 10.34$	$p = 0.0013$
Oil and gas industry average is equal to the pumping average, the knowledge area emphasized by the next largest number of instructors	$\chi^2_1 = 3.75$	$p = 0.0527$
Panel B: Skills		
Cognitive average is equal to the operations average, the category emphasized by the next largest number of instructors	$\chi^2_1 = 76.63$	$p < 0.001$
Operations average is equal to management average	$\chi^2_1 = 8.01$	$p = 0.0046$
Interpersonal average is equal to management average, the category emphasized by the next largest number of instructors	$\chi^2_1 = 22.24$	$p < 0.001$

Comparing Skills Sought by Employers and Skills Emphasized by Instructors

In Bozick et al. (2017), researchers surveyed employers regarding the skills demanded by high-need jobs in their fields. For each skill, the researchers indicated the proportion of respondents that sought that skill for their high-need jobs. The skills in that survey overlapped

with the skills in the current survey of instructors. In comparing the two surveys, we subtracted the percentage of instructors emphasizing a skill, as defined above, from the percentage of employers seeking that skill for their high-need jobs. Differences were ordered from positive to negative. A positive difference indicates that more employer respondents were seeking the skill. A negative difference indicates that more instructors were emphasizing that skill in the course.

Differences in Outcomes By Partnering With Industry

We looked for differences in outcomes by whether instructors indicated that they partner with industry. Specifically, instructors were asked: Do you work with or partner with individuals or companies in local oil and gas or advanced manufacturing industries for any aspects of your work in [course]?

We used a random effects model to calculate the adjusted average response for each category. We modeled outcomes in the following way:

$$Y_{ic} = \beta_0 + \beta_1 Partner_{ic} + \mathbf{X}_{ic}\boldsymbol{\beta}_2 + \alpha_c + \mu_i + \varepsilon_{ic} \quad (\text{Eq. 1})$$

Y_{ic} is the average Likert scale for a respondent in a particular knowledge area or skills category for instructor, i , in college, c . Y_{ic} was constructed by averaging the Likert scale response for all items in a particular category for each respondent. $Partner_{ic}$ is an indicator for partnering with industry, $PartTime_{ic}$ is an indicator for teaching part-time at the college, and \mathbf{X}_{ic} is a vector of instructor characteristics. This vector includes the natural log of the number of courses taught, the natural log of the number of sections taught, length of the course, the natural log of the number of credit hours of the course, the natural log of the number of times the instructor has taught the course, years of experience of the instructor, an indicator for having worked outside of teaching in the past, the number of course hours per week, the number of lab hours per week for the course, an indicator for being a part-time instructor, an indicator for the fall wave of the survey, and an indicator if this was the second course that the instructor responded to (instructors could respond to a maximum of two courses). α_c is a college fixed effect that accounts for average differences among colleges in the sample and μ_i is an individual random effect to account for the fact that some respondents completed the fall and spring surveys. Finally, ε_{ic} is an instructor-semester level idiosyncratic error term.

The coefficient of interest is β_1 , which will estimate the difference in average responses for instructors who indicated they partner with industry. A test of the null hypothesis will indicate if this difference is statistically different from zero. The statistical significances in our results come from these tests of the null hypothesis. The reported average responses and their 95 percent confidence intervals are the marginal means calculated at the sample average value of all other covariates.

Comparing Instructor Ratings of Student Difficulty with Instructors' Desired Supports

For each course, instructors were asked to rate the degree of difficulty that students faced in learning an emphasized knowledge area on the following scale: “few or no students,” “less than half my students,” or “more than half my students.” For each emphasized knowledge area, instructors were also asked those resources that they wished they had in greater quantity or quality to support student learning. Instructors could indicate a need for: money, time, noncomputer equipment, computer software/hardware equipment, tutors, help using the computer, or no needs. To examine the relationship between these two variables, we first summed the number of resources instructors indicated they needed for each emphasized knowledge area in a certain course. That is, we created a variable that ranged from zero resources needed to six resources needed for a given emphasized knowledge area in a course reported on by an instructor. We then modeled the relationship as follows:

$$Y_{ick} = \beta_0 + \beta_1 Resources_{ick} + \alpha_k + \gamma_{ic} + \varepsilon_{ick} \quad (\text{Eq. 2})$$

Where Y_{ick} represents the degree of student difficulty instructor, i , reported in course, c , for emphasized knowledge area, k . $Resources_{ick}$ represents the number of resources the instructor reported needing in that course for that emphasized knowledge area. α_k represents a knowledge area fixed effect of the 30 knowledge areas that an instructor could emphasize within a course. Finally, γ_{ic} are instructor-by-course fixed effects and ε_{ick} is a stochastic error term. The instructor-by-course fixed effects allows us to compare responses across emphasized knowledge areas within a course that an instructor teaches. This will account for any instructor specific characteristics for a given course. Meanwhile, the knowledge area fixed effects will account for stable differences in emphasized knowledge areas. The coefficient of interest is β_1 , which will indicate how the degree of reported student difficulty in a knowledge area is related to each additional reported need for a resource. We clustered our standard errors by instructor.

The above model assumes a linear relationship between the number of resources needed for a knowledge area and the reported student difficulty in that knowledge area. Therefore, it assumes that the effect of one additional support is constant. To understand which supports may be driving the overall result, we run a second regression where $Resources_{ick}$ in Equation 2 is replaced with dummy variables for each of the six supports. Coefficients on each dummy variable will uncover how the expressed need for a particular type of support is related to perceived student difficulty. Table C.2 below displays the results of both models.

The outcome variable, Y_{ick} , is not continuous, but rather is ordinal in nature. We therefore use conditional ordinal logit models. The coefficients on ordinal logit models can be hard to interpret. We therefore presented odds ratios in the body of the report. The odds ratio for the coefficient on *resource* in Table C.2 is 1.56. That is, for each additional increase in a reported needed resource, the odd of reporting a higher degree of student difficulty is 56 percent. The

odds ratio for the coefficient on *noncomputer equipment* is 3.34, meaning when instructors indicate a need for noncomputer equipment they are 3.34 times as likely to report a higher level of student difficulty.

Table C.2. Relationship Between Perceived Student Difficulty and Perceived Needed Resources in Emphasized Knowledge Areas

Panel A: Total Resources Requested	
Resources	0.444* (0.200)
Panel B: Individual Request Resources	
Time	0.742 (0.465)
Tutors	0.665 (0.463)
Computer equipment	-0.699 (0.705)
Noncomputer equipment	1.207* (0.364)
Computer help	0.264 (0.743)
Money	0.208 (0.385)
Instructor-by-course fixed effects	Yes
Knowledge area fixed effects	Yes

NOTES: Standard errors are clustered at the respondent level. A conditional ordinal logit models was used in the regression.

* $p < 0.05$.

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