Connecting Hands and Heads

Retooling Engineering Technology for the Manufacturing 5.0 Workplace

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EXECUTIVE SUMMARY

The manufacturing sector that has rebounded from the havoc wrought by the Great Recession is a more automated and digitized environment. Manufacturing 5.0, the term we have adopted to describe a new era of production enabled by the “Industrial Internet of Things” (IIoT), portends even more change, as increasingly sophisticated machines are used to transform processes and improve productivity. A manufacturing environment where machines are computer controlled, production is digitally connected to suppliers and customers, and all aspects of operation are constantly monitored and analyzed requires workers with a new and emerging array of skills. This will only exacerbate existing gaps in Ohio’s workforce supply as demand grows for middle- and high-skilled workers.

The looming need for workers who can keep automated systems operating, anticipate potential production problems, and reconfigure machines to accommodate new processes suggests the importance of a more systemized and integrated approach to educating and training the Manufacturing 5.0 workforce. Over the past few years, state and local policymakers and workforce development agencies have begun responding to the concerns of area manufacturers. A number of Ohio manufacturers, in turn, have rightfully taken steps to address identified workforce challenges, reaching out to local

vocational schools and community colleges to develop training programs. However, important partners in building the manufacturing workforce of the future have been largely left out of the process: universities.

OMI argues an expanded role for universities in preparing and retraining the Manufacturing 5.0 workforce. Data analysis and discussions with manufacturers across the state reveal a critical need for a set of application-based engineering technology degrees that connect hands and heads in the digitized, integrated manufacturing environment. Developing engineering technology or applied engineering educational programs with multiple on and off ramps will facilitate the growing need for business-oriented engineering leaders to run the factories of tomorrow. In addition, universities are critical to expanding the state's skill development capacity by serving to "train the trainer."

Ohio already has existing infrastructure for addressing the changing workforce needs of the state's manufacturing industry. The increasingly digitized and integrated plant floor has enabled greater productivity, better connectivity, and integration of workforce development and educational programs. However, revamped policies to speed curricula and programmatic changes based on industry needs will allow the state to build the manufacturing workforce needed to compete and thrive.

INTRODUCTION

Over the past decade, a workforce paradox has been playing out in the manufacturing industry: an undersupply of skills despite an oversupply of workers; reports of jobs going unfilled in a time of high unemployment.

The seeming contradiction may best be characterized as a prioritizing of emergencies. The devastating tsunami of the Great Recession that left idled workers and shuttered factories in its wake obscured the shifting tide of technological change that was reshaping the factory floor and the manufacturing workforce. In fact, the powerful economic force served to accelerate the evolution of production.

Manufacturers who had adopted productivity-enhancing technologies of robotics and automation to thrive amidst growing global competition continued those efforts to survive the historic economic decline. As the economy began to recover, the factory floor had been transformed — employing more automation and fewer workers and requiring a higher and broader set of skills to operate within a more sophisticated and high-tech environment. For the first decade and a half of the 21st century, manufacturers limited hiring, but now due to job growth in certain occupations and an urgent need to replace retiring workers, manufacturers are poised to hire new workers, particularly those with machining and electro-mechanical maintenance skills and increasingly those with digital skills.

Technological change, global competition and protracted economic downturn combined to usher in and hasten the era of Manufacturing 5.0. Manufacturing 5.0 is the term we at the Ohio Manufacturing Institute have adopted to describe the fifth phase of industrial revolution, the shop-floor digitalization of manufacturing. Figure 1 marks the five distinct phases from mechanical mass production to the American system of assembly-line production, the adoption of electric motor drive systems into tools, the

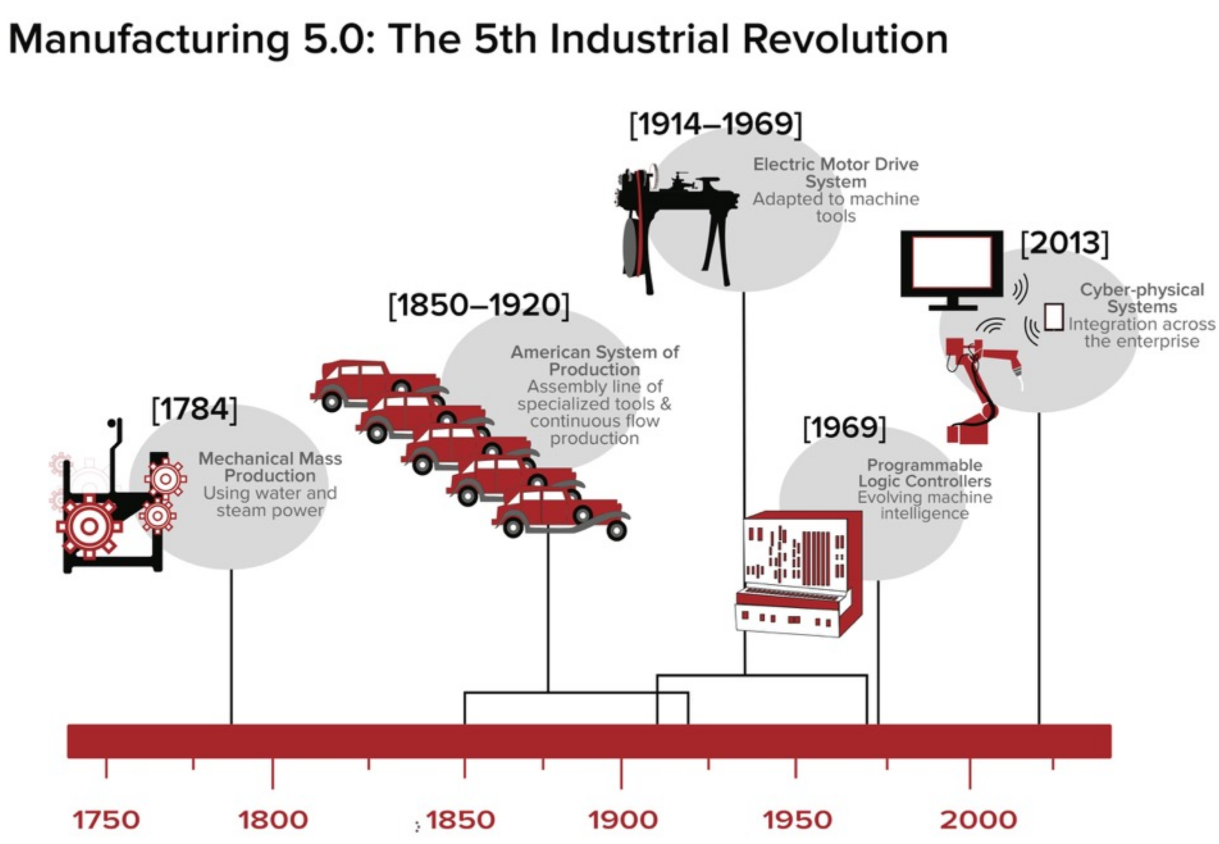

Figure 1

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rise of machine intelligence and programmable logic controllers and now to the dawning of cyber-physical systems. The embedding of microprocessors into tools and the collecting of data through a connected “Industrial Internet of Things” (IIoT) has enabled the digital integration of all aspects of manufacturing operations; machines are computer controlled, production is digitally connected to the supply chain and customers, and utilization and capacity are seamlessly monitored and analyzed.

Disruptive technologies associated with the digitalization of the shop floor will result in a major jump in productivity over the next five years. These sweeping changes are taking off slowly, gathering momentum, and will be going full bore less than a decade from now. Preparing statewide and nationally for the manufacturing skills of the near future must begin to take shape in the present.

Manufacturing 5.0 will further exacerbate the profound effect disruptive technologies have had on the production workforce, creating higher demand for workers with the skills to operate or repair computerized systems and with the ability to use data to make decisions. This will result in changes in the mix of skills demanded in plants. There is, and will continue to be, lower demand for semi-skilled workers who tend machines. Demand for engineering technicians – the people who will keep the robots working – will intensify. Skilled manufacturing workers are increasingly expected to exhibit an understanding of business practices as well as production operations and use that understanding to anticipate potential issues and solve them before they become problems. Although the expansion of technology has focused attention on the need for greater technical skills, "soft" interpersonal skills are increasingly sought after within the Manufacturing 5.0 environment.

These changes augur a need for a new, more integrated and coordinated approach to educating and training the Manufacturing 5.0 workforce. This is especially true in Ohio, where manufacturing continues to serve as a driver of state and regional economies. As the third most productive manufacturing state in the nation, Ohio manufacturing's gross domestic product has rebounded from its precipitous decline during the recessionary years of 2008 and 2009, with first-quarter 2016 GDP roughly 16% higher than the industry's pre-recessionary peak in 2007. Manufacturing employment in Ohio had rebounded nearly 12% by 2017 over its nadir in June 2009 following the recession, but there were still 92,000 fewer manufacturing jobs in the state than in 2007, according to Bureau of Labor Statistics data. Despite these losses, manufacturing continued to account for more than 12.5% of private-sector employment in Ohio and 5.6% of U.S. manufacturing jobs.

The transformation taking place on the shop-floor has begun to attract the attention of policymakers and educators, yet the focus has been on training and credentialing for short-term, immediate skill demands. That is an important and largely underappreciated avenue for talent development. However, better-targeted and more short-term credentialing only addresses part of the challenge. The need for a set of application-based engineering technology degrees connecting hands and heads is becoming increasingly apparent in the digitized, integrated manufacturing environment; demand for workers with appropriate skills is only likely to continue to expand over the next decade. That argues for an expanded role for Ohio and national universities in preparing and retraining the Manufacturing 5.0 workforce. Engineering technology or applied engineering educational programs with multiple on and off ramps will facilitate the growing demand for business-oriented engineering leaders to run the factories of tomorrow.

ENGINEERING TECHNOLOGY FILLS MANUFACTURING 5.0 TALENT GAPS

According to the Accreditation Board for Engineering and Technology (ABET), the national organization that accredits higher education science, engineering and technical programs, engineering technology differs from engineering in both curricular focus and career paths:

- **Curricular Focus** – Engineering programs often focus on theory and conceptual design, while engineering technology programs usually focus on application and implementation. Engineering programs typically require higher-level mathematics, including multiple semesters of calculus and calculus-based theoretical science courses, while engineering technology programs typically focus on algebra, trigonometry, applied calculus, and other courses that are more practical than theoretical in nature.
- **Career Paths** – Graduates from engineering programs often pursue entry-level work involving conceptual design or research and development. Many pursue graduate-level work in engineering. According to the ABET, graduates of four-year engineering technology programs are most likely to enter positions in engineering sectors such as manufacturing, product design, testing, construction, or technical services and sales. Those who pursue further study often consider engineering, facilities management, or business administration.

Although the vital role workers trained as engineers play in innovation and productivity gains tends to be recognized and often discussed, the important contribution of workers trained in engineering technology has gotten much less attention. However, employer observations and employment projections presented in this report suggest a training and education gap that needs to be closed – and quickly.

A series of six focus groups with manufacturers around the state reveal three broad immediate and near-term concerns in finding workers with the skills they need to operate and grow: **specific technical skills**, such as the ability to program, operate, maintain, and repair increasing complex computerized machines or to prepare food, beverage, chemical and biotechnology process-manufactured goods; **operational and management skills**, such as the ability to interpret and implement new processes that arise out of new products and understand business challenges, and **basic readiness and interpersonal skills**, such as showing up for work on time, communicating individually and within a team, and being prepared for workplace expectations. The first two skill categories, in particular, align with the curricular focus of engineering technology degrees, with the former more traditionally aligned with an associate's degree and the latter with a bachelor's level degree.

The focus groups expose looming workforce gaps that suggest an opportunity for strategic collaboration on the part of manufacturing employers and state educational providers to develop a broader and deeper pool of talent. Two-year and four-year postsecondary institutions, as well as high schools and vocational programs, have a role to play in expanding the pool of young workers with the mix of skills and knowledge to meet the changing needs of Ohio manufacturers. Manufacturers, in turn, acknowledge the role they must play in developing a workforce with the necessary technical and analytical skills. However, they seek opportunities to partner with educational institutions to not only prepare new workers but retrain incumbent ones.

Manufacturers say degree programs are not set up to meet the retraining needs of incumbent workers and are narrowly focused when broad-based skills that provide a foundation for workplace training in more specialized expertise is preferred. Employers know that skills demanded of both high- and middle-skilled workers are evolving quickly as changes in the manufacturing landscape speeds toward digitalization and IIoT. Workers increasingly must function at the intersection of operational technologies (OT) and information technology (IT), monitoring and controlling digital devices or facilitating and enhancing complex processes and activities within the enterprise.

Skilled manufacturing workers will increasingly need to understand both business and practical applications to identify and solve issues in advance. At the same time, manufacturers will demand workers who not only demonstrate prowess in technical skills but also exhibit interpersonal aptitude and other soft skills. More and more, a triumvirate of skills, mobility, and leadership will be seen as critical in new hires and incumbent workers. For example, manufacturers are increasingly interested in retraining programs for veterans, who already possess many of the soft skills and self-discipline employers want. Career ladders will be truncated and require constant learning in this new manufacturing environment for workers to advance. What will Manufacturing 5.0 mean for the future workforce and who will take the lead in adequately educating and training workers? OMI sets out in this report to develop standardized solutions to this broad-spectrum problem.

BY THE NUMBERS

Nationwide, the U.S. Bureau of Labor Statistics projected manufacturing employment to decline by 6.7 percent in the decade from 2014 to 2024. Although the number of workers engaged in many traditional production occupations, such as assemblers, machine setters, and mold makers, is projected to continue to decline over the coming decade, several others that enable and support the modern, automated manufacturing facility are expected to surge. Table 1 provides the projected employment growth among select occupations with large concentrations of employment in manufacturing industries. The first bundle of occupations includes technical and production-related activities often associated with manufacturing activities, several of which have increasingly become the topic of policies and programs. The second bundle includes occupations that typically require at least a bachelor's degree in science, engineering, technology or mathematics. Many of these occupations are designed to increase the number of STEM workers. As can be seen in Table 1, a large portion of these occupations are associated with manufacturing activities. Nearly three-fourths of industrial engineers, 60% of materials engineers, half of mechanical engineers and chemical engineers, and more than one-third of electrical engineers are employed in manufacturing. The third bundle of occupations are supervisory and managerial activities associated with manufacturing.

Table 1 shows projected growth in occupational employment through 2024. Occupations expected to grow tend to be ones requiring the technical skills to program, maintain, troubleshoot, and repair increasingly sophisticated production machinery. For example, the number of computer-controlled machine operators and programmers are projected to grow by more than 17% by 2024, adding an additional 25,000 operators and more than 4,000 programmers. The number of machinists needed to set up and repair machine tools is expected to reach 343,200 nationwide by 2024, a 7.8% increase over

2014 employment levels. An expected 13.2% increase in industrial machinery mechanics would increase the ranks of such workers to nearly 201,000 nationwide over the next decade. The number of supervisors of such workers is also predicted to grow by more than 5,300. Although several of the occupations in Table 1 are not expected to see job growth through 2024, there will still be high demand for workers due to retirements. For example, the number of industrial production managers is expected to shrink through

Table 1. Employment Growth and Replacement Projections for Select Manufacturing-Related Occupations

Code	Title	2014 Total Occupational Employment	2014 Occupational Employment in Manufacturing	Share of OCC EMP in Mfg. 2014	Projected % Chg. in Total Occupational Employment, 2014-2024	Projected Chg. In Occupational Employment in Manufacturing, 2014-2024	Projected Job Growth, 2014-2024	Projected Replacement Employment Needs, 2014-2024	% of 2014 Workforce Projected to be Replaced by 2024	Median Annual Wages 2014
	Techncians & Production Occupations									
51-4012	Computer numerically controlled machine tool programmers, metal and plastic	25,100	23,600	94.0%	19.1%	17.8%	4,800	7,600	30.3%	$50,580
49-9041	Industrial machinery mechanics	332,200	177,400	53.4%	18.0%	13.2%	59,700	86,200	25.9%	$50,040
51-4011	Computer-controlled machine tool operators, metal and plastic	148,800	146,300	98.3%	17.5%	17.2%	26,000	45,200	30.4%	$37,880
49-9044	Millwrights	40,900	15,300	37.4%	15.2%	2.6%	6,200	8,300	20.3%	$52,440
51-4041	Machinists	399,700	318,400	79.7%	9.8%	7.8%	39,200	115,500	28.9%	$41,700
49-9043	Maintenance workers, machinery	91,200	58,700	64.4%	8.2%	3.2%	7,500	14,600	16.0%	$44,550
51-4121	Welders, cutters, solderers, and brazers	397,900	238,400	59.9%	3.6%	0.3%	14,400	114,100	28.7%	$39,390
51-2041	Structural metal fabricators and fitters	79,200	66,100	83.5%	2.0%	0.6%	1,600	13,000	16.4%	$37,730
17-3027	Mechanical engineering technicians	48,400	24,900	51.4%	1.9%	-4.4%	900	11,900	24.6%	$54,480
17-3024	Electro-mechanical technicians	14,700	7,100	48.3%	0.7%	-7.0%	100	3,600	24.5%	$55,610
17-3023	Electrical and electronics engineering technicians	139,400	54,800	39.3%	-2.0%	-10.2%	-2,800	36,900	26.5%	$62,190
17-3026	Industrial engineering technicians	66,500	54,400	81.8%	-4.5%	-6.8%	-3,000	19,300	29.0%	$53,330
	STEM-degreed Occupations									
17-2031	Biomedical engineers	22,100	9,700	43.9%	23.1%	26.8%	5,100	5,800	26.2%	$85,620
17-2141	Mechanical engineers	277,500	136,800	49.3%	5.3%	-1.4%	14,600	87,900	31.7%	$84,190
17-2061	Computer hardware engineers	77,700	32,400	41.7%	3.1%	-13.3%	2,400	16,000	20.6%	$115,080
19-2032	Materials scientists	7,300	3,100	42.5%	2.7%	-9.7%	200	1,600	21.9%	$99,430
19-2031	Chemists	91,100	33,500	36.8%	2.6%	-9.6%	2,400	20,000	22.0%	$73,740
17-2041	Chemical engineers	34,300	16,900	49.3%	1.7%	-7.1%	600	9,400	27.4%	$98,340
17-2131	Materials engineers	25,300	14,400	56.9%	1.2%	-4.2%	300	8,900	35.2%	$93,310
17-2071	Electrical engineers	178,400	61,900	34.7%	1.0%	-8.7%	1,800	39,300	22.0%	$94,210
17-2112	Industrial engineers	241,100	172,300	71.5%	0.9%	-2.1%	2,100	70,700	29.3%	$84,310
17-2011	Aerospace engineers	72,500	33,100	45.7%	-2.3%	-10.9%	-1,700	22,400	30.9%	$109,650
	Managers and Supervisors									
11-9041	Architectural and engineering managers	182,100	66,100	36.3%	2.0%	-7.1%	3,700	55,800	30.6%	$134,730
11-3061	Purchasing managers	73,000	22,100	30.3%	1.0%	-5.9%	700	17,200	23.6%	$111,590
51-1011	First-line supervisors of production and operating workers	606,900	432,900	71.3%	-3.1%	-5.6%	-18,700	114,600	18.9%	$57,780
11-3051	Industrial production managers	173,400	136,700	78.8%	-3.7%	-5.6%	-6,400	55,500	32.0%	$97,140

2024, but 55,500 replacement workers with appropriate skills will be needed to fill existing positions.

In Ohio, the number of machinists is expected to grow by 10%, employing 32,300 such workers by 2024. The growing demand, combined with an aging workforce hitting retirement age, is expected to yield 1,150 openings annually. A nearly 20% growth in computer-controlled machine tool operators over the decade is projected to bring about 610 annual job openings over the coming decade. The state is projected to have 740 annual openings for industrial machinery mechanics to meet an 18% growth in employment. Nearly 20,000 industrial machinery mechanics are expected to be employed in Ohio by 2024.

Table 2 provides the expected Ohio and U.S. employment change in manufacturing-related occupations identified as “high-demand” by JobsOhio. Select occupations related to the “high-demand” jobs are included for comparison. As can be seen, the nation is projected to see a relatively similar number of annual openings in machinists and industrial machinery mechanics, but Ohio is projected to need substantially more machinists.

Table 2. 2014 Employment and 10-Year Projections for Relevant "High-Demand Jobs" Designated by JobsOhio

								Projected Annual Openings	
OCC Code	Occupation	2014 OH EMP	2024 OH EMP*	2014 U.S. EMP	2024 U.S. EMP*	OH 10-Yr Chg.	U.S. 10-Yr. Chg.	OH	U.S.
17-3023	Electrical and Electronic Engineering Technicians	3,620	3,560	139,400	136,600	-2%	-2%	90	3,410
17-3024	Electro-Mechanical Technicians	600	580	14,700	14,800	-3%	1%	20	370
17-3027	Mechanical Engineering Technicians	2,560	2,620	48,400	49,300	2%	2%	70	1,280
49-9044	Millwrights	2,990	3,370	40,900	47,100	13%	15%	100	1,450
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	12,430	14,730	148,800	174,800	19%	17%	610	7,120
41-4041	Machinists	29,270	32,300	399,700	438,900	10%	10%	1,150	15,470
51-4111	Tool and Die Makers	11,080	9,780	77,800	67,700	-12%	-13%	60	380
51-4121	Welders, Cutters, Solders & Brazers	15,670	15,730	397,900	412,300	0%	4%	460	12,850
51-8091	Chemical Plant and System Operators	1,850	1,780	38,100	34,600	-4%	-9%	70	1,440
Related Occupations									
51-4012	Computer-Controlled Machine Tool Programmers, Metal and Plastic	1,380	1,630	25,100	29,900	18%	19%	70	1,240
17-3029.09	Manufacturing Production Technicians	3,560	3,590	70,100	69,900	1%	0%	90	1,710
17-3026	Industrial Engineering Technicians	3,570	3,490	66,500	63,500	-2%	-5%	90	1,630
49-9041	Industrial Machinery Mechanics	16,780	19,800	332,200	391,900	18%	18%	740	14,590
11-3051.0	Industrial Production Managers	12,210	11,990	173,400	167,000	-2%	-4%	350	4,910
11-3051.1	Quality Control Systems Managers								

*Projections from ONET

Table 3 provides the employment for "high-demand" manufacturing occupations by Ohio region. As can be seen, employment in the occupations vary widely by region, with Northeast Ohio having the highest number of jobs for each of the occupations of interest. The table suggests that regions may have different priorities for supporting the development of in-demand occupations.

Table 3. "High-Demand" Occupations Employment by Region, 2014-2015

OCC Code	Occupation	NW OH EMP	Western OH EMP	SW OH EMP	NE OH EMP	Central OH EMP	SE OH EMP
17-3023	Electrical and Electronic Engineering Technicians	480	400	650	880	550	80
17-3024	Electro-Mechanical Technicians		60	120	420	30	
17-3027	Mechanical Engineering Technicians	380	510	290	740	400	70
49-9044	Millwrights	750	340	300	820	360	50
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	1,540	2,010	1,920	5,750	950	600
41-4041	Machinists	4,800	4,330	3,890	11,400	1,930	740
51-4111	Tool and Die Makers	1,320		520	4,360	590	130
51-4121	Welders, Cutters, Solders & Brazers	1,940	2,050	2,080	6,300	1,680	1,360
51-8091	Chemical Plant and System Operators	200	70	450	680	1,170	

THE VIEW FROM MANUFACTURERS

Focus groups with manufacturers representing Ohio's six regions reinforce the view of growing demand for workers in both discrete and process manufacturing. Those who can operate and program computer numerically controlled (CNC) machines, machinists, electrical and electronics engineering technicians, and mechanical engineering technicians are sought after in all corners of the state. So are industrial production managers, industrial machinery mechanics, and first-line supervisors of mechanics, installers, and repairers. And, given the strength of the polymer and chemical industries in the Midwest, it's not surprising that focus group participants called attention to the importance of workers with process engineering skills. In general, manufacturers also reveal concerns over a broader base of engineering-related occupations and concerns over basic workforce readiness skills at a time when top-tier engineering schools have largely veered away from engineering technology or applied engineering programs.

“If we want to hire an engineer, we can do that,” said one Central Ohio manufacturer who voiced a refrain from focus group to focus group. “Where we have a gap is hourly technical people to fix machines.” In increasingly automated operations the design of million-dollar machines is too complex to handle internally; production of the machines is an outsourced specialty service, but maintaining such valuable, critical equipment is the challenge. “We don’t need anyone to design a machine, we need them to say why the machine is not working.”

“If you are a skilled maintenance person, you have a job for life,” echoed a Northwest Ohio manufacturer. “They can go 500 feet down the street and get a job the next day.” Young people who graduate out of a technical program, such as one of the 22 Robotics & Advanced Manufacturing Technology Education Collaborative (RAMTEC) offerings around the state, may have earning potential as high or even higher than workers who graduate with a four-year degree, focus group participants noted. For example, electrical and electronic engineering technicians earn a median wage of nearly $60,000, despite typically holding an associate’s degree or less.

Manufacturers in urban areas served by universities with science and engineering programs may have no trouble finding degreed engineers, but employers in the state’s rural areas face a hurdle of attracting well-educated workers. “The workforce is simply not there,” said one small Northwest Ohio manufacturer. The well-educated workers – or even those the company invests in to train – often get snapped up by larger employers. He cited the example of a young worker the company trained as a mold repairer. He left for one of the area’s largest employers. “A 19-year-old making $75,000 a year – we can’t compete with that.”

Beyond discrete technical skills, workers who understand process – who can envision new product specifications and translate them into efficient systems to produce them – are valuable, especially in increasingly automated environments. Process technicians must be able to develop functional designs and descriptions that can be programmed into machines that automate the process. “For what we are looking for, it’s not out there,” said a Northwest Ohio manufacturer. “They haven’t been developing that. The pipeline is too long and is just starting to get filled.” A Southeast Ohio food manufacturer indicated a lack of experienced process instrumentation technicians, especially temperature-based instrumentation. Increasingly, companies must rely on third parties and even service technicians from Europe, which increases production costs.

In addition to in-demand occupations predicted to see strong growth over the next decade, manufacturers point to evolving technologies that will require workers with new or updated skills. Increasingly sophisticated robotics and mechanized systems have already transformed manufacturing processes and workforces, creating demand for workers with more programming skills, as well as a combination of electrical and mechanical skill sets, than those workers they replace. This multidisciplinary skill set is sometimes referred to as mechatronics. Although automation has contributed to substantial declines in manufacturing employment, shrinking employment should not mask the growing need for workers skilled in maintaining and repairing the robots and heavily mechanized systems. Despite the proliferation of robotics clubs and classes in high schools and even primary grades as a fun, hands-on way of learning emerging skills, focus group participants noted a disconnect in translating the skills learned in these settings into the competencies needed in the work environment. Succeeding in robotics competitions is not the same as maintaining and overseeing robot function on the production floor.

A dearth of workers with electrical and automation skills has driven some manufacturers to reach out to area schools and form partnerships. For example, when a Central Ohio food manufacturer couldn't find competent programmable logic controller (PLC) coders and electrical engineers, it launched an internship program with a Dayton school to train workers who already understand liquid properties, heat exchangers, control valves, and design.

"The hardest job to find is electrical maintenance," said a Northwest Ohio manufacturer. "Robotic programming and electrical control engineering – that's where the job needs are going to be. We had an electrical and instrumentation supervisor who couldn't find anyone so we just didn't fill [the position]."

Exacerbating the problem is a difficulty in finding qualified instructors to teach electrical maintenance, as well as engineering technicians, added a representative of a Southeast Ohio subsidiary of a global manufacturing company. "We're not able to get the level of expertise even from our retirees," she said.

Growth in additive manufacturing, where 3-D products are made by adding layer upon layer of plastic, metal or other materials, will require workers with different skills and abilities than those engaged in subtractive and forming activities. As an example, 3-D printing of auto parts will become such a routine part of manufacturing that major parts assemblies will also take over mold making and, eventually, tool and die making. At this point, additive manufacturing is assumed to supplement, not replace, more traditional production processes, so workers with the skills to drill and forge will still need to be developed even while attention turns to talent demands of emerging additive manufacturing technology.

The “Internet of things,” or IoT, is ushering in a new industrial age. Industry 4.0 refers to the “smart factory” where sensors enable all processes to be electronically linked, monitored and analyzed. Approximately 84% of manufacturing executives responding to the second annual MPI Group survey on IoT indicated that smart devices and embedded intelligence will have a significant or some impact on their businesses over the next five years, an increase of 20 percentage points from the previous year. The digitizing of factory processes, which connects smart assets together, will require workers with analytical skills to use algorithms to identify trends in a prescriptive fashion and monitor productivity.

Despite the productivity gains that should arise from digital factories, being internally wired and connected to the cloud will lead to increased demand for workers trained in cybersecurity. Safety of processes and products is a top-of-mind concern for manufacturers, but cybersecurity needs will expand safety concerns and, thus, create demand for workers with the knowledge and skills to prevent and thwart the dangers of Internet hackers and disruptions.

Even among occupations that are not projected to see large growth in numbers, the graying of the manufacturing workforce is creating a grim vision of the future. One Central Ohio manufacturer likened the problem to a “python eating a pig.” “Skills have evolved,” he said. “Millennials have great skills sets but not the experience of how to run a program and how to communicate with people and build a requirements document that forms a picture that makes tea or diapers or engine blocks.” These are skills workers learn over years of experience.

"A critical factor for us is training incumbent workers to grow with the technology," said a Southeast Ohio manufacturer.

In addition to the challenge filling evolving and emerging technical roles, manufacturers around the state also report concerns over finding workers with the skills and knowledge to manage them. "We can't find plant managers," said a Northeast Ohio manufacturer. "You can't get a person to make a decision." The decades-long economic leaning out of manufacturing processes and workforces has served to flatten company hierarchies. That has served to push a certain amount of decision-making down to the shop floor. They want to see "managerial courage" from the level of machinist on up. Moreover, the lean operations many manufacturers have been forced to adopt for their economic survival have allowed little time for developing young workers into the next generation of plant managers. "They don't want to make a decision. If they don't have all the information, they are stuck."

Focus group participants around the state question whether the ability to identify problems, brainstorm solutions, and decide on a reasoned course of action is missing from high school and even postsecondary curricula at the very time new tools and processes are requiring more such skills, even among non-management workers.

"There are decisions machinists have to make every day at every level," said one Northeast Ohio manufacturer. But "I think [decision-making and problem-solving are] being left out from the education system."

"There seems to be a large deterioration in training these skills," echoed another participant in the Northeast Ohio focus group. "So lots of us are investing heavily" in trying to build capacity. “We’re willing to teach the technology side if [a candidate] demonstrates that they have the capacity [to learn].”

In addition to immediate and future needs in finding workers with the ability to apply or manage new and evolving technologies, manufacturers worry about maintaining valuable resources of the past. Knowledge transfer from workers with skills honed over years of experience is top-of-mind as employers with aging workforces see retirements looming. Nationwide, more than 3.7 million manufacturing workers – or 24% of the entire manufacturing workforce – were age 55 or older in 2016, according to Bureau of Labor Statistics data. Another 3.9 million workers are at least 45 years old. That means nearly half of today’s entire manufacturing workforce will retire within the next two decades or less. By comparison, 45% of health care and social assistance workers, less than 44% of the business and professional services workers and 41% of information workers are age 45 or older.

The “leaning” of manufacturing operations in order to survive intense competition on a world scale has left little “fat” or slack in workforces to allow for job shadowing and mentoring that facilitate talent succession, whether on the plant floor or in management offices.

Several focus group participants indicated that they have begun identifying workers due to retire and developing plans for retaining company knowledge assets as they lose employees. A Northwest Ohio manufacturer described implementing an annual workforce audit to estimate the number of potential retirements over the next three years, identify critical positions, and develop a plan for addressing the anticipated need for replacement workers. A participant in the focus group of Southeast Ohio manufacturers cited attempts to get retiring workers to transfer their skills, either through in-house training programs or community college and technical school courses, but the workers lack the necessary pedagogy skills.

However, focus group participants acknowledged that they have been late in responding to the challenge. “We waited too long to focus on training,” one Northeast Ohio manufacturer observed. They also observe that workers with mechanical and technical know-how may lack the ability to transfer their knowledge and skill to others. In other words, would-be trainers may themselves need training or coaching in order to become effective transmitters of knowledge. “We need to do a better job of training,” echoed another manufacturer in North Central Ohio.

“Our biggest concern is the loss of plant knowledge that you know you are facing as people walk out the door,” echoed a Southeast Ohio manufacturer. “Even if you get the very best candidate, there is a learning curve. Add a layer on that that they don’t have the aptitude or understanding of the plant. There’s a cultural shift.”

A NEED FOR HIGHER AND BROADER SKILLS

Although the sweeping technological changes that have remade manufacturing activities and work environments have created a need for manufacturing workers possessing technical aptitude, focus group participants indicated that these “new” skills are not enough. Workers need to have a basic understanding of operations and processes in order to understand the whys and hows of the machinery and technical tools. A North Central manufacturer said that given the choice between a candidate who understands the fundamentals but needs training on the technology and a candidate with an understanding of the technology but lacking the fundamentals, he would choose the former. “If machinists don’t learn with a manual machine, they don’t understand the CNC machine and how it operates in the field,” he said. “In order to troubleshoot and fix [the machines], they need to understand the basics.”

An analysis of data from the Occupation Information Network (O*NET), an extensive, regularly updated database sponsored by the U.S. Department of Labor, supports a view of the in-demand “middle skill” manufacturing occupations as STEM intensive. Although the “E” in STEM tends to be rather narrowly defined as “engineering,” all of the occupations focus group participants identified – and the JobsOhio website has labeled as in-demand – require a relatively high level of engineering and technology knowledge. In fact, looking across all 942 occupations included in the O*NET database, electro-mechanical technicians, CNC programmers, industrial machinery mechanics, industrial production managers, and tool and die makers all ranked in the top 10% of occupations in terms of the level of engineering and technology knowledge they required. Electrical and electronics engineering technicians, industrial engineering technicians and mechanical engineering technicians, along with the varied engineering fields, were also in that group. Relying only on educational status may tend to obscure the relatively high “STEM” knowledge associated with these “middle-skill” occupations. The educational level associated with most of these occupations is post-high school certification. Figure 2 depicts how these changing expectations of workers is expected to restructure workplaces and truncate career ladders.

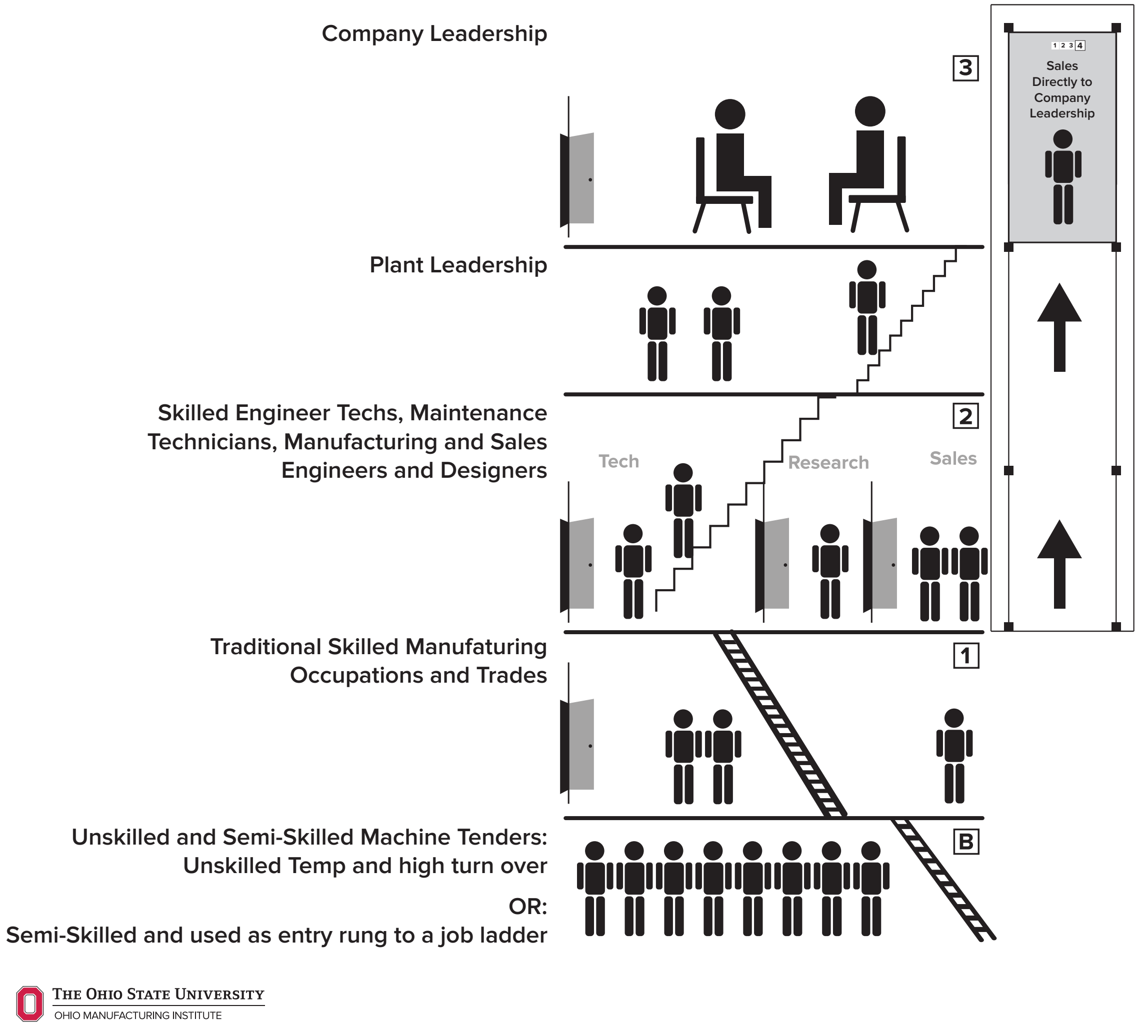

Figure 2

In addition to engineering and technology knowledge, a high level of mechanical and production knowledge is shared across the in-demand manufacturing occupations. Analysis of the O-NET data reveals that workers performing these production occupations also need a high level of skill in operation monitoring and analysis, repairing, quality control, equipment selection and maintenance, troubleshooting, as well as a comparatively high command of physics and design. Focus group participants echoed the increasing demand for workers with repairing, quality control, and maintenance skills, as well as mechanical and physics knowledge.

In addition to information about the knowledge, skills, and abilities associated with specific occupations, the O-NET data also provide insight into the technology and tools that workers are expected to master. Many of the in-demand manufacturing occupations, for example, are expected to be familiar with computer-aided design software, spreadsheet software, analytical or scientific software, and enterprise resource planning software. For example, advertisements for electro-mechanical technician jobs frequently seek applicants with expertise in AutoCAD, Excel, and SAP software. Ads for mechanical engineering technicians may be expected to know Visual Basic programming language and 3D solid modeling software (See Appendix A).

Yet, focus group participants point to shortcomings within the pool of available young talent that fall outside the usual bounds of on-the-job training.

(One of the biggest and most recurrent workforce issues focus group participants cited relates to the prevalence of drug use among job applicants. A shockingly large percentage of potential workers, they report, fail to pass drug tests. In a manufacturing setting, where safety and precision are paramount, drug use among workers is a primary concern. The “epidemic” of opioid addiction, as well as an increasing decriminalization of marijuana use, attract national attention and reflecting changing societal mores. However, they present particular challenges for manufacturers. Although the problem of drugs in the workplace is an area for advocacy and policy discussion, it is beyond the scope of this report.)

Manufacturers describe communication, interpersonal, critical-thinking and other "soft" skills as frequently deficient among new hires. Even more troublesome is the absence of work-readiness skills, such as showing up on time and following instruction. "Soft skills may be more important [even than the technical skills], being willing to learn and take direction," said one Northwest Ohio manufacturer. "In older people, we're willing to put up with a lack of soft skills because they have good mechanical skills."

Soft skills are necessary for career advancement. "We look for the ability to be self-directed, self-actualizing," the focus group participant said. "We decided we needed to sharpen our interviewing in order to ferret that out."

ADDRESSING NEEDS AROUND THE NATION

The insights from focus group participants, combined with the data on job growth and replacement projections, point to a manufacturing workforce challenge that is just beginning to be felt. Manufacturers in Ohio and across the nation are going to need to hire or train thousands of workers with the appropriate knowledge and skills to fill thousands of new or vacant positions over the next decade. Given that manufacturers already report difficulty in finding CNC programmers, electro-mechanical technicians, and plant managers, the skill deficit is only expected to worsen. Moreover, the skill needs will continue to change as new technologies are pulled into manufacturing plants in the form of new machines, new products, and new processes.

Community colleges and technical schools have rightfully begun to tackle the current and projected skill challenges by developing new programs, realigning existing ones, and partnering with area manufacturers to identify and address specific needs. Manufacturers themselves are reporting stepped-up in-house training, frequently assisted by local community colleges or outside consultants. Such training partnerships and educational programs, which often culminate in a certificate or associate's degree, tend to be the focus of policy discussions and public support for the workforce needs of manufacturing.

However, the anticipated need to develop managers and to grow the training capacity suggests an important role for four-year institutions in assisting manufacturers to develop the workforce of tomorrow. As seen in Table 1, large shares of engineers and scientists who have completed at least a bachelor's degree in STEM fields work in manufacturing. Demand for thousands of replacement workers projected to fill openings for engineers and scientists created by retirements over the coming decade will continue. Yet, focus group participants indicate the need for workers who understand both manufacturing processes and business operations. Workers who understand the tasks of the technician as well as those of the engineer. Workers who understand discrete production activities as well as process engineering systems. Workers with technical as well as managerial training (Figure 2).

A few universities around the nation (e.g., Purdue University's College of Technology, Missouri University of Science and Technology, Penn State University, East Tennessee State University, and Brigham Young University) have responded to this evolving talent demand by developing integrated bachelor's degree programs in engineering technology with special focus on the needs of manufacturers. Such majors supplement courses common to technical programs, such as metals processing, computer-assisted manufacturing, and quality control, with courses in engineering and management, such as design principles and manufacturing leadership.

ADDRESSING THE NEEDS OF OHIO MANUFACTURERS

Given the continued concentration and strength of manufacturing activities in Ohio, it is particularly important for the state to recognize and respond to the evolving knowledge and skill development needs of its manufacturing workforce. As can be seen in Table 2, Ohio accounts for a significant portion of national employment in the "high-demand" industries. The 12,430 CNC operators employed in Ohio in 2014 made up more than 8 percent of such jobs nationwide. As jobs for CNC operators are predicted to see strong growth through 2024, Ohio's need for such workers is expected to expand even more. Over the 10-year projection period, Ohio alone is expected to need roughly 6,100 additional CNC operators and see job openings for 700 CNC programmers.

Ohio accounts for a little more than 7 percent of total national employment of machinists and millwrights. These occupations are also predicted to see growth in demand through 2024, despite the anticipated contraction in manufacturing employment overall. Ohio is expected to see some 11,500 job openings for machinists over the decade.

Although industrial machinery mechanic was not included among the state's list of "high-demand" manufacturing occupations, it was a job focus group participants indicated as important but difficult to fill. The Bureau of Labor Statistics predicts 18 percent growth in employment of industrial machinery mechanics through 2024. Ohio captures about 5 percent of such employment nationwide, which translates into about 7,400 expected job openings in the state over the 10-year projection period.

Industrial production managers also were not included among the JobsOhio list of "high-demand" occupations, and employment levels are projected to decrease through

2024. However, manufacturers participating in focus groups across the state indicated difficulty in hiring such workers. Despite a general contraction in employment levels, the need for replacement workers to fill spots vacated by retiring experienced workers is expected to create openings for 3,500 industrial production managers in the state over the 10-year period. That's roughly 7% of the roughly 49,100 industrial production managers that will be needed nationwide.

As noted earlier, focus group participants suggest evolving skill needs for manufacturing workers, where sweeping changes in technology, increasingly complex machinery, and leaner and flatter operations demand more of workers. This indicates a need for evolution or transformation in the programs that educate and train new workers to fill newly created positions or those open due to retirements, as well as incumbent workers who need to expand their skills to meet changing job demands. One company, for example, teamed up with a staffing solutions provider to develop a 12-week manufacturing boot camp for veterans.

HIGHER EDUCATION'S ROLE

The programs highlighted below demonstrate an expanded role for four-year institutions in helping to meet the workforce challenges of manufacturers, especially in the areas of plant operations and management. Miami University already offers students pursuing a bachelor's degree in engineering the option of a concentration of study in manufacturing engineering management. The concentration focuses on the teamwork, problem solving, and communications skills needed within the manufacturing setting. Introductory engineering classes and general business classes in accounting, marketing, operations and supply chain management, and leadership are combined with manufacturing-specific classes in design, processes, project management, and stochastic modeling.

However, the employment projections data and focus group insights suggest the potential value of a more integrated and regionally responsive approach to addressing the anticipated need for workers with the skills and expertise to function in the Manufacturing 5.0 environment.

In this respect, the Purdue Polytechnic Institute structure may serve as a particularly instructive model of the possibilities for differentiation but coordination that arise from a large research university with a network of regional campuses. Purdue Polytechnic's specialized engineering technology majors -- automation and systems integration, mechatronics, robotics, aeronautical, audio, electrical, and mechanical – are offered on the main campus in West Lafayette, as well as at nine satellite locations throughout Indiana. The mechanical engineering technology degree, for example, aims to prepare students to manage machines, processes, and people by focusing on the skills that cut across major employers—critical thinking, leadership, and teamwork. The various engineering technology specializations stress hands-on learning applied toward solving real-world problems.

Purdue Polytechnic also has developed graduate degree programs in engineering technology, including a concentration that focuses on the leadership and technical skills needed in advanced manufacturing settings. An online master's degree in engineering technology is directed at working professionals in manufacturing and other industries who are looking to develop the expertise in managing new technologies.

In addition to the programs offered on main campus, Purdue Polytechnic worked with local employers and industry leaders to design an engineering technology degree that is flexible enough to respond to the local skill needs as well as improve the overall pool of advanced manufacturing talent statewide. The institution also is working to expand the pipeline of workers with the skills needed to operate in advanced manufacturing and other technology-intensive environments by training future teachers. Graduates of the engineering technology teacher education program are equipped to teach engineering concepts and technical skills related to prototyping, robotics, and automation to high school and middle school students.

The success of the Purdue program reveals the value of combining hands-on technical learning, an understanding of business operations and decision-making, and "train the trainer" approaches to traditional academic strengths in engineering instruction and research. The program also suggests the opportunity for enhanced talent development when states leverage the capacities of their large public universities and their local educational and training institutions in more collaborative and coordinate

Penn State University offers a master of manufacturing management degree that is a joint program of its Behrend School of Engineering and its Sam and Irene Black School of Business. The program was created in response to demand for managers with understanding of technology, engineering concepts, and business principles. Manufacturing methods, such as Lean and Six Sigma, are stressed, as well as effective communication and decision-making.

Miami University of Ohio offers a bachelor's degree in engineering management that equips graduates with interdisciplinary skills in business and engineering.

Manufacturing engineering is one of four possible concentration areas and teaches students to integrate information, assess and solve business and engineering problems, and effectively lead and communicate with teams. Students learn about manufacturing design and automation, as well as operations management and marketing. The degree is targeted toward the combined technical and business awareness needed to perform jobs such as technical sales, purchasing, and quality control. Indicating the demand for such interdisciplinary skill sets, the program reports a near 100 percent placement rate for graduates. The university has 11 college partners throughout the state where students can complete their associate's degree and then pursue a four-year online degree through Miami without leaving their original campuses.

The University of Cincinnati offers bachelor's degrees in engineering technology in the areas of mechanical, electrical, and computer. Manufacturing is one of three concentrations for the mechanical engineering technology degree. These programs combine technical awareness with more people-oriented "soft" skills and exposure to budgeting and project management. In addition, UC's Clermont College offers a two-year degree in manufacturing engineering technology, as well as certificate and employer-sponsored training modules. The two-year program centers primarily on technical skills, such as machine design, computer numerical control technology, and computer integrated manufacturing.

Cleveland State University offers a bachelor's degree in engineering technology in the areas of mechanical and electronics. And Ohio Northern University offers a degree in manufacturing technology, with concentrations in robotics and management. The small, private college promises individualized attention and hands-on experience working on projects for area employers.

Despite the existing engineering technology programs offered at universities around the state, insights shared by focus group participants and employment projections suggest that greater capacity and more collaboration on a standardized approach with room for specialization will be essential for meeting future workforce needs. Manufacturers have also expressed an interest in the benefits to workers of aligning two-year associate degree programs available throughout the state's network of community colleges and technical schools to bachelor's and master's degree programs among the state's public universities, particularly at The Ohio State University. Ohio State's network of regional campuses, supported by and connected to the engineering curricula offered on main campus, presents an opportunity to build on existing resources and shape education and training options to address region-specific talent needs of Ohio manufacturers. Efforts are under way at Ohio State to develop an engineering technology degree option to address industry needs.

CONCLUSION

The manufacturing workplace is changing, which means the education and training programs that supply manufacturers with knowledgeable and skilled workers need to change too. Finding the talent necessary to compete and grow is a top-of-mind worry for Ohio manufacturers who participated in six focus groups around the state. Manufacturers are recognizing that they must do more to attract, train and develop workers with the skills needed and with the ability to adapt to tomorrow's changes. Yet, after decades of cutting employment as a means to thrive, or at least survive, in an increasingly competitive marketplace, manufacturers are struggling with the challenges of developing the Manufacturing 5.0 workforce – from hiring young workers and molding future plant leadership, to identifying new skill sets and transferring the knowledge retiring workers have honed over a lifetime.

Moreover, manufacturers know that time is not on their side in addressing workforce challenges. The technologies and tools of modern manufacturing have been changing quickly and, thus, so have the understanding and expertise necessary to use them. This helps to explain the skills paradox seen over the past few years, where unemployment rates have been high at the same time employers, many of them manufacturers, have complained of a lack of skilled workers. The profound impact and lingering effects of the Great Recession are also continuing to shape employers' workforce demands.

Manufacturing in Ohio, and the nation as a whole, has continued to grow in productivity and add value. It has largely done this through automating processes and focusing on high-value production activities. This overall trend, which has allowed manufacturers to produce more with fewer workers, is not likely to change. This produces a difficult message for policymakers and educators to interpret: fewer manufacturing workers will be needed overall and many of the job openings will reflect replacement needs, not employment growth. But many of the job openings in manufacturing, whether through growth or replacement, will be more critical to production and will require a higher level of skill.

Further distorting efforts to address the manufacturing talent needs of the future has been a bias toward "high-skill" STEM occupations in research and professional services, failing to acknowledge the sizable share of engineers and scientists, as well as a large number of “middle-skill” STEM workers, such as technologists and technicians. While policies and programs have been right to support the research and development necessary to innovative breakthroughs and disruptive technologies, it’s also important to remember that the *products* that incorporate innovations technologies are what drive economic growth. This suggests a greater focus on skills that enable workers to *apply* technologies and innovations within the production process are warranted. In other words, engineering degrees at the university level cannot become purely research-oriented degrees in applied physics.

Focus group participants suggest the need for more and clearer paths to attain these important skills. “I would much prefer that we figure out how to improve the pool,” said a Northwest Ohio precision tool manufacturer. “Kids are not getting a clear understanding of what is needed in the workforce and then guided to get those skills.”

This report has detailed the potential for developing an engineering technology degree program as a flexible method for helping young workers, and incumbent workers, access and expand career opportunities. Multiple on and off ramps to manufacturing career pathways could be linked by different levels of engineering technology degrees and certifications that come out of vocational schools, community colleges, and universities. Such a broad and flexible education and training network would require universities to reinvent engineering technology majors and collaborate with community colleges and career and technical centers to standardize curricula for a broad range of prepared workers.

Engineering technologists are now typically called industrial maintenance technicians, but that job title will change. Employers are demanding graduates with knowledge of production and applications, and higher education must listen to industry to determine how to help fill the skill gaps being experienced on the plant floor. This presents a huge challenge for academic institutions because educating engineering technologists and technicians is expensive. There is no offsetting revenue from research overhead to subsidize their education. Moreover, a strong engineering technology will not drive a university up the all-important rankings. However, programs aligned to manufacturing challenges that produce work-ready graduates will lead to employment for young workers and support the regional and state economy.

Failure to find suitable workers at competitive wage rates is likely to drive further automation of manufacturing processes. A limited pool of entry-level workers with the right set of skills drives up wages for such workers; higher costs — whether in higher wages or higher health care costs — encourages manufacturers to speed up the Manufacturing 5.0 transition, further limiting employment growth and altering education and training needs. Such a cost challenge is already looming on the logistics side of manufacturing and emphasizes the need for multidisciplinary engineers and engineering technologists with leadership potential.

Helping young workers invest in developing the skills that lead to good jobs, while helping manufacturers find the skilled talent at a wage rate that allows them to remain competitive, is the challenge for educational institutions and training programs. It is also critical to reinvestment in U.S. manufacturing, especially seizing on opportunities emerging in domestic production of high-value durable goods.

Whether due to replacing retiring workers or responding to the evolving skill needs of Manufacturing 5.0, manufacturers are going to be facing challenges in hiring and developing their workforce of the future. Universities, as well as community colleges, vocational training centers, and even high schools, have a role to play in helping to meet those looming workforce needs. The state, and nation, will no doubt need more engineering technologists and technicians who have a basic understanding of production processes and can manage shop-floor digital networks. Regions will need both the capacity to build the pool of workers with cross-cutting skills as well as the flexibility to respond to regionally specific labor market needs. This suggests the need for a more integrated approach to talent development that connects the state's research universities to its network of regional campuses and community colleges.

As a Southwest Ohio robotics manufacturer put it, that's the key to a sustainable and synergistic model for skills-based education. "How do you bundle [the state's talent development resources] into a skills-based education that will help companies?"

Government certainly has a role to play. Policies should be developed or revised to streamline programmatic and curricular responses to industry demand, as well as enable the flexibility and nimbleness to react quickly in increasingly technological environments.

Government policies could also be used to incentivize industry-educational partnerships in Ohio. Other states are pursuing collaborative partnerships to develop standardized, system-wide educational programs that address industry needs. For example, Colorado's TalentFOUND connects a broad swath of industry, education, and government players to better align initiatives and recognize shared goals. The statewide network is developing sustainable outcomes by measuring impacts on employers, jobs seekers, workers, and public programs.

Industry groups also have a role in promoting a better model of education and training. The Ohio Manufacturers' Association, in collaboration with its educational and government agency partners, is leading an organized effort to develop a statewide network of regional industry-sector partnerships focusing on workforce and training to address the gap in skilled workers. The effort aims to reduce workforce shortages by encouraging manufacturers and workforce education partners to work together to develop local priorities. The network will help participants to:

- Understand the characteristics of successful regional manufacturing sector workforce partnerships that build into statewide campaigns.
- Hear about best practices and initiatives under way across Ohio and how those might align with industry requirements.
- Learn about tools and resources that help create and support regional workforce development.

A statewide image campaign to raise the profile of manufacturing careers and highlight educational programs that develop talent for in-demand manufacturing jobs is also part of the equation.

However, successfully addressing the looming talent challenge will also require more on the part of manufacturers themselves. They must become more invested in local and regional workforce efforts and involve themselves in community college boards and high schools. They must also recognize their responsibility in developing the workforce they seek. As Mike Petters, president and CEO of Huntington Ingalls Industries, puts it:

"I've seen other companies that talk about the need for improved workforce development programs, but many of them just sit at the end of the workforce development pipeline and wait for the product to come out. Not surprisingly, they're not happy with the results. My view is that the more you engage in that product upstream, the better the results will be."

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Appendix A

	Occupation	Important Skills	ONET Description	"Hot" Technology Skills (defined as commonly in ads)	KSAS Required at High Level (1SD or >)
17-3023	Electrical and Electronic Engineering Technicians	Reading Comprehension, Critical Thinking, Complex Problem Solving	Apply electrical and electronic theory and related knowledge, usually under the direction of engineering staff, to design, build, repair, calibrate, and modify electrical components, circuitry, controls, and machinery for subsequent evaluation and use by engineering staff in making engineering design decisions.	Computer-aided design software --Autodesk AutoCAD, Bentley MicroStation, National Instruments Multism, PTC Creo Parametric; Development Environment Software--C, Microsoft Visual Basic, National Instruments LabView, Verilog; Object or Component-Oriented Software--C++, computer-aided software engineering CASE tools; Operating Systems Software--Linux; and the MathWorks MATLAB	Information Ordering, Equipment Maintenance, Equipment Selection, Operations Analysis, Repairing, Science, Troubleshooting, Computers and Electronics, Design, Engineering and Technology, Mechanical, Physics, Production and Processing, Telecommunications
17-3024	Electro-Mechanical Technicians	Monitoring, Operation Monitoring, Troubleshooting, Quality Control Analysis	Operate, test, maintain, or calibrate unmanned, automated, servo-mechanical, or electromechanical equipment. May operate unmanned submarines, aircraft, or other equipment at worksites, such as oil rigs, deep ocean exploration, or hazardous waste removal. May assist engineers in testing and designing robotics equipment.	Computer-aided design software--Autodesk AutoCAD, PTC Creo Parametric; Operating Systems Software--Linux, UNIX; Enterprise Resource Planning (ERP) Software--SAP; Spreadsheet Software--Microsoft Excel	Finger Dexterity, Information Ordering, Near Vision, Perceptual Speed, Selective Attention (2 SD), Visualization, Wrist-Finger Dexterity, Equipment Maintenance (2SD), Equipment Selection (2SD), Installation (2SD), Operation and Control, Operation Monitoring, Programming, Quality Control Analysis, Repairing (2SD), Troubleshooting (2SD), Computers and Electronics, Engineering and Technology, Mathematics, Mechanical
17-3027	Mechanical Engineering Technicians	Reading Comprehension, Active Listening, Critical Thinking, Operation Monitoring	Apply theory and principles of mechanical engineering to modify, develop, test, or calibrate machinery and equipment under direction of engineering staff or physical scientists.	Computer-aided design software--Bentley MicroStation, PTC Creo Parametric; Development Environment Software--Microsoft Visual Basic, National Instruments LabView; Computer-aided Manufacturing (CAM) Software--CNC Mastercam, 3D solid modeling software; analytical or scientific software--the MathWorks MATLAB	Number Facility, Perceptual Speed, Wrist-Finger Dexterity, Equipment Maintenance, Equipment Selection, Operation and Control, Quality Control Analysis, Repairing, Troubleshooting, Building and Construction, Chemistry, Design, Engineering and Technology, Mechanical, Physics, Production and Processing
49-9004	Millwrights	Installation, Operation Monitoring, Equipment Maintenance	Install, dismantle, or move machinery and heavy equipment according to layout plans, blueprints, or other drawings.	Computer-aided design software--Autodesk AutoCAD, Enterprise Resource Planning (ERP) Software--SAP; Spreadsheet Software--Microsoft Excel	Spatial Orientation, Visualization, Equipment Maintenance (2 SD), Equipment Selection, Operation and Control, Operation Monitoring, Quality Control Analysis, Repairing (2 SD), Troubleshooting, Design, Engineering and Technology, Mathematics, Physics
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	Critical Thinking, Monitoring, Operation Monitoring, Quality Control Analysis	Operate computer-controlled machines or robots to perform one or more machine functions on metal or plastic work pieces.	Computer-aided design software--Autodesk AutoCAD; Computer-aided Manufacturing (CAM) Software--1 CADCAM Unigraphics, CNC Mastercam, SmartCAM, Vero International VISI; Project Management Software--Microsoft Project; Spreadsheet Software--Microsoft Excel	Selective Attention, Spatial Orientation, Visualization, Equipment Maintenance, Equipment Selection, Operation and Control, Operation Monitoring, Programming (2 SD), Quality Control Analysis, Repairing, Technology Design, Troubleshooting, Chemistry, Physics
41-4041	Machinists	Critical Thinking, Operation Monitoring, Operation and Control	Set up and operate a variety of machine tools to produce precision parts and instruments. Includes precision instrument makers who fabricate, modify, or repair mechanical instruments. May also fabricate and modify parts to make or repair machine tools or maintain industrial machines, applying knowledge of mechanics, mathematics, metal properties, layout, and machining procedures.	Computer-aided design software--Autodesk AutoCAD; Computer-aided Manufacturing (CAM) Software--CNC Mastercam, CNC Turbo CAD/CAM, JETCAM; Electronic Mail Software--Microsoft Outlook; Spreadsheet Software--Microsoft Excel	
51-4111	Tool and Die Makers	Critical Thinking, Operation Monitoring, Operation and Control, Quality Control Analysis	Analyze specifications, lay out metal stock, set up and operate machine tools, and fit and assemble parts to make and repair dies, cutting tools, jigs, fixtures, gauges, and machinists' hand tools.	Computer-aided design software--Autodesk AutoCAD, Dassault Systemes CATIA; Computer-aided Manufacturing Software--1 CadCam Unigraphics, CNC MasterCAM, OPEN MIND Technologies hyperMill; Spreadsheet Software--Microsoft Excel	Category Flexibility, Visualization, Equipment Maintenance, Equipment Selection, Operation and Control, Operations Analysis, Quality Control Analysis, Repairing, Technology Design (2SD), Troubleshooting, Design, Engineering Technology, Mathematics, Mechanical, Production and Processing
51-4121	Welders, Cutters, Solders and Brazers	Reading Comprehension, Critical Thinking, Monitoring, Operation and Control	Use hand-welding, flame-cutting, hand soldering, or brazing equipment to weld or join metal components or to fill holes, indentations, or seams of fabricated metal products.		Spatial Orientation, Equipment Selection, Repairing, Design
51-8091	Chemical Plant and System Operators	Monitoring, Operation Monitoring, Operation and Control, Quality Control Analysis	Control or operate entire chemical processes or system of machines.	Spreadsheet software--Microsoft Excel	Perceptual Speed, Selective Attention (2 SD), Spatial Orientation, Speed of Closure, Equipment Maintenance, Mathematics skill, Operation and Control, Operation Monitoring (2 SD), Quality Control Analysis, Repairing, Chemistry
51-4012	Computer-Controlled Machine Tool Programmers, Metal and Plastic		Develop programs to control machining or processing of metal or plastic parts by automatic machine tools, equipment, or systems.	Computer-aided design--Autodesk AutoCAD, Dassault Systemes CATIA; PTC Creo Parametric; Computer-aided Manufacturing software--1 CadCAM Unigraphics, VeroSoftware VISI; Spreadsheet Software--Microsoft Excel	Mathematical Reasoning, Perceptual Speed, Selective Attention, Visualization, Wrist-Finger Dexterity, Equipment Maintenance, Equipment Selection, Mathematics, Operation and Control, Operation Monitoring, Programming (2SD), Repairing, Technology Design, Troubleshooting, Design, Engineering and Technology, Mathematics, Mechanical, Physics, Production and Processing
17-3029.09	Manufacturing Production Technicians		Set up, test, and adjust manufacturing machinery or equipment, using any combination of electrical, electronic, mechanical, hydraulic, pneumatic, or computer technologies.	Analytical or scientific software--Minitab, Computer-aided design software--Autodesk AutoCAD; Enterprise Resource Planning software--SAP; Spreadsheet Software--Microsoft Excel	Perceptual Speed, Visualization, Equipment Maintenance, Equipment Selection, Operation and Control, Operation Monitoring, Quality Control Analysis, Repairing, Troubleshooting, Design, Engineering and Technology, Physics
17-3026	Industrial Engineering Technicians		Apply engineering theory and principles to problems of industrial layout or manufacturing production, usually under the direction of engineering staff. May perform time and motion studies on worker operations in a variety of industries for purposes such as establishing standard production rates or improving efficiency.	Computer-aided design--Autodesk AutoCAD; Database User Interface and Query Software--Data Entry Software, Microsoft Access; Graphics or Photo Imagin Software--Graphics Software, Microsoft Visio	Category Flexibilty, Fluency of Ideas, Mathematical Reasoning, Number Facility, Visualization, Complex Problem-Solving, Judgment and Decision Making, Mathematics, Operations Analysis, Repairing, Science, Systems Analysis, Systems Evaluation, Technology Design (2SD), Chemistry, Design, Engineering and Technology, Mechanical, Physics, Production and Processing
49-9041	Industrial Machinery Mechanics		Repair, install, adjust, or maintain industrial production and processing machinery or refinery and pipeline distribution systems.	Computer-aided manufacturing software--Extranet Machine Tools Suite; Enterprise Resource Planning Software--SAP; Spreadsheet software--Microsoft Excel	Finger Dexterity, Information Ordering, Selective Attention, Spatial Orientation, Visualization, Wrist-Finger Dexterity, Equipment Maintenance (2SD), Equipment Selection, Installation (2SD), Operation and Control, Operation Monitoring, Programming, Quality Control Analysis, Repairing (2SD), Technology Design, Troubleshooting, Building and Construction, Design, Engineering and Technology, Mechanical (2SD), Physics, Production and Processing
11-3051.0	Industrial Production Managers		Plan, direct, or coordinate the work activities and resources necessary for manufacturing products in accordance with cost, quality, and quantity specifications.	Database User Interface and Query Software--FileMaker Pro; Document management software--Adobe Acrobat; Enterprise Resource Planning software--Oracle JD Edwards EnterpriseOne, SAP;	Deductive Reasoning, Fluency of Ideas, Mathematical Reasoning, Number Facility, Originality, Active Learning, Coordination(2SD), Judgment and Decision Making, Learning Strategies, Management of Financial Resources (2SD), Management of Material Resources (2SD), Management of Personnel Resources (2SD), Mathematics, Monitoring (2SD), Negotiation, Operation Monitoring, Persuasion, Quality Control Analysis, Systems Analysis, Systems Evaluation, Time Management (2SD), Administration and Management (2SD), Engineering and Technology, Mechanical, Production and Processing (2SD),