

Upskilling manufacturing: How technology is disrupting America's industrial labor force

June 2016

In conjunction with



pwc

I. Introduction

We can and must improve American education and technical training... One of the great bottlenecks for this country's economic growth in this decade will be...a great demand and an undersupply of highly trained manpower.

*—President John F. Kennedy
in an address and at the Economic Club
of New York on December 14, 1962*

US manufacturing is undergoing sea changes on numerous fronts—from swiftly evolving, disruptive technologies, to new customer expectations, to an entirely new set of global competitors. And, as technologies are adopted by manufacturers at a mind-boggling pace, capturing and nurturing the right talent to exploit that technology is looming as a pressing issue. This isn't a new problem. The post-WWII boom in US manufacturing came with concerns surrounding a STEM (Science, Technology, Engineering and Math) skills shortage we hear about today. But, while a generation ago, a high school degree was the ticket to a career in manufacturing, today, post-secondary education is increasingly a requirement.

We are entering an era with two major trends running on parallel tracks. First, we are seeing aggressive pushes to upskill traditional lineworkers through a variety of ways with a greater emphasis on embracing digital manufacturing as automation relentlessly takes on human tasks that are repetitive, onerous and even dangerous. At the same time, manufacturers are in hot pursuit of a corps of highly trained professionals (computer coders, app developers, data scientists, 3D printing specialists) to shepherd digital manufacturing from its current incipient stage to more mature levels over the next decade.

Manufacturers are, therefore, now locked in a race to lure in tech-savvy talent—or upskill existing forces—to harness new and disruptive manufacturing technology. Smart phones, tablets, coding, app

development, 3D printing and robots become the new wrenches on America's factory floors. They need a new generation of employees that possess the hybrid skills and comfort with innovation to adopt these technologies and those not yet invented.

In this report, we endeavor to answer one central question: what are the paths US manufacturers can take to nurture a future talent pipeline with the skills—both welders and app developers alike—needed to take advantage of today's technological advances and, most important, to be prepared for those, now unseen, that will emerge in the future.

To get a closer look at the US manufacturing talent picture—now and peering into the future—we surveyed 120 US manufacturers with a special emphasis on how advanced manufacturing technologies are impacting the workforce dynamics.¹ What we found is that while there is indeed some jitteriness over skills gaps, manufacturers are working to close those gaps. But we're still in the early stages. As manufacturers increase their application of advanced manufacturing technologies (e.g., 3D printing, robotics, Internet of Things) and are under greater pressure to produce faster and more productively, their needs for more qualified talent become ever pressing. At the same time, professional expectations of younger prospective employees (e.g., in the meaning and flexibility of work) are changing just from a generation ago.

Our survey reveals that many manufacturers are either on the road to developing a talent pipeline to exploit advanced manufacturing technology, or are in the process of ramping up efforts to do so.

Key findings in our research include:

- **Skills shortages are not uniformly felt today:** 33% of manufacturers say they have no or only a little difficulty in hiring talent to exploit advanced manufacturing technologies, while 44% have ‘moderate difficulty.’
- **The worry is that it will worsen:** 31% of manufacturers see no manufacturing skills shortage now but that there will be one in the next three years; 26% say it’s already peaked and is behind us; and 29% said it exists and will only worsen in the next three years.
- **The most common strategy to upskill employees in advanced manufacturing** is to train in-house, followed by recruiting local STEM students and offering outside vocational training.
- **Robots are not stealing manufacturing jobs:** 37% believe that the adoption of advanced manufacturing technologies will result in their hiring additional employees; 45% said it will have no impact on hiring; and 17% said it will result in hiring fewer employees.
- **But advanced tech is changing job requirements and descriptions:** Nearly three-quarters of non-factory floor manufacturing jobs are given to candidates with a four-year or advanced degree.

II. Changing demand for US manufacturing skills

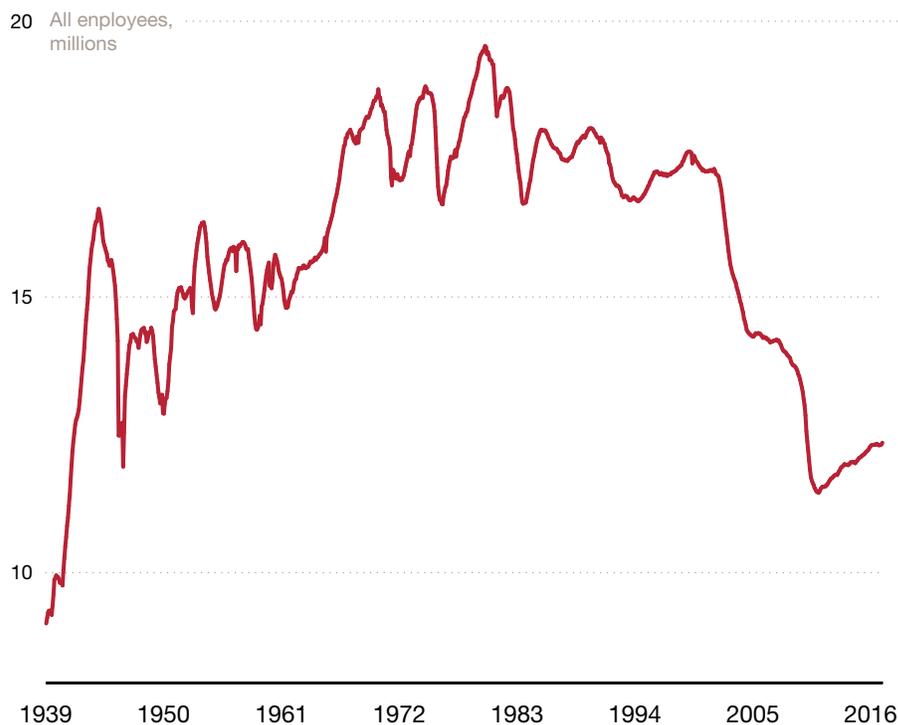
While the industrial workforce is historically small, manufacturers are out to make it the smartest ever

Where have all the factory workers gone? The US industrial workforce has been significantly diminished in the last decade.² Indeed, there are numerous perfect-storm factors that have contributed to the net decline over the last decade, including the recession, off-shoring of jobs, and an increase in automation. While there has been a partial recovery in the number of manufacturing jobs lost during the Great Recession, (bottoming out in early 2010), the number of 12.3 million manufacturing jobs at the end of 2015 is still roughly 14% less than the 14.4 million a decade ago (see chart). For a broader perspective, consider that the sector's labor force has shrunk to levels not seen since the 1940s (yet productivity levels have gone up steadily over the same period). But, while the manufacturing sector has added jobs steadily since 2010, it has done so at a much slower pace than that of the entire economy since 2010 (see chart).

Of course, there are regional pockets that have recovered more than others. Michigan is one of these, thanks in part to that region's healthier auto industry. According to a study by

The US manufacturing workforce is growing...but far below historical levels

US manufacturing sector employees, in millions (1939–2015)



Source: US Bureau of Labor Statistics database, http://data.bls.gov/timeseries/CES3000000001?data_tool=XGtable

Forbes, the number-one metropolitan area in the country for manufacturing employment growth since 2009 is the Detroit-Dearborn-Livonia area, which has experienced a 31% rebound to nearly 90,000 industrial jobs since the Great Recession.³

Nurturing the next-generation workforce is not only a manufacturing issue, but also looms as a national imperative, with the sector contributing some 12% of US GDP.⁴ The issue carries a degree of urgency to create opportunities for a large

swath of the young and unemployed US population. Consider one sobering statistic: some 19% of Americans between 20 and 24 years of age are not engaged in employment, education, or training, compared to 10.3% in Germany.⁵

But these regrowth spurts aren't happening everywhere, and increased adoption of industrial robotics, for example, is doing little to spur further manufacturing jobs creation. "We still don't really know how to solve the problem of jobs being lost through

2. Note: According to US Bureau of Labor statistics data: in Jan. 2010, total US employees numbered 129.7 million; in Dec. 2015 it was to 142.9 million. The number of manufacturing employees rose from 11.4 million in January 2010 to 12.3 million in Dec. 2015.

3. "The cities leading the US manufacturing revival," Forbes, July 23, 2015.

4. Federal Reserve Bank of St. Louis data <https://research.stlouisfed.org/fred2/series/VAPGDPMA>

5. OECD NEET database <https://data.oecd.org/youthinac/youth-not-in-employment-education-or-training-neet.htm>

automation,” said Dr. Daniel Araya, an author, education researcher, and Distinguished Research Fellow at the Hult Global Center for Disruptive Innovation in an interview with PwC. “At the same time, I do agree that new jobs will always be created in the wake of lost jobs. But how do we balance the workforce for the long term—so we all still have jobs? Automation could cause a very high level of social dislocation, and that’s something we really need to take seriously and resolve. I am not sure that most of us are prepared for the sort of society that automation is creating for us—and at a much faster pace than we might be ready for,” added Dr. Araya.

Most manufacturers see general skills shortages, but split on how it will play out... Manufacturers are not speaking in a unified voice on the skills shortage issue. In fact, 44% said that there is no skills shortage presently—though most of them see a shortage looming in the next three years. Roughly one in four manufacturers believe a skills shortage has already peaked and will abate in the next three years, while another 29% believe the skills shortage is worsening and will continue to worsen over the next three years. Just 14% see no shortage and none on the horizon. “A fundamental problem about the conversation of skills gaps is: what skills are we really talking about—

Nearly two-thirds of manufacturers see talent shortage worsening in next three years

Q. How do you expect the US manufacturing skills shortage to evolve in the next three years?

Answer options	Response percent	Response count
There is no manufacturing skills shortage, and there will not be one in the next three years	14.0%	17
There is no manufacturing skills shortage now, but there will be one in the next three years	30.6%	37
The manufacturing skills shortage has already peaked and will be less acute in the next three years	26.4%	32
The manufacturing skills shortage is getting worse and will be even more acute in the next three years	28.9%	35

Answered question 121

Two of three manufacturers encountering difficulty finding high-tech skills

Q. In the last year, how much difficulty has your company encountered in acquiring the talent to exploit advanced manufacturing technology (e.g., 3D printing, IoT, robotics, automation, virtual/augmented reality)?

Answer options	Response percent	Response count
No difficulty	13.1%	16
Little difficulty	19.7%	24
Moderate difficulty	44.3%	54
Substantial difficulty	15.6%	19
Extreme difficulty	7.4%	9

Answered question 122

AAs, BAs, certifications?” said Robert Lerman, PhD, Institute fellow in the Center on Labor, Human Services, and Population at the Urban Institute and professor of economics at American University in an interview with PwC. “Are our STEM skills competitive with other countries? While these are in no way trivial measurements, they can miss measuring occupational employability skills.”

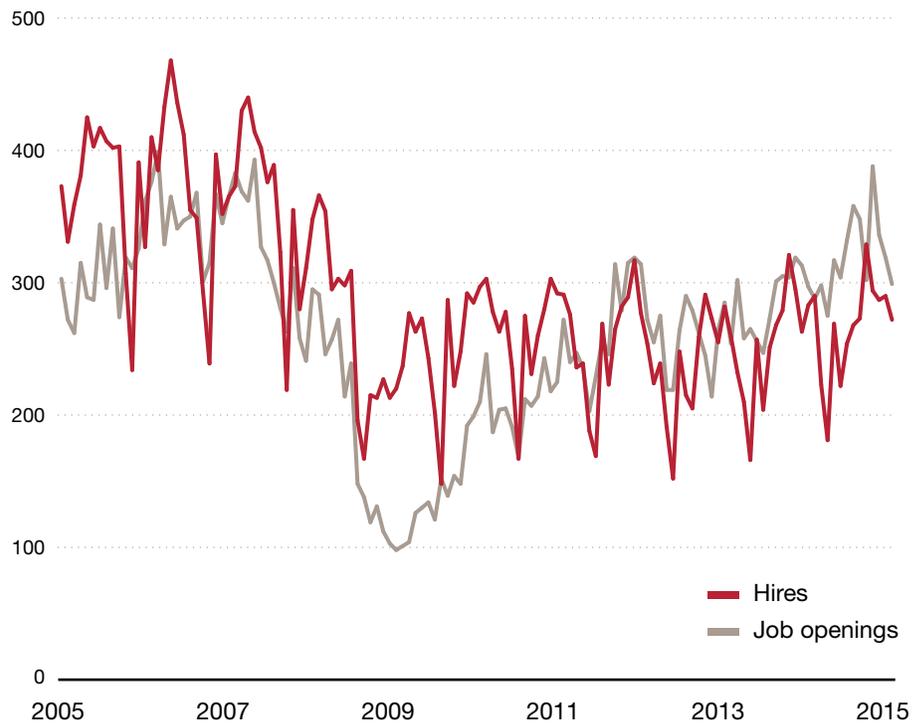
...But they’re struggling to secure talent to exploit advanced technology However, when asked about difficulty attracting talent to exploit advanced manufacturing technologies, the picture changes. Only 13% of manufacturers said they have encountered no difficulty in acquiring talent to exploit advanced manufacturing technology (e.g., 3D printing, Internet of Things, robotics, virtual/augmented reality).

Job openings still outnumbering hires Indeed, as our survey reflects—and as reflected in government and other data—manufacturers are facing challenges in finding workers with general manufacturing skills and, especially, the talent to exploit emerging advanced technologies. The number of ongoing unfilled positions in manufacturing further supports and reflects current or anticipated concerns about securing the right people for the right job. Openings for manufacturing jobs continue to outnumber the number of hires by tens of thousands. Consider, for example, the gap in July 2015, when there were 388,000 openings and 294,000 hires. This gap is also grounded in jobs posted in Indeed.com, the online jobs search aggregator. In contrast, other industries are experiencing more hires than publicized openings, such as the construction and leisure and hospitality industries.⁶

More manufacturers believe advanced tech adds jobs than those who see declines When asked the age-old question surrounding machines stealing our jobs, more than one in three manufacturers we surveyed said that investing in advanced technology during the next three years will expand people in their workforce. This could be explained by the need for talent to harness value from new investments manufacturers are making in advanced manufacturing technologies, such

Manufacturing job openings exceeding hires

US manufacturing job openings and hires, in thousands (2005–2015)



Source: US Bureau of Labor Statistics database

Advanced technology not seen as jobs killer

Q. In the next three years, what will be the impact of your investment in advanced manufacturing technology (e.g., 3D printing, robotics, IoT, automation, virtual reality) on the size of your workforce?

Answer options	Response percent	Response count
Anticipate they could likely reduce our workforce	17.2%	21
Anticipate no change in the number of employees	45.1%	55
Anticipate hiring additional people (e.g., to manage new technology)	37.7%	46

Answered question 122

6. Job Openings and Labor Turnover—November 2015, Bureau of Labor Statistics, US Department of Labor, January 12, 2016.

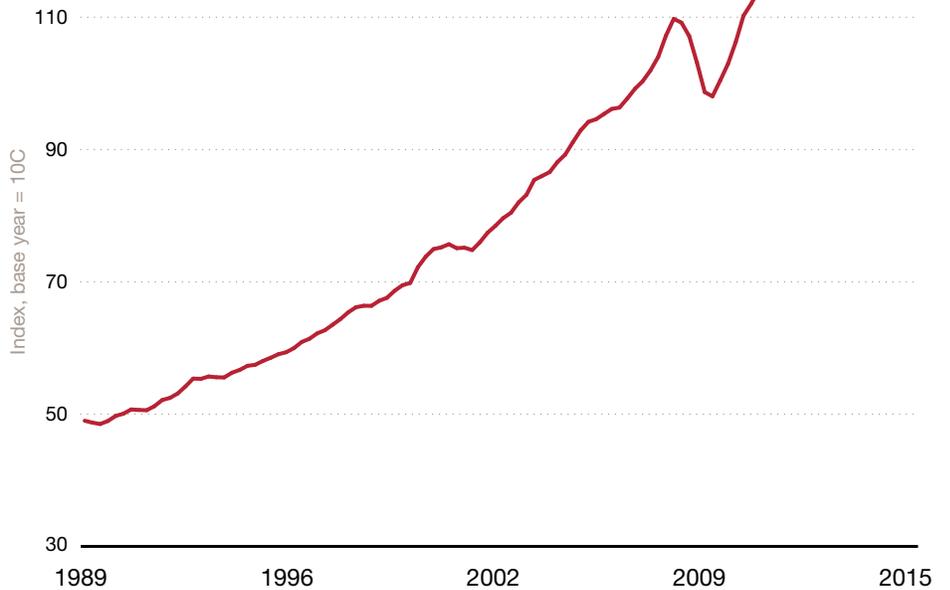
as Internet of Things technologies, automation technologies, and additive manufacturing technologies. Roughly half said they anticipate no net change (which may suggest that they are relying on and upskilling existing talent to carry out adoption of advanced manufacturing technologies). Meanwhile, the rest, or 17%, expect that adoption of technologies will likely lead to a reduced workforce in their operations.

Output, productivity and wages rise—despite fewer workers

Meanwhile, manufacturing productivity has not only rebounded from pre-recession levels, but it has also soared above them (see chart). Industrial output, too, has reclaimed pre-recession levels (see chart). Wages have also gone up steadily since before the recession—from a national average of \$20.69 an hour in 2006 to \$25.49 in 2015 (see chart). Indeed, we have entered an era of a workforce of historically few factory workers, yet one yielding greater productivity and output.

Productivity's plateau

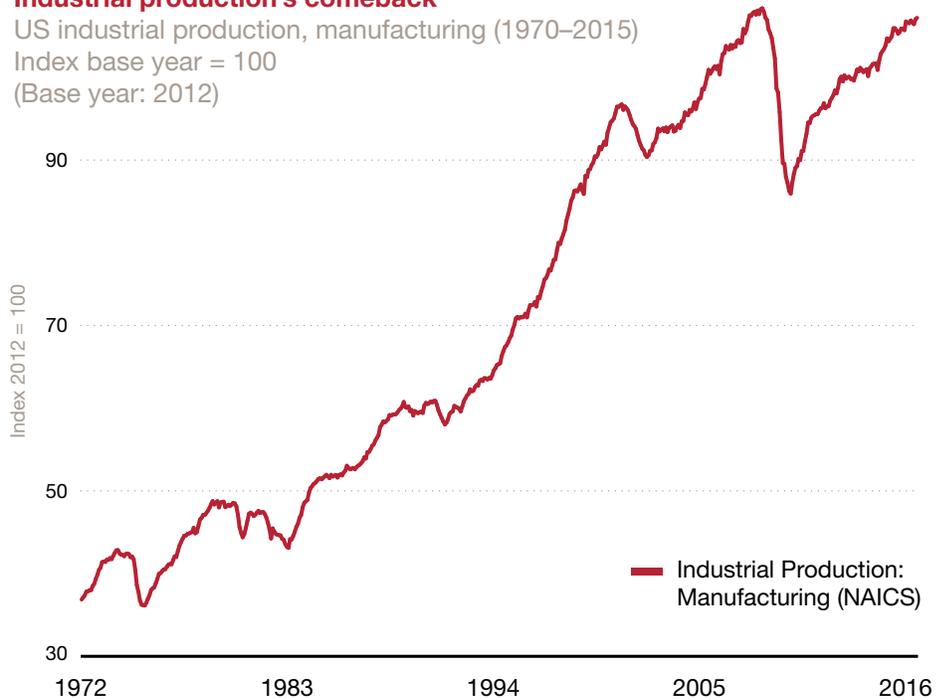
US manufacturing sector labor productivity, output per hour (1989–2015)
Indexed base year = 100
(Base year: 2009)



Source: <http://data.bls.gov/pdq/SurveyOutputServlet>

Industrial production's comeback

US industrial production, manufacturing (1970–2015)
Index base year = 100
(Base year: 2012)



Source: Federal Reserve Bank of St. Louis website, <https://research.stlouisfed.org/fred2/series/IPMAN>

III. The new face(s) of manufacturing

Guess who grew up in 2015? What a new generation is looking for in the job market, and how manufacturers are seeking to respond.

Searching for a new kind of employee The US manufacturing workforce has gone through enormous change in the last decade. Whether or not the size of the workforce ever returns to the previous highs of decades ago is an open question—and even, perhaps, a moot one. To tell a more complete story of where the future of the industrial workforce is headed, we need instead to look at the rapidly changing nature of that workforce—very much composed and led by a new generation: the connected, digitally smart Millennial generation. What is today’s labor market informing us about how the workforce could evolve over the next decade? “We are definitely seeing a new variety of titles being posted for manufacturing jobs and also an overlap or blending of skills are being sought by employers,” said Tara Sinclair, associate professor of economics at George Washington University and Chief Economist for Indeed.com, the world’s largest job search aggregator, in an interview with PwC. “Manufacturing jobs are looking more and more like tech jobs,” Sinclair added.

The Millennial majority. Next up? Gen Z In 2015, a significant demographic shift occurred in the American workforce: Millennials (born 1981 to 1997) became the largest cohort in the labor force, with 53.6 million (or 34% of the total workforce), eclipsing for the first time that of the GenXers (born 1965 to 1980) at 52.7 million.⁷ At the same time, the labor force is aging. By 2029, 20% of the US population will be over the age of 65.⁸ And, in 2016, Gen Z (born between 1994 and 2004)—a generation with no memory of a world without mobile apps—will be ushering its first class of college graduates into the workforce. “The younger job seekers are different in that they are very idealistic and at the same time expect bigger and more frequent job changes throughout their careers, but they’re also looking, as generations before them, for long-term advancement,” said Tara Sinclair.

For one thing, manufacturers realize the need for a workforce of problem-solvers that will adapt to and have comfort with swiftly changing technology. A survey of southeast Michigan manufacturers found that the most important education change needed to prepare the workforce include professional development for existing workers focusing on technology, increased apprenticeship opportunities, and wider availability of—and access to—computer science course work.⁹

“There is definitely a dramatic shift in the nomenclature of job titles, but what we’re seeing are titles that reflect the nature of how manufacturing is changing,” said Colby Spencer-Cesaro, senior director for research and strategy at the Workforce Intelligence Network for Southeast Michigan (WIN), a non-profit initiative formed to help strengthen the region’s workforce and economy. “In Detroit, manufacturing really means the auto industry and now that cars are becoming computers on wheels, the talent needed reflects that,” she said.

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Automation, more than off-shoring, is resulting in a diminished need for production and assembly workers.”

—Colby Spencer-Cesario, senior director for research and strategy, Workforce Intelligence Network for Southeast Michigan (WIN)

7. “Millennials surpass GenExers as largest generation in US labor force,” Pew Research Center, May 11, 2015.

8. Ibid.

9. “EUREKA! Innovation and Disruption in the Economy and how the workforce can prepare,” Workforce Intelligence Network for Southeast Michigan, 2015.

Smart factories, smart workers

Manufacturers are stepping up hiring of talent that can keep pace with their investments in the technology. That means a lifelong career in the local manufacturing plant straight out of high school is no longer a sure bet. In 1968, about 75% of advanced industry workers in the US had no college degree and by 1980 that percentage shrunk to 63% and by 2013 had further dwindled to roughly 25%.¹⁰

Our survey finds that 75% of ‘factory-floor’ jobs are being filled by those with post-secondary school (beyond high school) educations. Of those hired by manufacturers in 2015 for jobs on the factory floor, 47% had a vocational or junior college degree, 20% had a four-year college degree and 9% had an advanced degree (master’s or Ph.D.). “Overall, there is a drop in welders and a rise in IT, software development and engineering, and data science in the manufacturing hiring. Automation, more than off-shoring, is resulting in a diminished need for production and assembly workers,” said Colby

Our survey finds that 75% of ‘factory-floor’ jobs are being filled by those with post-secondary school (beyond high school) educations.

Spencer-Cesario. “The career pathways are changing. One used to graduate from assistant welder to welder to senior welder. Now, it might take you four years of training before you actually operate equipment, because today’s machinery might require you to have at least a couple years of training and a knowledge of calculus.” As a result, what prospective employees are looking for is also changing, she notes. “Kids who spend four years in vocational training will expect more than \$12 an hour and a title that reflects that training. And, for those with a four-year college degree, they

can pretty much work anywhere, so manufacturers have to make sure they offer them work that is not only lucrative but also has a path to move up—and something that’s meaningful to them. That’s the Millennial chorus we hear.”

Educational levels for hires in non-factory floor level jobs (e.g., R&D, mechanical engineering, prototype design) in the last year skewed higher: 22% holding advanced degrees, 50% with four-year college degrees, and 12% with junior college/vocational school education.

The highly educated factory

Q. What was the educational level of people you hired in the last year for jobs on the factory floor? (Note approximate number on each level.)

Answer options	Response percent	Response count
No high school degree	1.3%	–
High school graduate	23.7%	–
Vocational or junior college graduate	46.5%	–
Four-year college graduate	19.9%	–
Advanced degree (e.g., master’s or Ph.D.)	8.6%	–

Q. Among your hires in the last year for non-factory floor jobs (e.g., R&D, mechanical engineering, prototype design), what was their educational level when hired? Please select the one that most applies.

Answer options	Response percent	Response count
No hires	9.1%	11
High school graduates	6.6%	8
Junior college/vocational school graduates	12.4%	15
Four-year college graduates	49.6%	60
Advanced degree (e.g., master’s degree or Ph.D.)	22.3%	27

Answered question 121

10. “America’s Advanced Industries,” Brookings Advanced Industries Project, February 2015.

Poaching talent from non-manufacturing sectors? Millennials are looking outside their current occupation for new jobs, with only one in five of job seekers in this generation searching for jobs within their own given occupation more than 50% of the time, according to Indeed.com.¹¹ This matters. By 2020, Millennials will make up more than half of the workforce. An Indeed.com study examining search results of 430,000 employed Indeed-registered job seekers across 23 occupational categories, found that the ‘production’ was the fourth-largest (about 8% of the total sample) job category with 11% of all job seekers looking at its jobs postings.¹² “In order to attract talent in an increasingly tight labor market, manufacturers would do well to position themselves as makers and present their case for improving the world in some way,” said Tara Sinclair, economist at Indeed.com. “While wages continue to be the number-one reason for job seekers accepting one job over another, other factors figure in strongly, too, such as location and the degree of flexibility, for example, allowing workers flexible hours in the work environment. They also need to make clear how they can provide younger workers an upward career pathway to attract more talent,” she added.

Manufacturers are looking outside the sector—and even country—for a new breed of talent

Q. Among your hires in the last year for jobs on the factory floor, where was the majority previously employed?

Answer options	Response percent	Response count
Straight out of school	20.9%	24
In the manufacturing sector	66.1%	76
In a non-manufacturing sector	13.0%	15
Other (please specify)		6

Answered question 115

Q. Among your hires in the last year for non-factory floor jobs (e.g., R&D, mechanical engineering, prototype design), where was the majority previously employed?

Answer options	Response percent	Response count
Straight out of school	26.7%	32
In the manufacturing sector	56.7%	68
In a non-manufacturing sector	16.7%	20

Answered question 120

Q. Would US manufacturing be more competitive if it were easier for foreign nationals with the right technology skills to work in the US?

Answer options	Response percent	Response count
No, the US has enough homegrown talent	38.5%	45
Yes, it would increase US competitiveness	61.5%	72

Answered question 117

Tapping foreign talent? Looking beyond the pool of homegrown talent, manufacturers also recognize the need to draw foreign talent, such as those who are educated in the US, but do not secure a green card or are permitted

temporary work status, for example. Some 60% of manufacturers agreed that US manufacturing would be more competitive if it were easier for foreign nationals with the relevant technology skills to work in the US.

11. “The Millennial Advantage: How This Determined Generation Will Succeed,” Indeed.com, November 24, 2015.

12. “What Job Seekers Want: Occupation Satisfaction & Desirability Report,” Indeed.com, March 2014.

IV. Shaping the next-generation industrial workforce

Manufacturers today are doing their own training, hiring different skills, and making use of vocational education. More solutions are needed. One alternative is the German apprenticeship model, which is taking root in the US South. Is it enough?

As manufacturing adopts more advanced technologies, the need to recruit new talent—and upskill existing workers—will likely intensify. Consider that, globally, the industrial control and factory automation market is forecast to grow at a CAGR of 7% and reaching over \$200 billion by 2020.¹³ Such growth is likely in large part due to the proliferation of robotics, machine-to-machine communication, and the industrial Internet.

An upskill battle? So, what are manufacturers doing to ensure that their workforce possesses the digital IQ and know-how to exploit new and emerging technologies? When asked how they are raising the level of their workforce’s advanced manufacturing skills level, most manufacturers are training in-house, according to our survey, followed by either recruiting STEM students or funding training outside the company (at community colleges, for example). Interestingly, though, more manufacturers are

How manufacturers are raising their industrial IQ

Q. How is your company trying to raise the level of its employees’ advanced manufacturing skills (e.g., 3D printing, IoT, robotics, automation, virtual/augmented reality)? Please select all that apply.

Answer options	Response percent	Response count
Train existing employees in-house—as we believe we can train our current workforce to adopt advanced manufacturing technologies	74.2%	89
Hire new employees from outside the manufacturing sector	31.7%	38
Hire from other manufacturing companies	25.8%	31
Identify talented STEM students at local academic institutions and try to recruit them	40.8%	49
Provide training outside the company (e.g., community college, online, technology vendors)	40.0%	48

Answered question 120

Advanced degrees...for advanced manufacturing

Q. What level of employee is/will be most responsible for using advanced manufacturing technologies?

Answer options	Response percent	Response count
Unskilled production	1.7%	2
Skilled production	38.8%	47
Maintenance technician	7.4%	9
Engineer	49.6%	60
Scientist	2.5%	3

Answered question 121

raising their advanced manufacturing talent levels by hiring employees from *outside* the manufacturing sector than *inside* the sector.

It appears, though, that manufacturers do not agree on exactly which level of worker will take the lead on advanced manufacturing. When asked who they will rely on within their organization for using advanced manufacturing technologies, manufacturers split—

with about half of manufacturers saying it would be engineers, and 40% saying the responsibility will rest on skilled production workers.

So, as manufacturers continue to adopt more sophisticated technology that requires higher skills, our findings suggest that they are relying heavily on existing workers to raise the bar, especially in upskilling lower-level employees.

13. “Industrial Control and Factory Automation Market worth 202.42 Billion USD by 2020,” Markets and Markets press release, PR Newswire, September 24, 2015.

The apprentice: can it work in manufacturing? In the wake of the Great Recession and rising college debt, there has recently been a push for apprenticeships, with the number actively enrolled in Department of Labor (DOL)-Registered Apprenticeships rising to about 450,000 in 2015, up from about 350,000 in 2011, according to the DOL.^{14,15} It's important to emphasize, however, that these figures capture only those programs that are formally enrolled with the DOL. Still, these figures are dwarfed by apprenticeship programs in some other countries. In 2014, there were 43 apprentices per 1,000 employed individuals in Switzerland, 40 in Germany and 39 in Australia and just three in the US.¹⁶

“The US needs competency-based apprenticeships where companies follow certain standards so we get a commonality of skills—in the same way nurses and physicians are expected to have a common core of knowledge no matter where they studied,” said Robert Lerman, professor of economics at American University. “We’re still stuck in a college-for-all mentality—as if getting a four-year degree is the only path

to be a successful contributor to an economy, or provider of a family,” he added. Apprenticeships in the US are a patchwork of state-run programs—including long-standing initiatives in California and Wisconsin—with some more ambitious and advanced than others. “The results in vocational schools and junior colleges are uneven—it’s very costly for schools to purchase the right equipment that gives practical hands-on experience,” added Lerman. “Schools need to form tighter collaboration with companies. We do not have any institutional capacity to teach companies how to make apprenticeships work and how to determine even if it’s right for a company,” he added.

From Stuttgart to Charlotte: Is Germany’s worker training model the answer? Meanwhile, as foreign investment continues to pour into US manufacturing, some foreign firms—most notably German manufacturers—are moving to import their culture of apprenticeships. Germany’s apprentice programs, offered in most sectors, including hospitality and financial services, is a decades-long tradition now firmly entrenched in that country’s labor market culture.¹⁷

14. Apprenticeships, US Department of Labor website, https://doleta.gov/oa/data_statistics.cfm

15. Note: Registered Apprenticeships are those which sponsor and register program standards and apprentices with the US Department of Labor’s Office of Apprenticeship or a State Apprenticeship Agency (SAA) recognized by the DOL.

16. Gordon, Howard R.D., “The History and Growth of Career and Technical Education in America,” fourth edition, Waveland Press, 2014.

17. “Why Germany is so much better at training its workers,” *The Atlantic*, October 16, 2014.

Take, for example, Apprenticeship Carolina, which has increased the number of companies sponsoring registered apprentices to 700 in 2014 from 90 in 2007. It has enlisted the likes of Siemens, Daimler, and Volkswagen, which have created vocational training programs with state and local governments and local schools through public-private consortia to establish apprenticeships.¹⁸ Siemens Energy plant in Charlotte, North Carolina, invests up to \$170,000 in each apprentice, including tuition, books, and wages over its three-and-a-half-year program.¹⁹ Blum, an Austrian furniture hardware company, which has a plant in Stanley, North Carolina, has been at it for a while. Its Apprentice 2000 program, which started in 1995, spends about \$160,000 on a typical apprentice, who, after completing 8,000 hours in on-the-job training (and 1,800 hours of course work) earns an A.A.S. degree in manufacturing technology and a Journeyman's Certificate awarded by the state of North Carolina.²⁰

Germany's Festo is a leading world-wide supplier of automation technology and equipment and solution provider for industrial education. Festo Didactics, since the 1970s, has developed training systems for technicians, and recently expanded into the US. "Often, when Americans think of manufacturing they conjure images of being covered in grease and working in dangerous or arduous conditions with little prospect for moving up a career path," said Torsten Schimanski, Head of Festo's Learning Center, focusing on workforce development and qualification.

Schimanski added that apprentices in mechatronics (a hybrid degree, blending hydraulics, pneumatics, mechanics, and coding) could earn \$50,000 to \$70,000 upon completion. A more robust apprenticeship network could help lure more European companies to the US. Schimanski adds, "When European companies look into producing in the US, a first question often is: what kind of apprentice programs are on offer in the given state they are considering.

The new factory worker will increasingly be wearing a white shirt, not the blue overall. They'll still need to focus on machine operators and repair, but they'll also need a facility with coding and programming machinery and robots. They should not be shy about asking 'Can you tear apart a robot and put it back together again?'"

Then there's the potential for online education. Take, for example, the Digital Manufacturing and Design Innovation Institute, which is currently planning a curriculum of up to nine online courses that will lead to a certificate of completion, targeted to students and engineers. The courses will include up to 40 hours of lectures and also have evaluations and surround the Institute's three main research areas: advanced analysis, intelligent machining, and advanced manufacturing enterprise.²¹

18. "German-Style Training for American Factory Workers", *The Wall Street Journal*, Spectember 9, 2014.

19. "Apprenticeships Could Be Gateway to Middle Class," *US News.com*, January 12, 2015.

20. Blum, Inc. website retrieved at: <http://www.blum.com/us/en/04/10/80/>

21. "Online Digital Manufacturing Classes Coming Soon," *Automation World*, December 15, 2015.

When gaming meets manufacturing

To attract the gaming generation, manufacturers could possibly use virtual reality as a draw, and capture the talent they will likely increasingly need. According to a separate PwC survey of manufacturers, some one-third of manufacturers are using or will adopt virtual and/or augmented reality technologies in the next three years in their operations. That same survey found that the second most common application of VR/AR among manufacturers is for worker safety and training (with 28% of manufacturers choosing this).²² For example, operators of certain ‘critical mission’ or potentially dangerous environments such as oil extraction wells or chemicals facilities are using training simulators for virtual experience, creating an immersive, 3D environment—and incorporating headsets and Xboxes—to show workers the facility’s existing equipment, control systems, and processes. According to the National Training

Laboratory, learning retention rates of up to 75% are attained through simulation technologies, compared to about 10% through reading.²³ That means simulators can potentially accelerate the time it takes for an entry-level employee to move up to higher responsibilities. Other technology, such as smart glasses provide workers with augmented reality to call up data on a machine part—it is also adding productivity and safety to the workforce.

The convergence of virtual reality is happening in classrooms, too, to prep budding industrialists. Take Clemson University Center for Workforce Development, which has created virtual reality simulations of factory floors geared to K–12 and college students—such as a simulated assembly line and plant equipped with drilling machines and forklifts. Students go through the floor as a safety auditor and play the game by tagging safety violations.²⁴

I really think that we’re at the beginning of a very steep curve of entrepreneurship in this country and employers will need to adjust in order to leverage that. Being creative and entrepreneurial will be much more important than where you got your four-year degree from. And companies will need to allow their own workers the space and time to innovate in-house. You only see manufacturing as an attractive area if and when you know that what you’re making has some social impact, some meaning.

—Dr. Daniel Araya author, education researcher, and Distinguished Research Fellow at the Hult Global Center for Disruptive Innovation

22. “For US manufacturers, virtual reality is for real,” PwC blog, <http://usblogs.pwc.com/industrialinsights/2016/01/12/for-us-manufacturers-virtual-reality-is-for-real/>, January 12, 2016.

23. “Virtual is the new reality,” *Automation World*, August 7, 2015.

24. “Clemson takes manufacturing training to virtual reality,” *Upstate Business Journal*, October 29, 2014.

Wild cards: the maker generation and the gig economy A proliferation of ‘maker places,’ ‘fab labs,’ or ‘innovation hubs’—estimated to number some 2,000 globally—are enabling a growing number of ‘maker movement’ entrepreneurs, designers, and start-ups.²⁵ Lowering costs of industrial tools such as design software and 3D printing are making it possible for small start-ups to prototype products in ways only established manufacturers could do a decade ago. Makerspaces democratize industrial design, craft and, to some degree, production. Additionally, new ways to fund a start-up are further lowering the barriers to enter manufacturing. Start-ups can also look to crowd-financing, such as Kickstarter. This movement could be a win-win for US manufacturers. As the so-called ‘makers’ invent, design, and prototype their products, some reach the point of scaling up and will look to existing manufacturers to enable that. Manufacturers will likely be looking to makers for more than orders; they could represent a deep and growing reservoir of talent to

enlist to their own ranks. “I think the emphasis has to be placed more on developing maker skills—becoming an innovator rather than an expert. And large companies will benefit from this shift—they acquire the talent or the ideas, or outsource more,” said Dr. Daniel Araya.

Rise of the freelance class Tethered closely to the maker movement is the growing legions of freelancers, which manufacturers will increasingly be able to hire on a contract or part-time basis, or court to join their workforce. This so-called ‘gig economy’ is a 53-million-strong army of freelancers, who now account for one in three workers, according to the US Bureau of Labor Statistics.²⁶ The growing pool of freelancers present manufacturers not only with opportunities to outsource skills they may not have in-house, but also represent a pool of talent they can draw from. As the labor force changes in these ways—with entrepreneurship and freelancing changing the workforce, manufacturers will likely need to assess how they can leverage such shifts.

25. “How Makerspaces Help Local Economies,” *The Atlantic*, April 17, 2015.

26. “Why an Ex-Google Coder Makes Twice as Much Freelancing,” *Bloomberg.com*, January 19, 2016.

V. Paths to building a more competitive industrial workforce

The persistent gap between openings and hires suggest that US industrial manufacturers are struggling to build the workforces they want by sticking with traditional approaches to everything from training to recruiting. Here is a look at what works today and what might come to factor more in the not-too-distant future.

Practical and widely used	
Train in the workplace	This is what most manufacturers do today to advance the skills in their workforces. They believe they are best placed to teach employees how to make use of new technologies, and fit them to their business needs.

Practical and increasingly in use	
Train outside of the workplace	Options are widening and improving. Manufacturers are teaming up with community colleges or vocational schools to meet demand for different skills and equipment. Vendors and online courses are also expanding in this space. Progress on nationally accepted credentials across different skill sets would accelerate uptake.
Recruit STEM graduates directly	This is typically done via job fairs, well-crafted internships, and above all, productive relationships with educational institutions. Manufacturers may be surprised to learn the level of commitment this option can require to succeed. For example, top legal, financial, and professional services firms devote entire divisions to the task of recruiting promising university graduates.

Not widely used, but poised to grow quickly	
Hire outside of the industry	Just one in four manufacturers we surveyed say they look for and hire people who are not already in their industry. Yet as manufacturers invest and deploy advancing technologies, hiring from outside the sector will likely grow. Consider that 13% of all manufacturing job postings in Michigan in 2015 were for IT workers and that the number-one category of IT jobs sought by manufacturers was “software developers for applications”. Additionally, production jobs draw a significant amount of interest from job seekers outside manufacturing; manufacturing jobs requiring skills from other fields (e.g., gaming, CAD simulation, virtual reality) could draw candidates from—and compete with—other fields. The learning curve for manufacturing HR is steep. Competition for talented people in tech is fierce; keeping up with the skill sets in demand is also challenging.

Promising if untested for the US labor market	
Apprenticeships	This German import is gaining more adherents in the US, particularly among government officials and others who study labor trends. German manufacturers are bringing the model to their facilities in the US through public-private consortia to establish apprenticeships. ²⁷ Siemens Energy plant in Charlotte, North Carolina, invests up to \$160,000 in each apprentice, including tuition, books, and wages over its three-and-a-half-year program. ²⁸ Meanwhile, the US government and states are making moves to support and mainstream apprenticeship programs in the manufacturing sector.

Wild cards	
Import talent from outside the US	A majority of manufacturers we surveyed (60%) believe that the industry would be more competitive if it were easier for foreign nationals with the relevant technology skills to work in the US. However, this is a wild card, given the uncertainty around the likelihood of the US continuing to raise the number of visas for skilled, non-US workers.
the Maker Generation and the Gig Economy	Lowering costs of industrial tools such as design software and 3D printing are making it possible for small start-ups to prototype products. Manufacturers will likely be looking to makers for more than orders; they could represent a deep and growing reservoir of talent to enlist to their ranks. Tethered closely to the maker movement is the growing legions of freelancers. As various aspects of the design process take place outside of the manufacturing space, manufacturers will likely increasingly look to hire freelance designers and others on a contract or part-time basis, or court to join their workforce.

27. “German-Style Training for American Factory Workers”, *The Wall Street Journal*, September 19, 2014.

28. “Apprenticeships Could Be Gateway to Middle Class”, *US News.com*, January 12, 2015.

Acknowledgements

PwC would like to thank the following interviewees for their time and for their generosity in sharing their ideas and insights for this report.

Torsten Schimanski, workforce development and qualification manager of Festo Didactics.

Robert Lerman, PhD, Institute fellow in the Center on Labor, Human Services, and Population at the Urban Institute and professor of economics at American University

Tara Sinclair, associate professor of economics at George Washington University and Chief Economist for Indeed.com

Colby Spencer-Cesaro, senior director for research and strategy at the Workforce Intelligence Network for Southeast Michigan (WIN)

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