INDUSTRY 4.0 INNOVATION GAP:

MANUFACTURERS AND COLLEGES SHOULD DRAW INSPIRATION FROM GERMAN PIONEERS

Introduction

Manufacturing in the U.S. and Canada is marked by negative stereotypes left behind from 1955; repetitive and simplistic duties in grimy workplaces, without a chance to change or advance a career, are the images most people see when they imagine what it means to work in a factory. But, a new future for manufacturing is here—it is Industry 4.0.

Industry 4.0, or the Smart Factory, represents a paradigm shift from the assembly lines popularized by the U.S. automotive industry. Whereas the values typified by those initial factories prioritized profitability over people and safety standards, modern manufacturing has evolved to place an equally high value on clean technology, renewable energy, robotics, and on-demand, yet affordable, customization. What this means for manufacturing is not only a new way of production, but new skill requirements for workers.

What is Industry 4.0?

In countries such as Germany and Japan, Industry 4.0 is a well-established approach in manufacturing. But in North America, companies are falling significantly behind. They have yet to make meaningful strides in the transition to Industry 4.0 and remain relatively ignorant of its practices and benefits. Mention the phrase to most U.S. or Canadian manufacturing executives and you're likely to get a lot of raised eyebrows, notes a 2015 McKinsey article.[1]

"If they've heard of it, they are likely confused about what it is. If they haven't heard of it, they're likely to be skeptical of what they see as yet another piece of marketing hype, an empty catchphrase," write Cornelius Baur, Senior Partner, and Dominik Wee, Partner, both based in McKinsey's Munich office. "And yet a closer look at what's behind Industry 4.0 reveals some powerful emerging currents with strong potential to change the way factories work."[2]

The McKinsey article contextualizes the name, which it calls the "fourth major upheaval in modern manufacturing," within the "lean revolution of the 1970s, the outsourcing phenomenon of the 1990s, and the automation that took off in the 2000s."[3] What is clear is that Industry 4.0, whether it's technically a revolution, lies at the intersection of major "disruptions" from the likes of big data and analytics and advanced robotics.

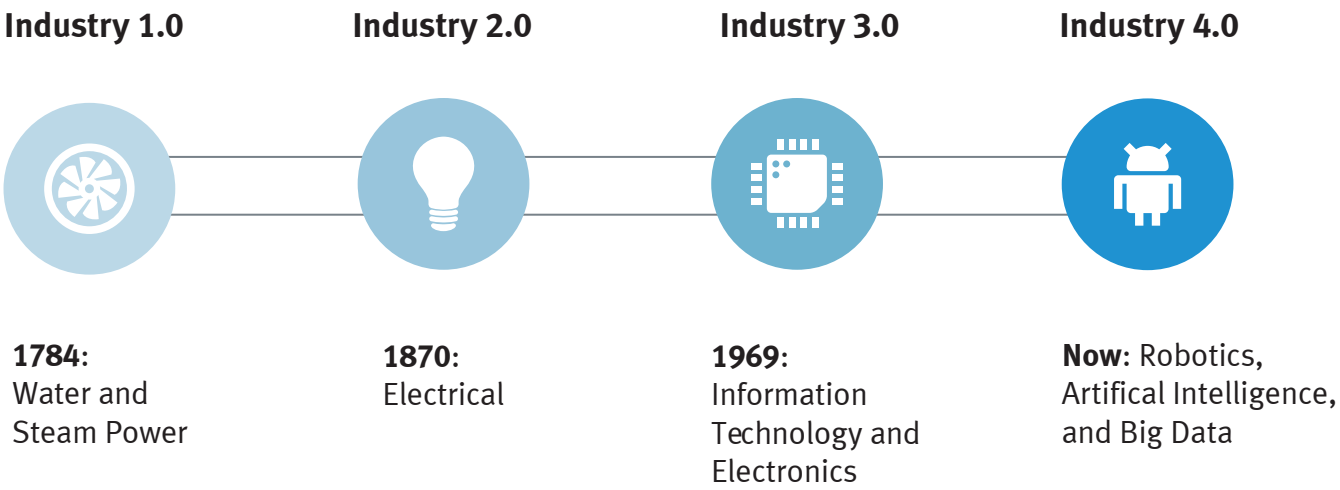
"Smart Manufacturing applies information and manufacturing intelligence to integrate the voice, demands and intelligence of the 'customer' throughout the entire manufacturing supply chain," adds the Smart Manufacturing Leadership Coalition. "This enables a coordinated and performance-oriented manufacturing enterprise that quickly responds to the customer and minimizes energy and material usage while maximizing environmental sustainability, health and safety, and economic competitiveness."[4]

Industry 4.0, which is often referred to as the "fourth industrial revolution," relates to what is called the Internet of Things. This new ecosystem, in which everyday objects are "plugged into" the Internet, transforms traditional factories to smart ones. "Here, machines 'talk' to products and other machines, objects deliver decision-critical data, and information is processed and distributed in real time resulting in profound changes to the entire industrial ecosystem," according to an Accenture article.[5] (The common timeline of industrial revolutions is Industry 1.0 relates to the 18th century's water and steam power; Industry 2.0 to the 19th century's electrical energy; and Industry 3.0 to the 1970s, with information technology (IT) and electronics.)

This kind of connectivity and interfacing is something that people are familiar with in their private lives, as when a cell phone "talks" to the car, says Thomas Lichtenberger, President at Festo Didactic North America, a leading provider of technical education equipment and training. "This kind of communication, where every device communicates with another and exchanges information, is getting smarter and smarter," Lichtenberger says. "We are familiar with it in our private life, but this is exactly what is happening now in industry."

The Internet of Things (IoT), notes a 2014 WIRED article, "is far bigger than anyone realizes." In the article, Daniel Burrus, founder and CEO of Burrus Research, writes that IoT "revolves around increased machine-to-machine communication; it's built on cloud computing and networks of data-gathering sensors; it's mobile, virtual, and instantaneous connection; and they say it's going to make everything in our lives from streetlights to seaports 'smart.'"[6]

Four Industrial Revolutions:



Industry 4.0 Pioneers

Announcing a national Advanced Manufacturing Partnership (AMP) at Carnegie Mellon University in 2011, U.S. President Barack Obama allocated more than $500 million to the effort, which the White House describes as a joint investment of industry, higher education, and the federal government in "emerging technologies that will create high quality manufacturing jobs and enhance our global competitiveness." The president referred in his remarks to a "renaissance in American manufacturing." That renaissance, which is still in the making, takes its cue in part from German leadership in advanced manufacturing.[7]

That leadership became apparent in 2008, when Germany's manufacturing sector did "exceedingly well," while most of the industrialized world was reeling during the financial crisis, notes the American Society of Mechanical Engineers.[8] A 2014 "Wall Street Journal" article suggests that U.S. manufacturers can look to Germany's success as a model.[9] And in 2016, U.S. Secretary of Commerce Penny Pritzker said the "fourth industrial revolution" is changing products in pockets and homes alike and "is shifting the very nature of work for our people." Secretary Pritzker notes that President Obama's inspiration for the National Network for Manufacturing Innovation was the Fraunhofer Institutes,[10] Germany's leading applied research organization, which employs 24,000 people across 67 institutes.[11]

The International Society of Automation further illustrates the point by comparing the way other countries are now adopting technology to drive significant innovation to how Japan used automation and robotics in the late 1990s to significantly increase its market share of the automotive industry. During Japan's ascension in automotive production, the U.S. had access to the same technology but did not use it. That cost the U.S. more than half of its market share.[12]

Despite the warnings, industry in North America, however, isn't prepared for the fast-evolving landscape, and it clings too often to outdated techniques and approaches to production. This is not merely a question of taste or philosophy. Companies that fail to embrace advanced manufacturing risk overpaying for underperforming plants.

Only 33 percent of the more than 2,000 companies from 26 countries that PwC surveyed in its 2016 report "Industry 4.0: Building the digital enterprise" said that their companies had achieved appropriate levels of advanced digitization today. By 2020, 70 percent expected to meet that mark. Industry 4.0 will revolutionize industrial production, according to the report, to the tune globally of $493 billion annually in increased digital revenue until 2020, and $421 billion globally in annual cost reduction in the same time span. That means that between 2015 and 2020, those surveyed, on average, expected to reduce their annual costs by an average of 3.6 percent, and to generate 2.9 percent more in increased revenue per year yielding a net gain of 6.5 percent.[13]

Ready or Not: Industry 4.0 Arrives in North America

That optimism for the future governed the statistics in the U.S. and Canada as well, where 37 percent of those surveyed in the PwC study expected revenue gains exceeding 20 percent in the next five years, and 39 percent thought they would reduce their costs over that same span by more than 20 percent. Half expected to increase their efficiency by more than a fifth by 2020.[14]

As PwC's data clearly demonstrates, Industry 4.0 isn't a lofty theory; it's already in practice. Significant investments in Industry 4.0 will amount globally to $907 billion per year until 2020, according to the study.[15]

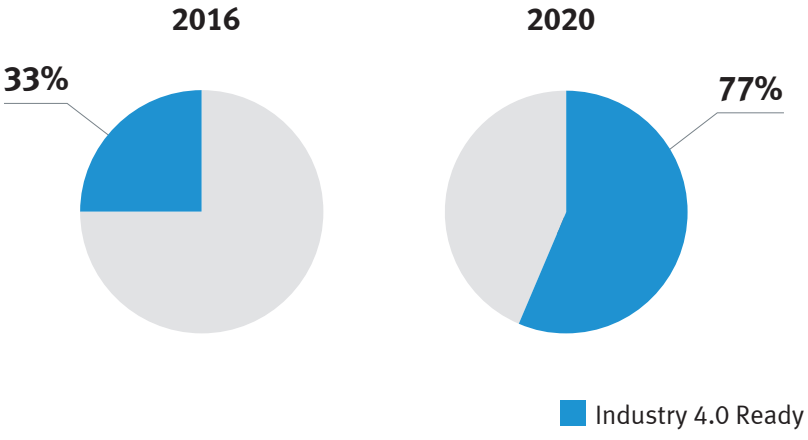
"Don't buy the hype. Buy the reality. Industry 4.0 will be a huge boon to companies that fully understand what it means for them," noted Reinhard Geissbauer, Jesper Vedsø, and Stefan Schrauf in their article "A Strategist's Guide to Industry 4.0" in PwC's Strategy + Business. "Change of this nature will transcend your company's boundaries – and probably the national boundaries of the countries where you do business."[16]

Impact on Higher Education

For colleges and universities with manufacturing-related degrees and certifications, Industry 4.0 also signals changes. New workers entering manufacturing today need new skills and higher levels of education than workers did a decade ago. By 2018, 38 percent of workers in manufacturing will have some post-secondary education, according to the Georgetown University Center for Education and the Workforce report "Help Wanted: Projections of Jobs and Education Requirements Through 2018." In 2008, 34 percent of workers in

Embracing Industry 4.0

Most companies are still working to achieve advanced levels of digitization, but are optimistic about meeting the mark soon.



the industry had some training beyond high school. While the predicted increase in necessary educational attainment is small, the authors of the report point to automation of routine functions as the cause. As machines and robots increasingly do the rote responsibilities of workers, employers will seek to hire individuals with more training to complete higher-level tasks.[17]

Research from the National Skills Coalition (NSC) comparing the available jobs by skill type and the number of workers available to fill them, further confirms the need to adapt training. According to NSC, 54 percent of jobs in the U.S. are considered middle skills jobs – those that require more than a high school diploma but not a four-year degree – but only 44 percent of the workforce have the skills needed for these positions. Comparatively, more than 20 percent of the workforce is trained for low skill positions, while the positions themselves make up about 15 percent of job demand. Based on this data, there is an obvious opportunity to engage the U.S. workforce in higher levels of education to fill the need of middle skill jobs.[18]

These two trends will require higher education institutions to increasingly be in-tune with the changing industry and skills requirements. So far however, higher education as a whole is lagging behind in meeting the needs of employers. Even more telling is that administrators don't seem to realize it.

A 2013 Lumina Foundation Gallup study found that just 11 percent of business leaders agreed strongly that college graduates are prepared for the kinds of jobs they are seeking to fill. That number departs significantly from the 96 percent of college and university chief academic officers who were extremely or somewhat confident that their institutions prepare students for their future careers.[19]

But, there are some, like Jeff Selingo, author of the book "There Is Life After College: What Parents and Students Should Know About Navigating School to Prepare for the Jobs of Tomorrow," who lay some of the blame on workers themselves.

"In a day and age when careers and industries expand and contract at an alarming speed, workers can't expect that their undergraduate or even graduate education will be enough to sustain them for their entire working life," Selingo writes in a LinkedIn post. "Nor can workers expect that companies will invest in every facet of their professional development, given that today's workers switch jobs and careers much more than their counterparts in the past."[20]

So as colleges and universities change their curricula to teach the new skills required by Industry 4.0, it is clear students who want to enter manufacturing must also adapt a life-long learning mentality. The title alone of the "Harvard Business Review" article "Employers Aren't Just Whining – the 'Skills Gap' Is Real" by James Bessen, a Boston University School of Law economist, is telling. Bessen writes:

"Those workers who acquire the latest skills earn good pay; those employers who hire the right workers and train them well can realize the competitive advantages that come with new technologies."

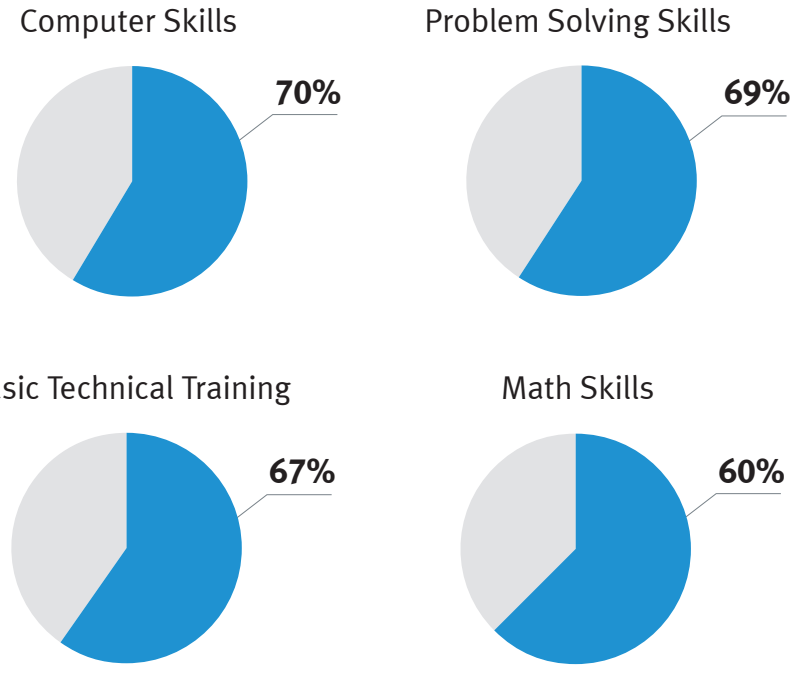
The scope of the skills gap varies according to industry and location, but a survey of more than 450 manufacturing executives conducted by the Manufacturing Institute and Deloitte yielded the following areas in which manufacturing employees were most deficient: technology and computer skills (70 percent), problem solving skills (69 percent), basic technical training (67 percent), and math skills (60 percent).[22]

Changing the Image of Manufacturing

There are also cultural challenges that may complicate the pipeline to advanced manufacturing. "In the United States, there can be a 'uniquely American' view of manufacturing that comes from the loss of so many manufacturing jobs in the past 30 years due to globalization, the North American Free Trade Agreement (NAFTA) treaties, and jobs moving to East Asia and to Mexico," says Mike Nager, Business Development Manager at Festo. "When graduates consider a career in manufacturing, or when their parents consider those sorts of jobs for their kids, there tends to be a very sour taste in their mouths, because the manufacturing they remember is from their grandparents' days," Nager says.

Wanted: Industry 4.0 Skills

New production processes require new skills, here is what employers are looking for:



In Germany, where the Festo Group has operated for nearly a century, that stigma doesn't exist. "Germany never shed its manufacturing base. It created many of the technologies that we are using today," Nager says. Advanced manufacturing, which is on the rise in the United States and Canada, presents a very different environment than the sweatshops and poor conditions, lack of job security, and closing of plants that used to typify North American manufacturing.

"When a new plant opens up – no matter what they're manufacturing – it's typically well-lit. It's clean. You can eat off the floors," Nager says. "It's sophisticated. It's robot programming. It's very high end, and it's very technical."

As those sorts of plants proliferate in Europe and Japan, North America lags behind considerably. That's a danger that troubles Daniela Vidal, the Director of Opportunity Development at the University of Southern Indiana. (More on the work she is doing below in a case study.)

"With the rapid pace of change that we are experiencing globally in technology, our industrial base really needs to embrace moving into the 21st century," she says. "Or they're really going to fall behind or disappear. If there's a real disruption in the market, they're not going to survive unless they have their eye on the ball."

Training for Industry 4.0

Advanced Manufacturing has been somewhat of a blind spot in higher education for some time, and Industry 4.0, which is still a brand new concept, isn't yet getting the attention it deserves.

"Advanced Manufacturing is a very viable option for people at the technician, engineering, and professional levels to consider," says Nager, who works with colleges and universities in North America that aim to create innovative, robust and effective advanced manufacturing curricula for their career and technical education programs. Festo equipment is increasingly being used in laboratories and classrooms in the U.S. and Canada to teach hands-on technical skills.

There are however slight shifts happening that signal a pending change. STEM (science, technology, engineering, and mathematics) programs – particularly engineering programs – throughout the U.S. and Canada are undergoing some soul-searching about their curricula and how well their courses are serving students in their post-graduation job searches, according to Nager, who is hearing from employers who crave more talent that has graduated from more holistic educational training.

"What I've heard time and time again is that they want the engineers to be able to form into teams," he says. Executives want their employees to know how to communicate with their bosses, with their team members, and

also with colleagues across disciplines. Mechanical and electrical engineers can no longer afford to remain in silos. They not only need to communicate well and work well together, but they also need to work with business colleagues and those across the company. But, colleges often mirror these partitions with departments and degree paths that are equally disconnected. "There's a culture that has to be overcome," Nager says.

To help overcome that culture, it's vital to bridge the gap between industry and the academic sector. "This is not strong enough," says Lichtenberger. Four-year institutions in North America tend to approach practical training in a different way than do high schools or two-year colleges. There's a need, according to Lichtenberger, for more focus on solution-driven training if there is to be a closing of the skills gap in advanced manufacturing. "Everything is global now, and everything is getting much more complicated," he says.

Where the technological innovation space, in which mobile apps and start-ups receive so much attention, is both saturated and high-risk, advanced manufacturing is just as innovative, and it actually changes the world. It's essential, according to Lichtenberger, to consider the truly impactful rather than focusing exclusively on the most hyped.

There's a need, according to Lichtenberger, for more focus on solution-driven traning if there is to be a closing of the skills gap in advanced manufacturing.

In an increasingly-complicated economy, young people and those seeking to change careers need to be trained for tomorrow's jobs in "smart" factories, where workers need to both understand how each element of the production apparatus work, and also have the confidence and skill set to embrace change and "disruptions."

"In the past, you had a technician telling the machine what to do and how to do it and coordinating everything. In the future, it will be the other way around," Lichtenberger says. "The machine will tell the worker what he or she is supposed to do."

The future will not be the stuff of science fiction, where robots displace human workers, however. There is a growing need for skilled workers. By 2020, advanced manufacturing practices will create 2.1 million new jobs, says the World Economic Forum.[23] Many of those jobs will require new skills such as managing and interpreting the data that "smart" factories gather on a perpetual basis. That data can point to areas that need to be retooled or overhauled, as well as to aspects of production that are proving very successful.

While all these aspects of Industry 4.0 have not been fully realized, "we have to prepare our students and workers very early in their careers," Lichtenberger says.

The Holy Grail here, if the technology and talent can match up, is an increase in flexibility in production. Previously, according to Lichtenberger, companies had to make a tough decision at a fork in the manufacturing road: opt for mass-producing low cost products, or instead customize single pieces, that come with a higher price tag.

Consumers who could afford the latter got just what they needed at an expensive price, while those with more limited means had to tailor their needs to what was already mass produced, even if it literally didn't fit. "With Industry 4.0 and all the communications and smart technology, they can be low cost and still be very flexible," Lichtenberger says.

Nager agrees. "The advantage for the consumer is that you'll be able to pay the same – or close to the same – price for the customized products as you do for the mass-produced products," he says.

By handing the decision back over to the customer, Industry 4.0 delivers what the customer wants to buy rather than what best suits the manufacturer to make, according to Nager, although the new paradigm also helps manufacturers deliver the customized products much more cheaply. One example of how this works is monitoring energy use.

"Imagine a plant that has a variable energy cost that's not fixed at a certain number of cents per kilowatt hours. It actually varies during the day depending on how much load there is and how much the utilities are providing," Nager says. Skilled employees can curate and analyze all of that information and know exactly what it costs to make a particular item. High-energy operations could be moved to off-peak times if the factory is sufficiently flexible.

"The result might be a couple of percentages of savings on cost, which in the manufacturing industry is huge," Nager says.

Given the interdisciplinary and multidisciplinary nature of the changes that are already occurring, it's a ripe time for higher education to partner with industry – particularly those that are pioneering in the Industry 4.0 space – to ensure that tomorrow's workforce is ready for the challenges of tomorrow's workplace.

Case Study: Students Learn in Cyber Factories at University of Southern Indiana

The reactions that Daniela Vidal, the director of opportunity development at the University of Southern Indiana, gets from industry leaders and other guests that she leads on tours of the university's Cyber Physical (CP) Factory speak for themselves.

Visitors who see the equipment – eight modules, each of which has different components that perform specific manufacturing processes – are "blown away," according to Vidal. "They are very excited. A lot of times we get comments like, 'Oh. I wish I was back in school.'"

The CP Factory, which the university purchased from Festo Didactic in 2012 and which Festo is helping the university use to train students and faculty in advanced manufacturing, can be used to teach a wide variety of skills, to both beginner and advanced students. The lab, according to Vidal, has an automated storage retrieval system, a robot, a press, a drill, and a system that helps check for quality control. There are screens and controls on both sides of the modules, so students can surround the equipment and work on different tasks simultaneously.

Visitors who see the equipment are "blown away," according to Vidal. "They are very excited. A lot of times we get comments like, 'Oh. I wish I was back in school.'"

The equipment, which the university purchased with federal grant monies, has actually proven more advanced than industry in the region, where companies tend to operate very traditionally. "They say they need it. They say they want it all the time," Vidal says, but local companies haven't yet afforded their employees enough time to train in advanced manufacturing. She plans to spread awareness among those businesses.

"We have a very mature manufacturing base here. We are one of the oldest, most mature manufacturing bases in the country," she says.

It doesn't bother Vidal at all that higher education is being cast in the role not only of training students, but also of teaching industry. In fact, she sees that as a vital role for higher education. "The university should be the one helping our industry see what the rest of the world is doing," she says. "We are in the forefront helping industry advance."

There's been particular interest from the local naval base, which is also a federal research lab, and Vidal is seeking grant money to produce a mobile Industry 4.0 truck that can go to rural areas and spread the gospel of advanced manufacturing to people who aren't sufficiently aware of its potential and growth.

"The idea is not just to upgrade and modernize the established industry, but we are also pushing for entrepreneurial activity," she says.

Vidal, who has an extensive background in LEAN manufacturing, selected the Festo equipment in 2012 after a 2010 trip to Germany, where she was drawn to the flexible modules that she saw at the University of Stuttgart.

The University of Southern Indiana was starting a new program at the time, which built on existing advanced manufacturing and industrial supervision programs (both four-year) in the Engineering Department. There was also a new facility under construction at the time which became the Applied Engineering Center. Funding from the U.S. Department of Energy helped construct the automation lab.

One of the most impressive features of the lab, Vidal says, is its flexibility, which reflects real needs in industry. "You need to be able to move the equipment around to be able to serve your flow, and not the other way around," she says. And because each of the modules has a single plug, which controls power, air, and all the utilities, combined with the RFID chips on the carriers that direct the part to the machine based on instructions that can easily be changed, they system is very flexible indeed.

"You can unplug the modules and reconfigure them in a different layout to maximize throughput or to address bottlenecks, and all you have to do is plug it back in. It takes five minutes," Vidal says. "Then you can run the simulation again and see what effect it has on production rates and quality." That students don't need to reprogram the modules each time makes the lab even more user-friendly.

Vidal is excited to better implement the modules and automation training into both junior- and senior-level courses, as well as graduate-level curricula.

"This is something that we can use in at least seven or eight different classes, from engineering to advanced manufacturing and industrial supervision to our Master of Industrial Management and even our Master of Business Administration, which has a class called decision sciences," she says. "This equipment is very helpful in taking something that's only been done in theory and giving students the ability to see it in practice."

And to those in industry who are still skeptical of the paradigm shift, Vidal is prepared to present a business case for change.

"It's not a pie in the sky or going after the next fad. It's real. It's tangible," she says. "Here's the path for your business to upgrade and pivot to survive in this new economy."

An Evolving Space with a Bright Future

As is always the case with cutting-edge developments, there will be some false starts, many evolutions, and plenty of rapid change. New technologies and new products are surfacing regularly, and Industry 4.0 is certainly in a state of evolution.

For companies looking to adopt Industry 4.0 and colleges and universities educating students for these advanced manufacturing jobs, the time is ripe for a more earnest, committed, and creative "handshake."

"Extremely close collaboration between industry and education is needed, because what is needed in industry is changing almost on a monthly basis," Lichtenberger says.

There have always been those in industry and in education who have done a poor job of reading crystal balls. Many denounced the printing press, and even more came late to the realization of the Internet's significance. There have been countless examples in between, and there will be many more. At risk for both industry and higher education in the U.S. and Canada is seriously underestimating a major revolution due to an inability to overcome an outdated culture that too often stigmatizes manufacturing.

Extremely close collaboration between industry and education is needed, because what is needed in industry is changing almost on a monthly basis," Lichtenberger says.

Many North American parents consider it taboo to send their children to college to study manufacturing. "Very often, the image of manufacturing from the broader population in North America is that it's dirty and that it's not really desirable for young people to go into," Lichtenberger says. It would be a squandered opportunity, with widespread implications, if North America can't look over the Atlantic and learn from the positive image and reputation that advanced manufacturing has had in Germany.

In January 2015, the authors of the McKinsey article surveyed 300 manufacturing leaders, and found that just 48 percent considered themselves ready for Industry 4.0. Among suppliers, 78 percent felt prepared, according to the authors. Those numbers will continue to shift, which leaves employers and colleges and universities with a choice: Do they want to be early adopters, or do they want to have to undergo radical change down the road to catch up with those who have left them behind?

Works Cited

[1] Cornelius Baur and Dominik Wee. "Manufacturing's next act." June 2015. McKinsey & Company. Url: http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

[2] Cornelius Baur and Dominik Wee. "Manufacturing's next act." June 2015. McKinsey & Company. Url: http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

[3] Cornelius Baur and Dominik Wee. "Manufacturing's next act." June 2015. McKinsey & Company. Url: http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

[4] Smart Manufacturing Leadership Coalition. "Implementing 21st Century Smart Manufacturing: Workshop Summary Report." June 24, 2011. Url: https://www.smartmanufacturingcoalition.org/sites/default/files/implementing_21st_century_smart_manufacturing_report_2011_0.pdf

[5] Accenture. "Are you ready for Digital Industry 4.0?" Url: https://www.accenture.com/us-en/digital-industry-index

[6] Daniel Burrus. "The Internet of Things Is Far Bigger Than Anyone Realizes." November 2015. In WIRED. Url: http://www.wired.com/insights/2014/11/the-internet-of-things-bigger/

[7] White House press release. "President Obama Launches Advanced Manufacturing Partnership." June 24, 2011. Url: https://www.whitehouse.gov/the-press-office/2011/06/24/president-obama-launches-advanced-manufacturing-partnership

[8] Charles W. Wessner. "How Does Germany Do It?" November 2013. The American Society of Mechanical Engineer. Url: https://www.asme.org/engineering-topics/articles/manufacturing-processing/how-does-germany-do-it

[9] Chase Gummer. "Behind Germany's Success Story in Manufacturing." June 1, 2014. In Wall Street Journal. Url: http://www.wsj.com/articles/behind-germanys-success-story-in-manufacturing-1401473946

[10] U.S. Department of Commerce press release. "U.S. Secretary of Commerce Penny Pritzker Discusses Importance of Advanced Manufacturing at 2016 Hannover Messe Economic Forum." April 24, 2016. Url: https://www.commerce.gov/news/secretary-speeches/2016/04/us-secretary-commerce-penny-pritzker-discusses-importance-advanced

[11] Source: http://www.fraunhofer.de/en/about-fraunhofer/profile/facts-and-figures.html

[12] Bill Lydon. "Industry 4.0: Intelligent and flexible production." May/June 2016 URL: https://www.isa.org/intech/20160601/#sthash.MrefM2I6.dpuf

[13] PwC. "Industry 4.0: Building the digital enterprise." April 2016. Url: http://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[14] PwC. "Industry 4.0: Building the digital enterprise." April 2016. Url: http://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[15] PwC. "Industry 4.0: Building the digital enterprise." April 2016. Url: http://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[16] Reinhard Geissbauer, Jesper Vedsø, and Stefan Schrauf. "A Strategist's Guide to Industry 4.0." May 9, 2016. In Strategy + Business. Url: http://www.strategy-business.com/article/A-Strategists-Guide-to-Industry-4.0

[17] Anthony P. Carnevale, Nicole Smith, Jeff Strohl. Georgetown University Center on Education and the Workforce. "Help Wanted: Projections of Jobs and Education Requirements Through 2018." June 2010. URL: https://cew.georgetown.edu/wp-content/uploads/2014/12/fullreport.pdf

[18] National Schools Coaliton. "Congress Should Invest in Adult Basic Education" fact sheet. 2016.

[19] 2013 Lumina/Gallup study. "What America Needs to Know About Higher Education Redesign." Url: https://www.luminafoundation.org/news-and-events/today-s-business-leaders-say-it-s-what-you-know-not-where-you-go-when-making-hiring-decisions-new-study-shows

[20] Jeff Selingo. "The Future of Learning for Our Careers is Up to Us." March 28, 2016. On LinkedIn. Url: https://www.linkedin.com/pulse/future-learning-our-careers-up-us-jeff-selingo

[21] James Bessen. "Employers Aren't Just Whining – the "Skills Gap" Is Real." August 25, 2014. In Harvard Business Review. Url: https://hbr.org/2014/08/employers-arent-just-whining-the-skills-gap-is-real/

[22] Deloitte and the Manufacturing Institute. "The Skills Gap in U.S. Manufacturing: 2015 and Beyond." 2015. Url: http://www.themanufacturinginstitute.org/~/media/827DBC76533942679A15EF7067A704CD.ashx

[23] World Economic Forum. "Five Million Jobs By 2020: the Real Challenge of the Fourth Industrial Revolution." January 18, 2016. URL: https://www.weforum.org/press/2016/01/five-million-jobs-by-2020-the-real-challenge-of-the-fourth-industrial-revolution/