Defining Industry 4.0 for Community Colleges

Creating Connections in Manufacturing Communities with Community Colleges initiative Capstone Report

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The "Creating Connections in Manufacturing Communities with Community Colleges" initiative (Creating Connections) was implemented as a way to help community colleges address the changing technological advances of the manufacturing industry. With support from the Arconic Foundation, the American Association of Community Colleges (AACC) and the National Coalition of Advanced Technology Centers (NCATC) are honored to present our findings from the Creating Connections work. This toolkit is designed to highlight lessons learned from the cohort of community colleges engaging with this project, showcase promising practices, and highlight resources for other community colleges and industry partners to adapt in their own communities. The lessons learned from the pilot community college cohort can be leveraged into other programs and communities to help advance the community college work.

Project Overview:

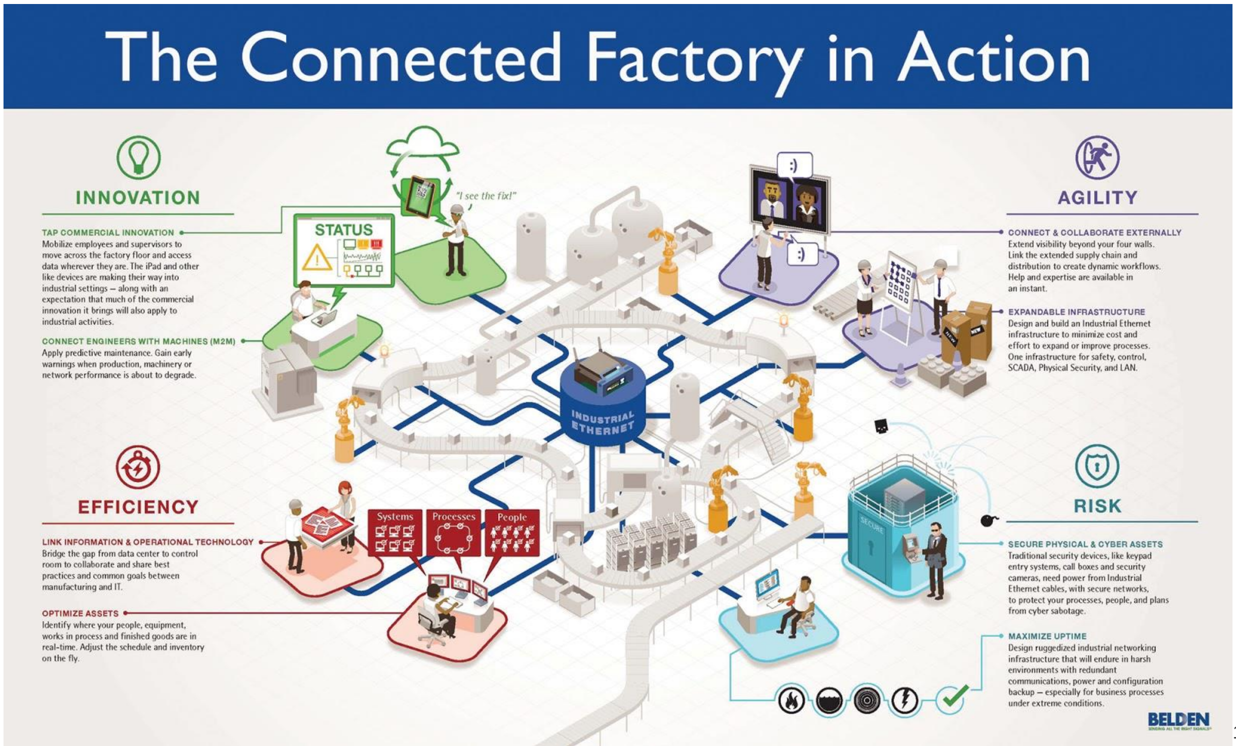
The Creating Connections initiative was designed to expand the industry connections and tactical applications for community colleges in the manufacturing industry. Over the course of nine months, AACC and NCATC provided customized technical assistance to nine community colleges to improve the processes for education and training on behalf of the employment pipelines for Arconic communities through asset identification, community preparation, and alignment. The community colleges involved in the Creating Connections initiative were:

- Cuyahoga Community College, Ohio
- Eastern Iowa Community Colleges, Iowa
- Grand Rapids Community College, Michigan
- Ivy Tech Community College, Indiana
- Lorain County Community College, Ohio
- Pellissippi State Community College, Tennessee
- Reading Area Community College, Pennsylvania
- Thomas Nelson Community College, Virginia
- Westmoreland County Community College, Pennsylvania

Colleges that were part of the initial pilot cohort were provided technical assistance through two in-person convenings, peer-to-peer calls with other cohort members, webinars with subject matter experts, and monthly check-ins calls. Colleges had the overarching objective to better incorporate support the integration of Industry 4.0 into their existing advanced manufacturing programs, and improve industry relationships in their respective communities. Through this project colleges also connected with national networks. AACC and NCATC partnered on this project to tap into their respective networks of community college members and subject matter experts. This pilot project showed that community colleges are well equipped to train program participants and fill the skills gaps in smart manufacturing. All of the cohort colleges had some existing manufacturing programs at their community college. All nine of the cohort colleges noted they had at least a course related to mechatronics and/or cyber security being offered at their college. Eight of the colleges offered at least one course in robotics and/or additive manufacturing. The most prevalent issues preventing community colleges were the ability to define Industry 4.0, find qualified faculty to teach classes relating to Industry 4.0, funding for smart manufacturing equipment, and curriculum development. The first task for this pilot was to identify the most appropriate definition of Industry 4.0 and collectively agree to the boundaries of the definition amongst those invested, and then apply that definition.

Defining Industry 4.0:

Industry 4.0 is the Fourth Industrial Revolution. This revolution is often characterized as "smart manufacturing" and the connectedness of cyber-physical systems. Industry 4.0 touches 11 areas across manufacturing and IT including, autonomous robots, additive manufacturing, Industrial Internet of Things (IIOT), artificial intelligence (AI), augmented reality (AR), simulation, systems integration, cloud computing, big data analytics, cybersecurity, and mechatronics. This wide array of focus areas touch all aspects of a factory floor. Through this pilot project, AACC and NCATC have developed a glossary to help build a common nomenclature with buy-in from industry representatives and community colleges on Industry 4.0. (*see Appendix B*)



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One of the greatest promises of Industry 4.0 is its potential to improve the quality of life for the world's population and raise income levels. Our workplaces and organizations are becoming

[1] https://www.belden.com/

"smarter" and more efficient as machines, and humans start to work together, and we use connected devices to enhance our supply chains and warehouses. There may be increased socioeconomic changes brought by the Fourth Industrial Revolution that could create a job market that is more segregated into “low-skill/low-pay” and “high-skill/high-pay” segments. Some jobs will become obsolete. Additionally, the changes may develop so rapidly, that even those who are ahead of the curve in terms of their knowledge and preparation, might not be able to keep up with the ripple effects of the changes. Industry will need to work to address many issues brought forth with Industry 4.0 by:

1. Focusing on regional engagement to better support the business, education, and government fields address the lacking common and clear understanding of what Industry 4.0 means to their respective industries.

2. Working to identify a common nomenclature as terms such as “smart factories”, “smart manufacturing”, and “smart automation” are synonymous with Industry 4.0, but the adoption of those terms creates varied understanding. Term choice typically varies by organizational culture - like it has with the term “mechatronics” for well over two decades. This will need to be addressed.

3. Observations through this work has shown that some industry partners show a lack of awareness of what Industry 4.0 means for their company’s future. The skills gap in advanced manufacturing remains a big issue for manufacturing employers, and these employers are not sure how to regularly engage with their local community colleges to address these issues.

4. Identifying where to begin incorporating Industry 4.0 into their manufacturing facilities remains a challenge. Companies should consider what their biggest threats to production efficiency are and security, narrow in on one area, and begin there. It would be very challenging and costly to change every piece of equipment, job description, and process at the same time. Start small with one area of the company.

5. Investing in workforce training with community and regional partners. Community colleges can address the skills gap needs with the support of industry. They can partner financially, by providing subject matter expertise, equipment, hosting apprentices, and serving in advisory capacities.

These industry-wide challenges are important to identify and address within workforce development programs at community colleges.

Challenges facing community colleges:

After defining common nomenclature and definitions in regards to Industry 4.0, the cohort of community colleges looked to begin implementation. Like many of their industry partners, community colleges were not sure where to begin and sort through all of the information around

Industry 4.0 to provide programs that would be equitable, accessible, and relevant. Each college looked into their existing programs to identify where any existing work being done as it relates to smart manufacturing on either credit or non-credit. This ranged from a module within a single course to associate degrees in cybersecurity. Many colleges chose to start with integrating into their mechatronics programs.

Community colleges educate approximately 41% of the undergraduates in the United States.[2] With over 1,100 community colleges across the country, higher education and training through community colleges remains highly accessible to many employer partners. However, one of the main challenges identified through the Creating Connections initiative, is that community colleges struggled to identify the exact Industry 4.0 needs of their partner employers. The cohort colleges had existing employer partners and industry advisors. Tapping into these networks, they were tasked to inquire specifically for their Industry 4.0 training needs. For community colleges to successfully begin integrating Industry 4.0 into their programs, community college executives will strategically need to address:

1. Instructor training – College leadership is often lacking a clear understanding of what requirements are needed for the faculty to move their college's existing and new programs forward. Colleges may want to partner with industry to "loan" qualified employees to the college to teach courses.

2. Equipment procurement – The latest equipment remains expensive, even with discounts offered distributors and industry partners. The ability to identify and secure funding to support the purchase of equipment to train a class of students remains a challenge. In addition to looking for grant opportunities, colleges should look into ways to share equipment amongst local colleges or industry partners.

3. Interdisciplinary cooperation – Many colleges have programs that have overlapping components on both the credit and non-credit sides. Industry 4.0 requires overlap amongst multiple specialties, such as IT and manufacturing, which are often housed in different departments at a college. Cross-functional teams must be created to drive these programs.

4. Curriculum development – As Industry 4.0 continues to evolve at a rapid pace, the length of time required for colleges to get approval before implementing new curriculum proves challenging to keep up with the pace needed by industry. Some colleges have begun implementing changes in non-credit programs first as the timeline can be implemented more quickly in the interim.

5. Where to begin? – Similar to what we heard from industry partners, community colleges are not sure where to begin to implement Industry 4.0. Many of the

[2] https://www.aacc.nche.edu/research-trends/fast-facts/

cohort colleges began with evaluating their mechatronics program, or adding a capstone course to an existing program.

Stories from the field:

Cuyahoga Community College (Tri-C) located in the heart of downtown Cleveland, Ohio used the project to continue refinement of their already merged Industry, Manufacturing, and Engineering departments to help better organize these three departments more tightly around Industry 4.0 / Smart Manufacturing. They are working on creating a roadmap to integrate industry 4.0. and will host an employer engagement session on January 10, 2019 to continue shaping, refining, and validating their current and future workforce needs in Smart Manufacturing. Their mechatronics program with partners Amatrol, Siemens, and Arconic Foundation remains strong and their cybersecurity program in computer science is strong, as well. They are planning to add IIOT to mechatronics through an Amatrol course and Cisco Industrial Cybersecurity certification for both incumbent workers and pipeline students. Tri-C will also be developing a full Smart Manufacturing Associates Degree for launch in 2020 based on this project involvement, their own advanced programs, the newly emerging Smart Automation Certification Alliance (SACA) competencies and standards along with regular industry engagement.

Eastern Iowa Community Colleges (EICC) acknowledged that Industry 4.0 landscape changes at a rapid rate and college leaders need to remain flexible to adapt to those changes, which means college, industry, and community leaders need a clear understanding of what Industry 4.0 is. Industry 4.0 will affect all aspects of the workforce and not just the technicians. It will affect decision-makers, managers, system design, maintenance, and Human Resource professionals, which is why Eastern Iowa is looking into creating community training courses for community members to better understand this changing industry. They are continuing to expand their apprenticeship programs and look for new ways to integrate Industry 4.0, including utilizing SACA. This project inspired both their credit and non-credit departments to work more tightly together on all curriculum, courses, programs, and certificates / degrees that are influenced by Industry 4.0. The Creating Connections project helped EICC expand their partnerships with national networks and industry partners, including with the Hope Street Group.

Grand Rapids Community College (GRCC) in Michigan set the project goal to gain an understanding of what Industry 4.0 is and what that can look like on their college campus. They are working on creating a roadmap to integrate industry 4.0. This program has forced collaboration amongst 3 programs: manufacturing, electrical, and computer science within the 60 credit boundary. This validated what all three programs have been hearing from employers. Their mechatronics program remains strong and their cybersecurity program in computer science is strong. Looking to transfer that into advanced manufacturing. They are going to add IIOT to mechatronics through an Amatrol course. Computer science network IIOT with Cisco industrial certification. Through this program they added two labs to their robotics course around Industry 4.0. Employers are not a homogeneous group. They all want something a little different, so it is challenging to understand what specifically they are looking for. They are considering developing a 3 credit course on Industry 4.0. GRCC shared there is a big value in making sure Industry 4.0 expands beyond one individual. There are many stakeholders at the college that need to be well informed, and work together across departments.

Ivy Tech Community College (Ivy Tech) located in Indiana used the project to elevate the Industry 4.0 related programs already in place and is thrilled that “Manufacturing is Cool Again!” Ivy Tech is implementing several different phases of Smart Automation and will be one of the pilot sites for the new SACA program in Indiana. They have already begun merging their HCAC, AG, Manufacturing and IT departments toward a much more collaborative approach and this Industry 4.0 project during 2018 has helped connect many more dots along this important journey. In addition, Ivy Tech has added 3D-Printers across their state at the K-14 levels with an even higher level of High School integration of Industry 4.0 content planned for 2019/20. Finally, Ivy Tech will continue to use the additional connections, suppliers, and colleges discovered in the Arconic Foundation project to integrate even more systems across the board and offer more certificates to students that employers desire and need.

Lorain County Community College (LCCC) located in Elyria, OH thirty minutes from downtown Cleveland, Ohio partnered with Tri-C and used the project to elevate the Industry 4.0 related programs already in place – like MEMS, Cyber security, Advanced Manufacturing and Robotics. LCCC is also working on creating a roadmap to integrate Industrial Internet of Things (II0T) into current certificates and degrees. LCCC will also be developing a full Digital Manufacturing Associates Degree for launch in 2019 based on this project involvement, their own advanced programs, and continued industry engagement. Additional focus areas for LCC are innovative delivery methods, work-based learning models (internships, apprenticeships, etc.) and their new BS degree in MEMS technology for technicians and technologists.

Pellissippi State Community College (PSCC) used their participation in Creating Connections initiative to boost their efforts in their community by creating more effective conversations and relationships with employers in their community, and reconnected with employers such as Arconic. Big data analytics will remain a priority area for them as they look to integrate more Industry 4.0 components into their existing programs, however their next step is to create a cyber security capstone course as part of their existing advanced manufacturing programs. The timing of this program proved valuable as PSCC develops plans to turn their MegaLab into a hub for smart automation and look to build continued and new partnerships to support that goal.

Reading Area Community College (RACC) benefited from having national industry and higher education leaders validate the importance of Industry 4.0 to their college. They have worked on building out a new certificate program focused on IIOT that will be launched in 2019. RACC found great value from this project in promoting collaboration and sharing of promising practices amongst the cohort. Moving forward, they will continue to work with their industry advisory panel to validate curriculum, will look to partner with more SMEs. One of the many observations made, was that there is not a clear roadmap “to get to Industry 4.0” for colleges, nor industry.

Thomas Nelson Community College (TNCC) used the Creating Connections project as an opportunity to teach some of their faculty about Industry 4.0 by having them take a lead role in this project. This inspired the faculty to also get out in the community and reengage with their employer partners to establish stronger, mutually beneficial relationships. Through this project, TNCC has been able to connect with national industry representatives such as Siemens and Festo, to help them conduct internal evaluations of their labs and upgrade their equipment and curriculum.

Westmoreland County Community College (WCCC) is located just outside of Pittsburgh, PA. Their industrial mechatronics program has continued to grow and evolve with Industry 4.0. WCCC has developed key partnerships with national organizations such as Siemens to help support their approach to support data driven manufacturing. They have recently partnered with the Massachusetts Institute of Technology (MIT) in Boston, MA on a national grant to help support program expansion in Boston in advanced robotics. The Creating Connections project has helped WCCC gain a better understanding of the industry. They have developed new curriculum to build a non-credit to credit program in Industrial Mechanics. As a result of this project, WCCC is investing in professional development for their staff, administrators, and faculty by hosting workshops on campus to share an understanding of Industry 4.0 and help support better collaboration between college departments and with community partners. Moving forward, WCCC will continue to focus on student recruitment and expand their mechatronics program.

In supporting the cohort of colleges, AACC and NCATC helped connect colleges with many SMEs outside of the cohort. The cohort heard presentations from representatives from the University of Hawai'i Community Colleges and Front Range Community College in Colorado on defining the Internet of Things (IOT). The cohort also had a chance to connect with administrators from Gateway Technical College in Wisconsin on their work to better integrate Industry 4.0 to quickly meet the changing workforce needs that a large employer, Foxconn, requires as they move to the region. As a result, Gateway Technical College has launched two new degrees: an associate degree in Advanced Manufacturing Technology which integrates an 8 credit certificate in Introductory Industry 4.0, courses in IIOT, mechatronics, robotics, etc.; and an associate degree in Supply Chain Management which requires courses in robotics, and programming. In addition, Gateway Technical College is working within their community to integrate advanced manufacturing pathways in K-12.

What's next for community colleges and industry?

The cohort colleges have shown that there is a need for community colleges to better define Industry 4.0 in their communities and that work is already being done across the nation to address this. The Creating Connections project showed there is national demand for skilled workers in smart automation. The cohort colleges have continued this work Community colleges are well positioned to address this need. Next steps for colleges wanting to begin incorporating Industry 4.0 into their curriculum:

1. Reach out to local employers and discuss what Industry 4.0 or smart automation means for their changing workforce needs.

2. Take an audit of what Industry 4.0 components are already being taught across the college and where they are housed at the college.

3. From there, determine which existing curricula can be leveraged or updated across departments and form interdisciplinary teams.

4. Continue to monitor new and emerging certifications from Industry partners such as the SACA certification that can be integrated into courses.

It is important that colleges understand they do not have to integrate every component of Industry 4.0 at once. They can start with one area of demand (such as cyber security) and build from there.

Additional resources:

In addition to resources shared through the AACC and NCATC networks, these additional resources may prove useful to support community colleges in incorporating Industry 4.0 components into their programs.

Understanding the industry workforce needs can help make the case for the need for investment in these types of programs. Deloitte's State of Manufacturing Report is an example of many reports that highlight the changing needs of the manufacturing industry. https://www2.deloitte.com/us/en/pages/manufacturing/articles/future-of-manufacturing-skills-gap-study.html?id=us:2el:3pr:skillgap18:awa:er:111418

New industry-recognized certifications will continue to pop-up and tracking those may prove useful. Credential Engine is one tool that can be used to help track which credentials various colleges are offering: https://credentialengine.org/

The U.S. Department of Commerce's National Institute of Standards and Technology Manufacturing Extension Partnership (NIST MEP)

https://www.nist.gov/

Smart Automation Certification Alliance (SACA) has launched a certificate in Industry 4.0

https://www.saca.org/

Appendix A

The primary goal of Arconic Foundation is to advance science, technology, engineering, and math (STEM) education and training worldwide, with a special emphasis on engaging and creating access for underrepresented and underserved groups. In addition, we are helping to change the perception of manufacturing by generating excitement around the rewarding career opportunities available to the next generation of talent. From career and technical education to the most advanced robotic and digital manufacturing disciplines, Arconic Foundation works with our nonprofit partners to give students an unprecedented view of the spectrum of STEM careers available to them. And our support helps provide the cutting-edge skills and hands-on experience that open doors to economic opportunity for individuals and communities around the globe. (https://www.arconic.com/foundation/)

The American Association of Community Colleges (AACC) is the primary advocacy organization for the nation's community colleges. The association represents more than 1,100 associate-degree granting institutions and more than 12 million students, nearly half of all undergraduates in the United States. AACC's Workforce and Economic Development Department unites community colleges, offices of economic development, workforce boards, labor market entities, employers, industry and other organizations to improve the economic prosperity of business, workers, and communities. AACC runs an average of 15 initiatives in its portfolio at any time; these initiatives have been organized on the basis of sector, geography, demographic, communities of practice, etc. (http://www.aacc.nche.edu/)

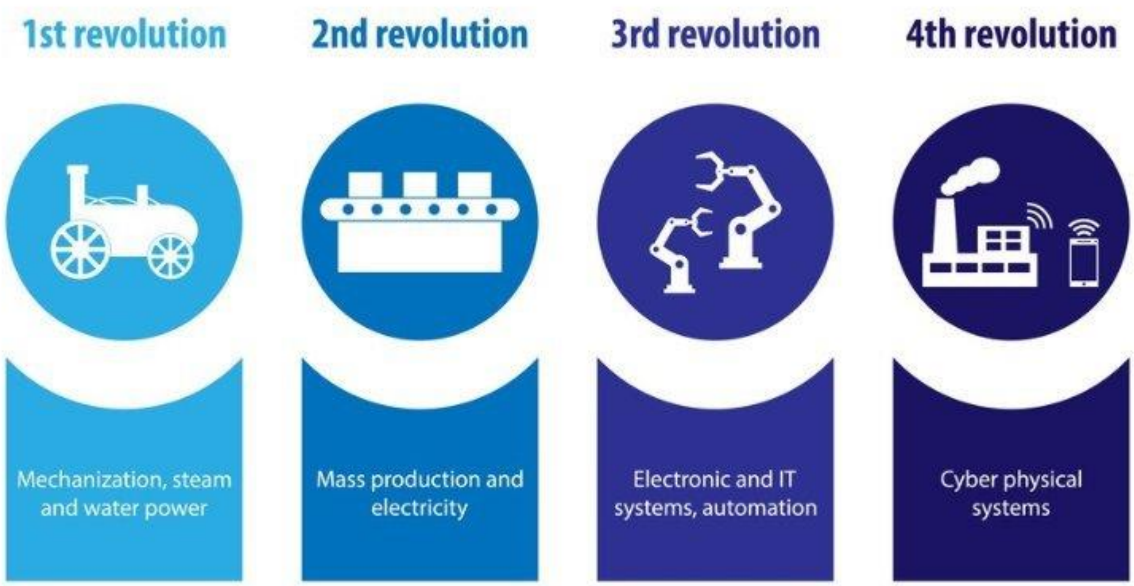
The National Coalition of Advanced Technology Centers (NCATC) has grown to over 170 member institutions including colleges, universities, and the corporate community across the United States and Canada. NCATC advocates and promotes the use of technology applications that enhance economic and workforce development programs and services. Advanced Technology Centers (ATCs) represent a commitment in the effort to reach, enhance, and add value to business. NCATC partners with members for the delivery of training and certificates, including areas such as advanced manufacturing, laser technology, and rapid prototyping/additive manufacturing. (http://www.ncatc.org/)

Appendix B

INDUSTRY 4.0 / SMART MANUFACTURING OVERVIEW & GLOSSARY

As a result of developments in the modern world, manufacturing is changing. This document is designed as a tool to help create a common understanding and nomenclature for community colleges, students, and industry employers to have conversations regarding these new developments. This document defines Industry 4.0, gives real world examples of its application, and explains associated concepts such as Cloud Computing, Smart Factory, Internet of Things (IoT), Cybersecurity, etc.

The third revolution of manufacturing in the 20th century brought us continued innovation in technology such as robots, IT, etc. Its systems have helped revolutionize productivity. Today, these types of systems are commonly known as "traditional manufacturing". The 21st century has brought continued technological improvements to move advanced manufacturing towards integrating Industry 4.0.



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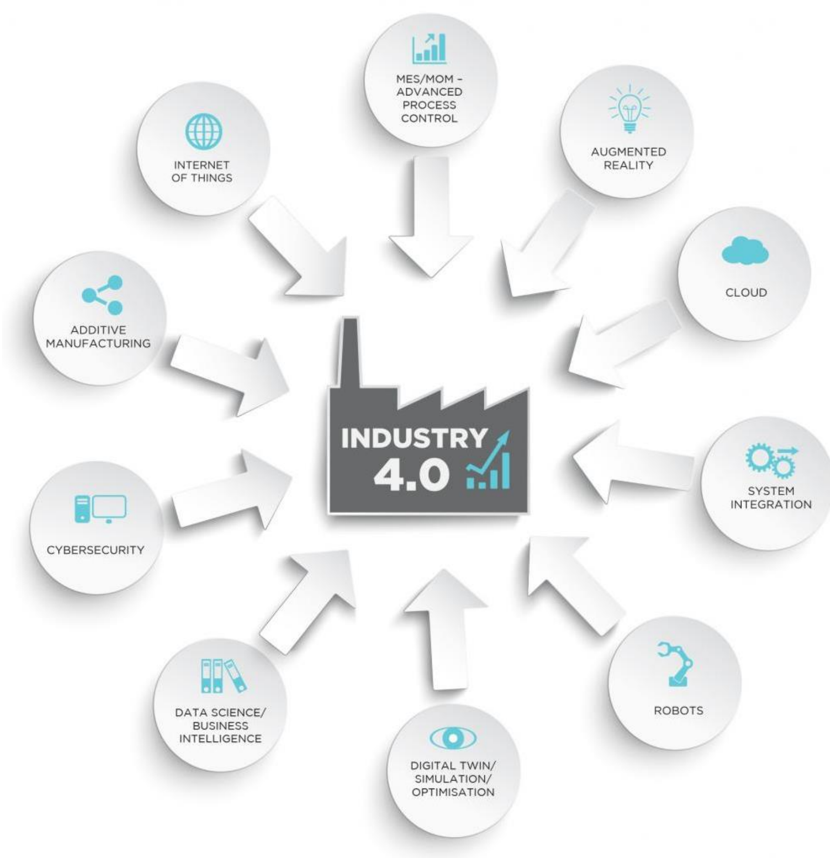
Industry 4.0 / Smart Manufacturing - The 4th Industrial revolution is about digitally interconnecting all components on a factory floor including, sensors, software, and data analytics. The application of "machines talking to machines". Within smart factories, cyber-physical systems monitor physical processes using a virtual copy of the physical world to make decentralized decisions. Over the Industrial Internet of Things (IIOT), these cyber-physical systems communicate and cooperate with each other, while at the same time humans must also monitor and make decisions across organizations.

Example from the field: A pilot facility, developed by The German Research Centre for Artificial Intelligence (DFKI) in Kaiserslautern, Germany, is demonstrating how a "smart" factory can operate. This pilot facility uses soap bottles to show how products and manufacturing machines can communicate with one another.[ii] Empty soap bottles have RFID tags attached to them, and these tags inform machines whether the bottles should be given a black or a white cap. A product that is in the process of being manufactured carries a digital product memory with it from the beginning and can communicate with its environment via radio signals. This product becomes a cyber-physical system that enables the real world and the virtual world to merge.



[iii]

Industry 4.0 has been driven primarily by 4 phenomena:

1) a rise in the volume of data readily available;
2) computational power and connectivity;
3) emergence of analytics and business intelligence capabilities – e.g. new forms of human-machine interaction such as touch interfaces and augmented-reality systems, and
4) improvements in transferring digital instructions to the physical world.

Industry 4.0 – Why should you care about this?

With the use of computers, automation and cloud technology, factories are becoming increasingly efficient and “smart”. Industry 4.0 is the latest phase for the manufacturing sector which has come about because of the Internet of Things and the accessibility of data. Factories that are known as “Smart Factories” are becoming more prominent, particularly in Europe and the U.S. The terms “Smart Factory,” “Smart Manufacturing,” “Intelligent Factory” and “Factory of the Future” all describe a vision of what more intelligent, flexible and dynamic industrial production will look like in the future. Manufacturing processes will be organized differently, with entire production chains – from suppliers to logistics to the life cycle management of a product – closely connected across corporate boundaries. Individual production steps will be seamlessly connected. These changes to production design will impact almost all aspects of the company such as, factory and production planning, product development and design, logistics, enterprise resource planning (ERP), manufacturing execution systems (MES), control technologies, and parts procurement. In a Smart Factory, machinery and equipment will have the ability to improve processes through self-optimization and autonomous decision-making. This is in stark contrast to running fixed program operations, as is the case today with traditional manufacturing.

Annaliese Kloe, Managing Director of Headland Machinery explains that “Industry 4.0 is being spoken about everywhere. In particular, it was widely reflected at EuroBLECH 2016. It will widely change the approach to the way that manufacturers work, so if you aren’t looking into this now then you’ll be left behind. It will revolutionize your business, so it is vital to get on board.”[iv] With an increasingly digital future ahead of us, this new era for manufacturing looks set to transform businesses worldwide. It is imperative for manufacturers to consider new technologies arising and explore how they can adapt their processes to comply with the expectations of the modern world and educators ensure the workforce is prepared to meet these changing requirements.

Glossary

Internet of Things (IoT) – The concept of connecting any device with an on and off switch to the Internet (and/or to each other)[v]. This includes everyday items from cellphones, coffee makers, washing machines, headphones, lamps, or wearable devices to components of machines, such as, a jet engine of an airplane, or the drill of an oil rig. The Industrial Internet of Things (IIOT) is a subset of IOT focusing specifically on the industrial application of IOT[vi]. IIOT opens opportunities in automation, optimization, intelligent manufacturing and smart industry, asset management, industrial control, moving towards an on-demand service model, new ways of servicing customers and the creation of new revenue models, the more mature goal of industrial transformation. IIoT is creating the potential benefit from the connection and integration of data from Information Technology (IT) systems and the data center with data from Operational Technology (OT) on the factory floor and connected devices.

Example from the field: At FANUC, IIoT, organizations across the globe can continuously monitor and infer equipment status, health, and performance to detect issues in real-time. Predictive maintenance analytics captures the state of industrial equipment, so you can identify potential breakdowns before they impact production. Not only can production outages cost millions of dollars but replacing broken equipment can costs tens of thousands of dollars in extra expenses.[vii]

Additive Manufacturing – is a process that uses a variety of machines that use technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete, etc. to build the product. The advantage to additive manufacturing compared to the more traditional, subtractive manufacturing - where items are created by cutting away at excess material to form the shape needed - is that additive manufacturing allows for less waste in raw material. 3D printing is another synonym commonly used to describe additive manufacturing.[viii]

Example from the field: Here is an example video showing the layering process: https://www.youtube.com/watch?v=rEfdO4p4SFc

Cloud Computing – Cloud computing means storing and accessing data and programs over the Internet instead of your computer's hard drive[ix]. This allows for easily shared information across multiple machines. There are multiple types of applications that are used in business and access through cloud computing. For example,

Example from the field: A business chose to implement a Software-as-a-Service (SaaS) application and now utilizing cloud computing, can access it remotely and securely through the Internet.

Big Data Analytics – this principle refers to a phenomenon where companies use software analyze and organize large volumes of data in search for trends and functional information. In Industry 4.0, circulation, collection, and analysis of information is a necessity because it supports productivity growth based on a real-time decision-making process. Machines and systems connected to the production plant (as well as other operational systems) must be able to collect, exchange, and save these massive volumes of information in an autonomous and secure way and without the need of human intervention.

There are four types of big data that really aid business[x]:

1. Prescriptive – This type of analysis reveals what actions should be taken. This is the most valuable kind of analysis and usually results in rules and recommendations for next steps.
2. Predictive – An analysis of likely scenarios of what might happen. The deliverables are usually a predictive forecast.
3. Diagnostic – A look at past performance to determine what happened and why. The result of the analysis is often an analytic dashboard.
4. Descriptive – What is happening now based on incoming data. To mine the analytics, you typically use a real-time dashboard and/or email reports.

Example from the field: With the huge amounts of data emanating from various digital sources the importance of analytics has tremendously grown and allows companies to improve business performance through analytics, manage large amounts of data, and provide better insights for decision-making in a timely fashion.[xi]

Cybersecurity – With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential. As the role of technology in corporate operations grows, security vulnerabilities—data theft, leakage of intellectual property, corporate sabotage, denial-of-service attacks—are growing.

Example from the field: The damage from cybersecurity attacks can affect a company's profits, reputation, brand, and competitive position. The damage can even affect a company's viability, as direct costs for data breaches can reach hundreds of millions of dollars.

Autonomous Robotics – Robots that perform behaviors or tasks with a high degree of autonomy. Some modern factory robots are "autonomous" within the strict confines of their direct environment.[xii] Autonomous robots, although they may not require as much hands-on operation to complete its assigned tasks, also lack varying degrees of freedom to adapt to their surrounding environment. The factory robot's workplace is challenging and can often contain chaotic, unpredicted variables that workers still need to address as the autonomous robots are not capable of making those decisions.

Example from the field: Robots designed to weld together two pieces of machinery can adjust the pieces into the correct position, move them along the line, and make slight adjustments within their programming. However, humans are still needed to set up and program the robots, and to inspect the end product to make sure it is meeting the necessary standards.

System Integration – is the process of integrating all physical and virtual components of an organization's system.[xiii] This includes horizontal and vertical integration of information systems beyond Computer Integrated Manufacturing (CIM) – which is the process of using computers to control the entire manufacturing process – of the 1990s[xiv]. Regardless of the varying industries such as utilities, manufacturing or transportation, companies want to get more from their existing assets and are retrofitting existing systems to include system integration. With Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains.

Example from the field: Total systems integration experts like Siemensxv provide solutions for all industries including, but not limited to Transportation, Energy, Manufacturing, Healthcare, and many more. See this short video for examples:
https://www.industry.siemens.com/topics/global/en/tia/reference-videos/pages/system-integrator.aspx

Simulation – This is the capability to perform virtual prototyping and automation in manufacturing industries is critical as industries seek to reduce the time moving through each engineering phase.

Example from the field: Siemens[xvi] demonstrates a simulation model during this short video clip: https://www.youtube.com/watch?v=HUayvHqQulE

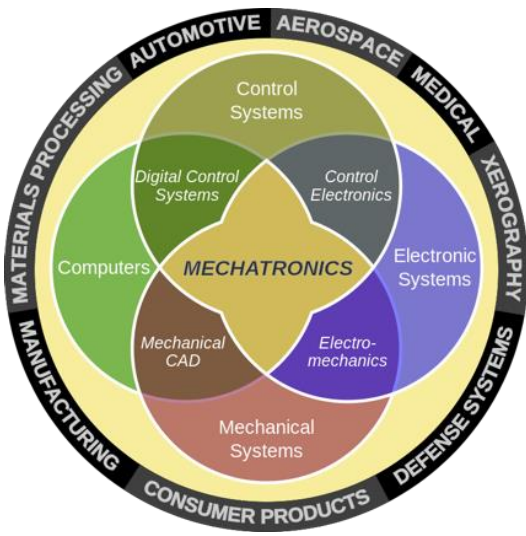
Artificial Intelligence (AI) – describes the ability of machines to imitate human mental prowess and make decisions. AI has multiple applications in Industry 4.0 including, machine s, software, and IOT. Machines, including robots, can be fitted with electrical circuits and electronic chips for control and command. Software programs are not programmed for pre-determined functions alone, the software will also contain a feedback or loop design to facilitate learning and adaptation. With IOT, hooking the AI system to the cloud is very useful for workers to perform refined data analytics, adaptive research, and real-time communications[xvii].

Example from the field: Today, there are scores of machine learning algorithms in use that sense, think, and act in a variety of different applications. Yet many of these algorithms are considered "black boxes," offering little if any insight into how they reached their outcome. Explainable AI is a movement to develop machine learning techniques that produce more explainable models while maintaining prediction accuracy - https://www.cc.gatech.edu/~alanwags/DLAI2016/(Gunning)%20IJCAI-16%20DLAI%20WS.pdf [xviii]

Augmented Reality (AR) – is a technology that layers computer-generated enhancements atop an existing reality in order to make it more meaningful by allowing the user to virtually interact with it.[xix] It allows companies to provide workers with real-time information to improve decision making and work procedures by blending digital components with the real world.

Example from the field: AR can support manufacturing in a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. Mitsubishi has used this technology to confirm maintenance procedures with the manual[xx].

Mechatronics – Mechatronics is a multidisciplinary field of science involving the analysis, design, synthesis, and selection of systems that combine electronics and mechanical components with modern controls and microprocessors.[xxi] Mechatronics' aim is a design process that unifies these subfields.



[xxii]

Example from the field: There have been rapid changes and improvements in the fields of electronics, computer and control systems over the last years. As a result of this, computer-controlled systems have been in increase in almost every field. The number of “only mechanically operating systems” is very few. Therefore, the design, production and maintenance of advanced products are no longer a single subject. It has become a must to use mechanics, electrics and electronics, hydraulics and pneumatic and computer technologies together. Mechatronics ranges from home technologies to advanced medical devices and from computer-controlled benches to robots.[xxiii]

The application fields of Mechatronics can be illustrated as follows:

- Control Systems (position, level, pressure and heat control systems…)
- Robots (transport and welding robots)
- Industrial Automation (barcode systems and production belts)
- Building Automation (security systems, automatic air conditioning and automatic door systems)
- Home appliances (washing machines and dish washers)

- Automotive (air bag, antilock braking system)
- Defense Industry (mine detection robots, automatically guided vehicles)
- Medical Applications (magnetic resonance, arthroscopic devices, ultrasonic probes etc.)
- Aeronautical Engineering (automatic pilots, unmanned aerial vehicles)
- Image and Sound Processing (automatic focusing devices, sound-operated devices)
- Production (Computerized Numerical Control -CNC, Numerical Control -NC)
- Laser optical systems (barcode)
- Intelligent measuring devices (calibration devices, testing and measuring sensors.)

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