World Manufacturing Forum
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THE 2019 WORLD MANUFACTURING FORUM REPORT

SKILLS FOR THE FUTURE OF MANUFACTURING

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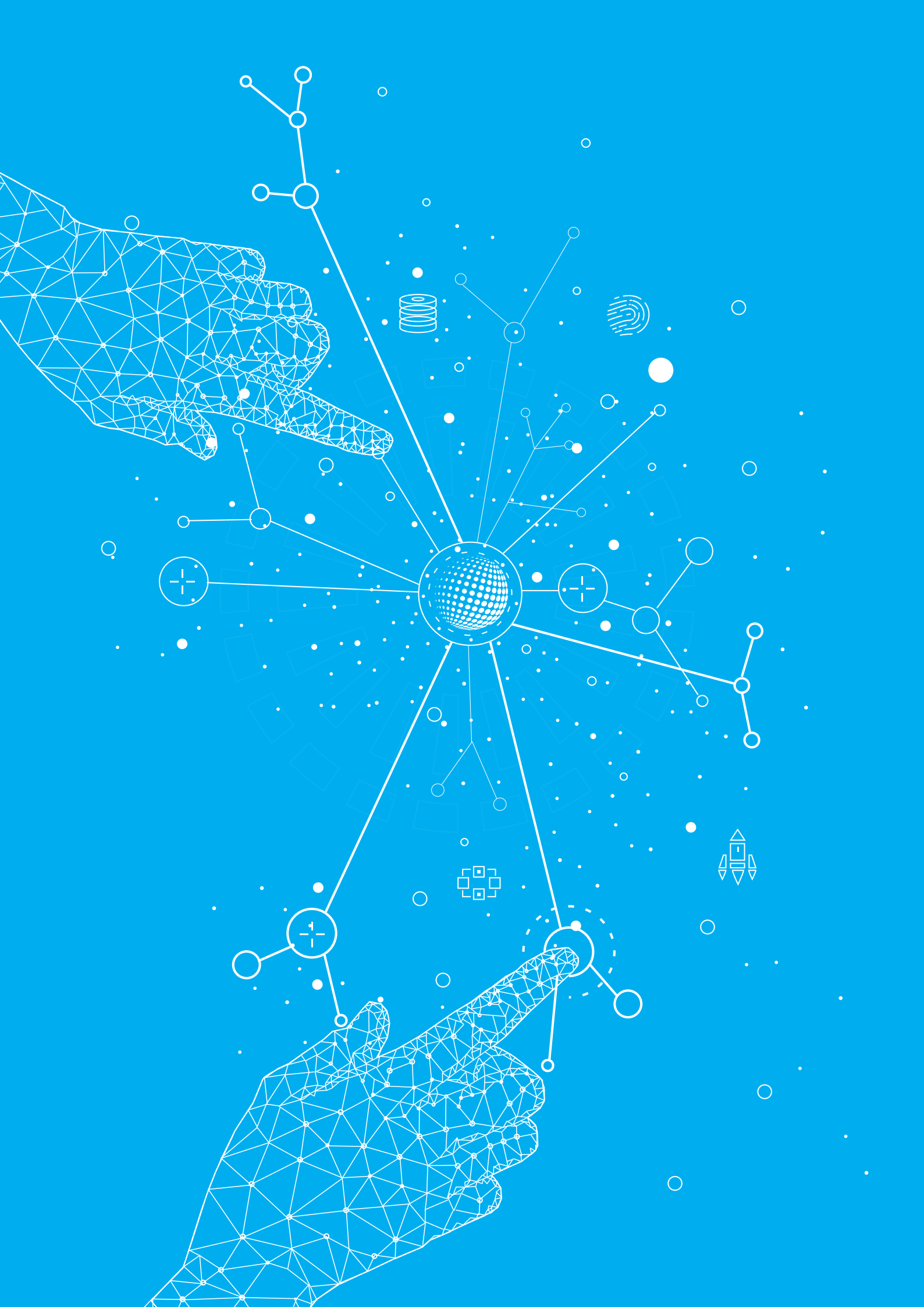

Foreword

Dear Readers,

The *World Manufacturing Forum (WMF) Report* series was first published in 2018 to discuss the most important themes in manufacturing and present *Ten Key Recommendations* to promote societal prosperity through socially aware and sustainable manufacturing growth. In the 2019 WMF Report, we have decided to focus on workforce skills development, one of the key recommendations identified in last year's Report.

The skills gap phenomenon is one of the most pressing issues faced by the industry today, reinforcing the need for industries to evolve in light of new technologies brought upon by rapid digitalisation in manufacturing. In addition, societal megatrends such as ageing workers compound the complexity of tackling the skills challenge, increasing the need for more creative solutions.

This whitepaper will analyse in detail the evidence, underlying causes and consequences of the skills gap phenomenon in manufacturing. It will also bring attention to the key skills that will be increasingly required in the manufacturing of the future and highlight the importance of skills assessment and development.

One important contribution of the *2019 WMF Report* is the identification of *Ten Key Recommendations* that can be adopted by different stakeholders such as policymakers, educators and industry leaders among others to foster workforce skills development through education and training and other lines of action.

We hope that this document will increase awareness on this timely issue and stimulate high level debates among different stakeholders leading to the development of policies and initiatives that encourage skills development in the manufacturing workforce.

In line with this, the topics and key recommendations covered in the report are discussed extensively at the *WMF Annual Meeting* held yearly in Cernobbio, Italy. Continuing its role as a platform that brings together different stakeholders to discuss the most important developments in the sector, the *WMF Annual Meeting* will bring global attention to the importance and relevance of the skills gap phenomenon and the need for extensive cooperation to tackle this industry-wide challenge.

In the coming years, the WMF will continue its efforts to produce research and analysis of key trends in the sector, and develop recommendations that appeal to the broadest group of manufacturing stakeholders. This is consistent with our goal to spread industrial culture worldwide, achieved by inspiring and shaping national and international agendas, and thereby promoting prosperity for all. We invite our stakeholders to partake in this important mission.

The 2019 WMF Editorial Board

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Executive Summary

The *2019 World Manufacturing Forum Report: Skills for the Future of Manufacturing* aims to explore in detail the skills gap phenomenon widely felt in the sector, identify the top skills needed by manufacturing workers, outline the main mechanisms in skills assessments and development, and finally, propose key recommendations to promote an educated and skilled manufacturing workforce.

The rapid pace of technological innovation is continuously changing the skill sets required to effectively perform roles within manufacturing. The lack of, and inability to acquire the necessary skills and competencies amplify skill gaps in workers and as a result, the industry is having increased difficulty in finding the necessary talent to fill manufacturing roles.

The *2019 WMF Report* will examine the key evidence regarding the existence of skill gaps such as changing jobs in manufacturing, lack of required skills among workers, difficulty in finding talent, and the trend in STEM degrees. It will then analyse key underlying causes of the skills gap such as the introduction of advanced technologies and automation, challenges in the education system, disconnect between companies and institutions, lack of efficient training programmes, misperceptions of manufacturing jobs, demographic trends such as ageing population, and the lack of versatile skill sets in workers. The impacts of the skills gap on competitiveness of the sector and society will then be discussed in detail.

The *2019 WMF Report* will outline the *Top Ten Skills for the Future of Manufacturing* that the WMF believes will be increasingly relevant for workers to stay competitive in the years to come. The list of skills has been developed through the inputs of global experts and analyses of published reports and literature. The skills have been identified keeping in mind the particularity of manufacturing and are intended to apply to a wide group of workers within the sector.

Identifying skills and competencies creates the impetus to identify the mechanisms to assess and develop those skills. The *2019 WMF Report* will outline the importance of skills assessments and the need for sustainable Human Resource Management (HRM) strategies in companies. It will examine the phases of the skill cycle, identify the key characteristics of an effective skills assessment and outline different skill assessment techniques and tools which could be adopted by manufacturing companies.

Acquiring new skills and competencies require inventive approaches and collaboration among different actors. While approaches such as outsourcing and novel recruitment methods are prevalent, the *2019 WMF Report* focuses on training and education to develop the skills and competencies in the manufacturing workforce. Different mechanisms will be identified such as educational design, use of technology to improve learning outcomes such as digital learning platforms, mobile learning, virtual and augmented reality and learning factories. Interventions to ensure the participation of older workers, women and other lesser-represented groups will also be discussed.

Finally, the *2019 WMF Report* proposes key short and long-term recommendations that can be adopted by governments, educational and training providers, companies and manufacturing workers to promote a skilled and educated workforce. Through these recommendations developed with global experts, the World Manufacturing Forum aims to bring attention to key actionable items necessary to ensure that workers are equipped with the skills and competencies in the manufacturing of the future.

The *2019 WMF Report* aims to highlight the importance of workforce training and skills development, influencing national and international agendas to develop and enact policies that promote these causes.

Project Methodology

The inaugural *World Manufacturing Forum Report,* first published in 2018, discussed the key megatrends and challenges affecting the manufacturing sector, outlined the WMF's vision of future manufacturing, and proposed key recommendations to promote globally resilient manufacturing.

The *2019 World Manufacturing Forum Report: Skills for the Future of Manufacturing* focuses on one of last year's key recommendations: *Promoting Education and Skills Development for Societal Well-Being*. The topic was chosen after thorough consultation with industry leaders, educators, and high-level policy makers, and was selected thanks to its significance and wide-ranging implications for the manufacturing sector.

To determine the structure and develop the content of the report, an extensive review of existing literature on the topic of skills development has been undertaken. The reports analysed include scientific journals, publications from consultancies, governments, NGOs and industry associations published within the last five years. To develop the content of the report, the Editorial Board also worked alongside an Advisory Board, an international committee which provided strategic feedback on the report's structure and content. It is composed of senior high-level individuals from universities, industry, associations, and other organisations.

Expert interviews are an integral part of developing the report content and most importantly the *Ten Key Recommendations* proposed by the WMF. The experts interviewed come from multinational companies and SMEs, industry and trade associations, international organisations, governmental and non-governmental organisations and renowned universities and research organisations. Expert interviews aim to increase the authority of the report ensuring that the views of the most important stakeholders in manufacturing are reflected.

Experts are selected based on their perceived knowledge and competencies as evidenced by their publications or roles within their respective organisations. Many experts interviewed come from roles or organisations that have a distinct focus on workforce skills development.

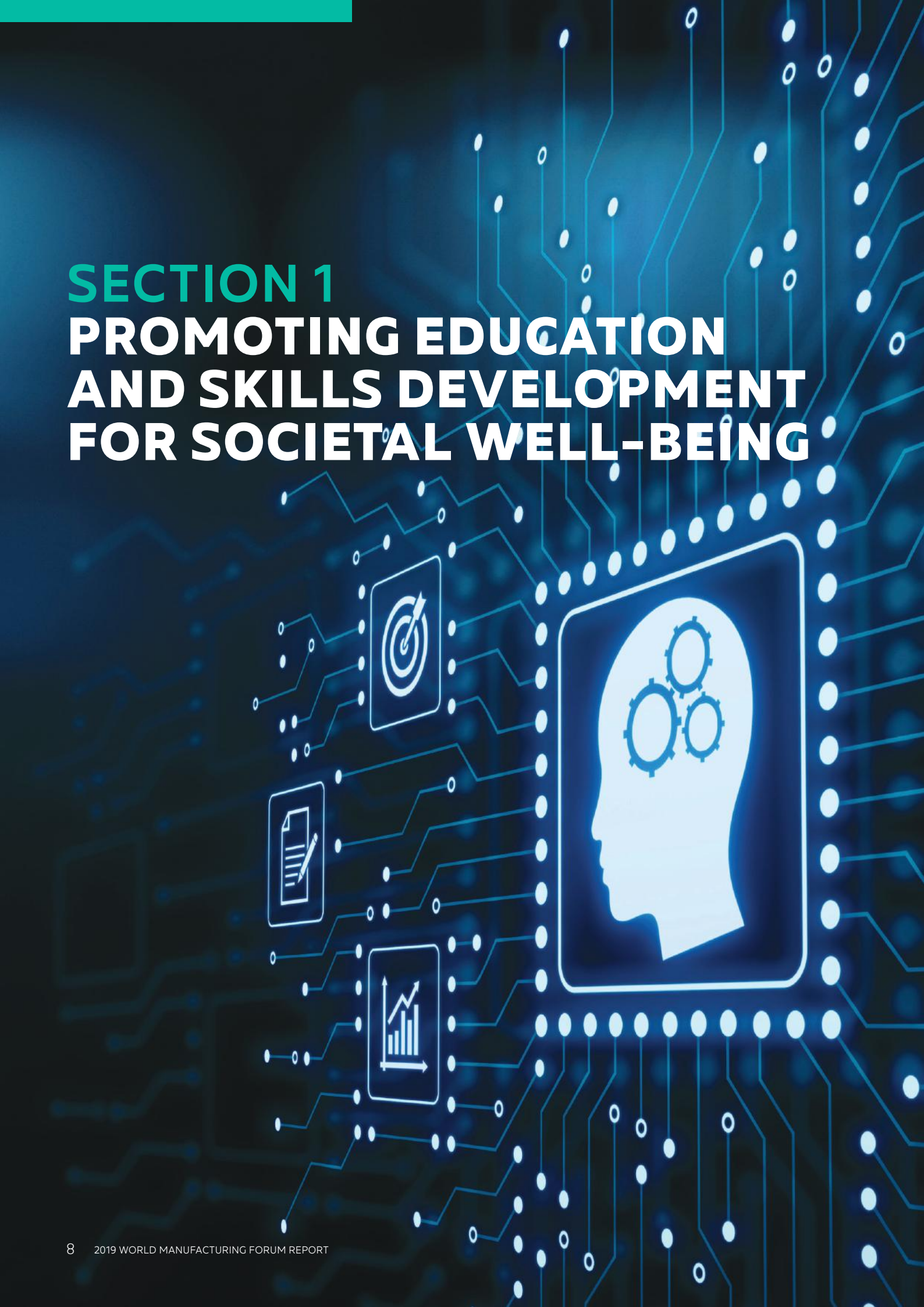
Expert interviews take the form of a phone call in which experts were asked to answer questions related to specific sections covered in the report. Most importantly, experts were asked about their key short and long-term recommendations to promote a skilled manufacturing workforce as well as a list of top skills they believe will be increasingly required in the manufacturing of the future.

Some experts also agreed to write case studies to highlight what particular organisations are doing in the area of workforce skills development.

In addition to case studies and essays provided by different contributors, the WMF also launched an open call to collect the best initiatives on skills for the future of manufacturing to highlight interesting initiatives on skills development from all over the world. A selection of initiatives has been selected and is featured in the section *WMF Open Call for Initiatives on Skills for the Future of Manufacturing*.

Thanks to strong collaboration between the WMF Advisory and Editorial Boards as well as a high-level international group of experts, the *2019 WMF Report* aims to provide an accurate and unbiased discussion of the skills gap phenomenon and propose recommendations that encapsulate the beliefs of a wide range of manufacturing stakeholders.

SECTION 1
PROMOTING EDUCATION AND SKILLS DEVELOPMENT FOR SOCIETAL WELL-BEING



The *2019 WMF Report* seeks to deepen the research and discussion on the topic of skills and education in manufacturing to help drive the world towards greater societal well-being in the wake of the changing manufacturing paradigm.

In the 2018 edition of the *WMF Report*, expert interviews of manufacturing leaders and stakeholders proved that promoting education and skills for societal well-being should be a priority for manufacturing community. Consistently, the WMF Editorial Board received feedback that skills and workforce development were of the utmost concern to manufacturing stakeholders. The WMF promoted this view by including it in the 2018 *Ten Key Recommendations* and urging nations and stakeholders to think critically about their education and skills platform and how to best develop the current and future workforce. Given the importance of this recommendation and the overwhelming feedback from manufacturing experts, the *2019 WMF Report* seeks to deepen the research and discussion on the topic of skills and education in manufacturing to help drive the world towards greater societal well-being in the wake of the changing manufacturing paradigm. Most importantly, education and skills help to bolster competitiveness and drive innovation, which in turn leads to scientific progress. Without skilled workers and proper educational systems, companies and sectors are unable to advance and compete in a global market. While the *2018 WMF Report* provided a deeper look at the current state of manufacturing, this report will examine the strong link between skills, education, the workforce, and manufacturing.

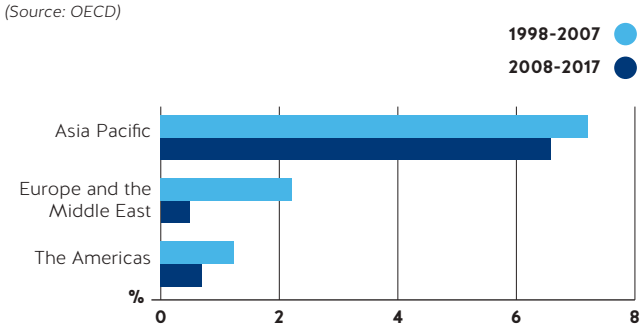
It is without doubt that manufacturing is in a time of great change and technological advancement. The so-called Fourth Industrial Revolution is moving manufacturing forward through technologies such as the Industrial Internet of Things (IIoT), Robotics, Automation, Artificial Intelligence (AI), Virtual and Augmented Reality among others. These new technologies are helping to advance manufacturing to unprecedented levels, allowing for highly technical, elaborate, and quality manufactured products and processes. However, with all of the added benefits of new technologies come equal challenges that the global community must work to overcome. The disruption caused by new technology calls for new, innovative solutions that result in a change to the skills and competencies that are required by manufacturers. Increasingly intelligent and technical machines and computers that are necessary to engage in the new era of manufacturing will require employees to understand and operate on an equally intelligent level. The skills necessary to excel in this new environment are rapidly switching from manual to cognitive based skill sets to manage intelligence systems such as robotics, AI, and advanced manufacturing.

As a consequence of the change due to advancements in manufacturing, there is a shortage of workers with the correct skills and competencies necessary to fill new roles. The Hays Global Skills Index, an annual assessment of trends impacting skilled labour markets, reported that regions such as Europe and the Middle East, Asia Pacific, and the Americas all have increased skill gaps and talent mismatches with no sign of improvement.[1] Growth in output is greatly slowing compared to that of a decade ago thereby decreasing productivity in companies due to a lack of skilled workers (See Figure 1). These statistics

Figure 1

GROWTH IN OUTPUT PER WORKER

(Source: OECD)



are indicative of a global skills shortage that is not only impacting workers and manufacturers but also the overall economic health of nations. With so much at stake, it calls into question what actions can manufacturing stakeholders take to help industry thrive while also helping workers and global economies.

These issues provided the basis for the WMF 2018 key recommendation to *Promote Education and Skills Development for Societal Well-Being*. Action is necessary to help navigate the changing landscape and to keep pace with innovation. In order to implement this recommendation, the approach is two-folded: the state of both future and current manufacturing workers require attention. On one hand, education must be improved to help train new students with relevant skills and to encourage students to pursue a future career in manufacturing. On the other, initiatives must be taken to help current workers make a shift in their skills and competencies in order to remain relevant and useful in this new era.

In order to help current and future students, it is important that nations promote and improve education programmes in order to meet new skills requirements. By changing learning subjects, techniques, and processes from the ground-up over time, educational systems will produce graduates better equipped with the skills and competencies necessary to fulfil needs in the manufacturing sector and other critical parts of industry. Educational programmes should consider highlighting skills such as digital literacy, an entrepreneurial mindset, emotional intelligence, communication and team-working. As discussed in chapter three, the skills needed today are vastly different from those that were needed a decade ago. As the list of skills necessary for the current manufacturing sector was being developed, it was striking how the list and what is needed has changed and evolved greatly due to new trends and technologies. These competencies will benefit students to be adept and agile in transitioning into emerging roles and working with rapidly changing technologies. Although some of these competencies highlight what may be traditionally considered “soft skills” and do not involve as much technical knowledge, they provide students with a foundational basis for thinking and reasoning which will allow them to learn the

"hard skills" and technical competencies of current times. In order for workers to stay relevant in the future, they must be able to adapt to rapidly changing technologies while modifying and adding to their technical knowledge with regard to future innovation. With these skills, students will become flexible future workers that are able to adapt and excel in order to work with new technologies and innovations. The machines and technologies that these students may begin to work on now will surely be replaced by more advancements throughout their career. It is no longer enough to learn one process or technology. Rather, students must prepare themselves to be exposed to constant change and learning within the manufacturing sector.

Universities and other academic institutions are also key players in updating and improving learning processes to meet new technology and market needs. Teaching methods must be updated to include new technology, critical core competencies, and new methods of teaching that incorporate technology as a medium of learning and other innovative mechanisms such as learning factories. By improving teaching at this level there will be better workers who have the skills necessary to work and manage twenty-first century technology. These changes not only need to be implemented at the secondary and university level but also in primary and lower schools. Technology is present in almost every facet of life, regardless of age. With the key role technology plays in society today, all students benefit from learning core skills that would in turn help them in a future manufacturing career.

In addition to promoting skills and education within formal educational settings nations are also well advised to promote and improve skills development in other areas. Vocational schools and informal learning environments are critical in helping to build up a skilled workforce that can meet market demands. These type of learning experiences can help to supplement more formal educational practices. Many new skills needed for emerging technologies are able to be taught in various educational settings that transcend the traditional classroom. In doing this, it is well advised that collaboration should be improved between educational institutions, industry, and industrial associations.

Further, skills development and education is recommended to be improved for current workers who need to advance and improve their skills to keep up with current technologies. Research on the future of jobs suggests that by 2030 almost half of current jobs will be gone and replaced by new positions due to changes such as automation.[2] With jobs and roles changing rapidly in the next decade, there also needs to be action in order to retrain and upskill workers to remain relevant in current markets. Programmes to help current workers understand and adapt to new technologies are highly recommended. This includes an intersection of manufacturing stakeholders from governments, industry and the educational sector. Additionally, due to the fast-changing pace of technology, life-long learning needs to be highlighted within the manufacturing community. Technology will only continue to progress at an accelerating pace and to be adequately prepared, workers will consistently need to learn and upskill themselves in order to keep pace with innovation.

Further, nations must also note that cannot solely focus on providing quality education experiences in order for workers to excel in the wake of the Fourth Industrial Revolution. National and local stakeholders will need to ensure they are retaining skilled workers in order to keep technological pace within certain regions. Key needs such as safe and enjoyable living environments are critical factors in attracting and retaining skilled workers. Without offering comprehensive benefits that elevate quality of life, nations can be at risk of losing qualified workers to other areas. Without a skilled workforce, nations risk not being able to embrace and adopt new technologies. Additionally, it is important to understand the differences in promoting skills and educational development with regard to areas that have specific sets of needs that need to be understood in context of accessibility and resources.

It is important to understand this recommendation in order to delve further into the topic of skills. From a large-scale manufacturing perspective, promoting skills and development for societal well-being is a key recommendation of the WMF and aims to help all nations succeed with an active and well-prepared workforce. This recommendation was one that resonated with many readers and WMF attendees in 2018. Through research, we have found that this still continues to be a pressing issue that is at the forefront of many manufacturing worries.

The goal of this report is to dive deeper into the reasoning behind the skills gap to understand where and why it is present by looking at statistical evidence. Next, skills need to be analysed in the context of this phenomenon to understand what is needed, what has changed and why. Finally, looking at the processes of skills assessments and then development provides a broader context to draw key recommendations that be used as an actionable list for stakeholders.

While there are many important and pressing topics that are a part of the global manufacturing community, workforce, skills, and development stood out among those that seemed most urgent. Simply put, while there are many things that must be addressed and considered in the manufacturing world, nothing is possible or made without people who know how to get the job done. Despite the technological advances, complex market trends, and other pressing considerations, manufacturing is still at its core about making things. To make things we must have people and we need the right people to continue our mission. This report aims to take a more in-depth look at this challenge and to provide more insight as to why this initiative is one that draws together the global manufacturing community. Though there is more work to be done- this topic allows for steps towards the future to work harmoniously for the betterment of our community and world.

Strategic Programme to Support Brazilian Industry in Digital Transformation

Luiz Eduardo Leão
Educational Technologies Manager, Vocational Training Unit, National Service of Industrial Training - Brazil

Frankwaine Pereira de Melo
Industrial Development Specialist - Vocational Training Unit, National Service of Industrial Training - Brazil

Marcello José Pio
Industrial Development Specialist - Studies and Prospective Unit - National Confederation of Industry - Brazil

Over the past decades, structural, technological, productive and organisational changes have affected the world of work and caused a significant restructuring of production flows. This phenomenon is set against a background of fast technological development aimed at increased productivity and competitiveness, and at creating an increasingly competitive and selective labour market. This can be observed based on the changes occurred since the Fordist model to current flexible production systems. In this context of constant change, the Brazilian manufacturing industry will incorporate a set of new technologies based on the concepts of the Industry 4.0, such as: 3D Scanner Equipment, Robot Handling Systems, 3D Printers, and Dry Machining Process. Such technologies will introduce a professional component that will generally require the full use of new soft skills, including: digital influence, service orientation, environmental and social perception, pattern recognition, critical thinking and improved technical skills, such as operations analysis, equipment selection, technological adaptations, equipment maintenance, and material resource management.

To help Brazilian industrial companies adapt to digital processes, SENAI works on two strategic fronts. One is related to identifying new job profiles using a specific method of prospective analysis that estimates the future need for qualified labour in the industry, according to technological and organisational changes over five, ten, and fifteen years, and to building new profiles through National Sectoral Technical Committees. The second front involves providing the required Vocational Training, Innovation and Technology solutions based on the challenges posed by this new industrial revolution, a programme called SENAI 4.0. This programme is divided into three steps that complement one another: Unveil 4.0, Take Action 4.0, and Connect 4.0.

In "UNVEIL 4.0," dissemination of Industry 4.0 concepts and "enabling" technologies are intensified through free courses, improvement courses and specialisation courses at www.senai40.com.br, where professionals and other interested parties have access to a portfolio of courses and consulting solutions. In addition, events such as seminars, congresses and meetings are also offered, with the participation of businesses of different sizes and industrial segments, to disseminate concepts and opportunities that will arise with the implementation of such digital transformation. In "TAKE ACTION 4.0," the programme will work directly with companies by diagnosing their maturity level and preparing a roadmap, with customised actions aimed at digital transformation implementation. For this step, over 1,500 consultants and researchers were trained and made available, and a network of eight-hundred Training Centres, twenty-five Innovation Institutes and fifty-seven Technology Centres was structured to allow effective programme assistance nationwide. Finally, in "CONNECT 4.0," environments are made available for companies to test their technologies, evaluate them and share results, disseminating knowledge on national scale, collaboratively with other businesses and institutions. This will allow players to gain a better understanding of how Industry 4.0 technologies are used, and have improved decision-making processes, focusing on improving business productivity.

Acting on both fronts, it focuses on identifying new Industry 4.0 skills and technologies, unveiling its concepts and making professionals and businesses aware of this challenge, offering new courses and technical improvement to such professionals, with customised maturity assessment, helping each business face this challenge according to their own reality, connecting everyone in a network, and sharing results and lessons learned will enable a promising and non-threatening future that will embrace dissemination of such an unavoidable industrial revolution that is already underway.

Managing Human Capital Investments in the Fourth Industrial Revolution
"Skills as Primary Assets"

Prof. David Romero,
Tecnológico de Monterrey, Mexico

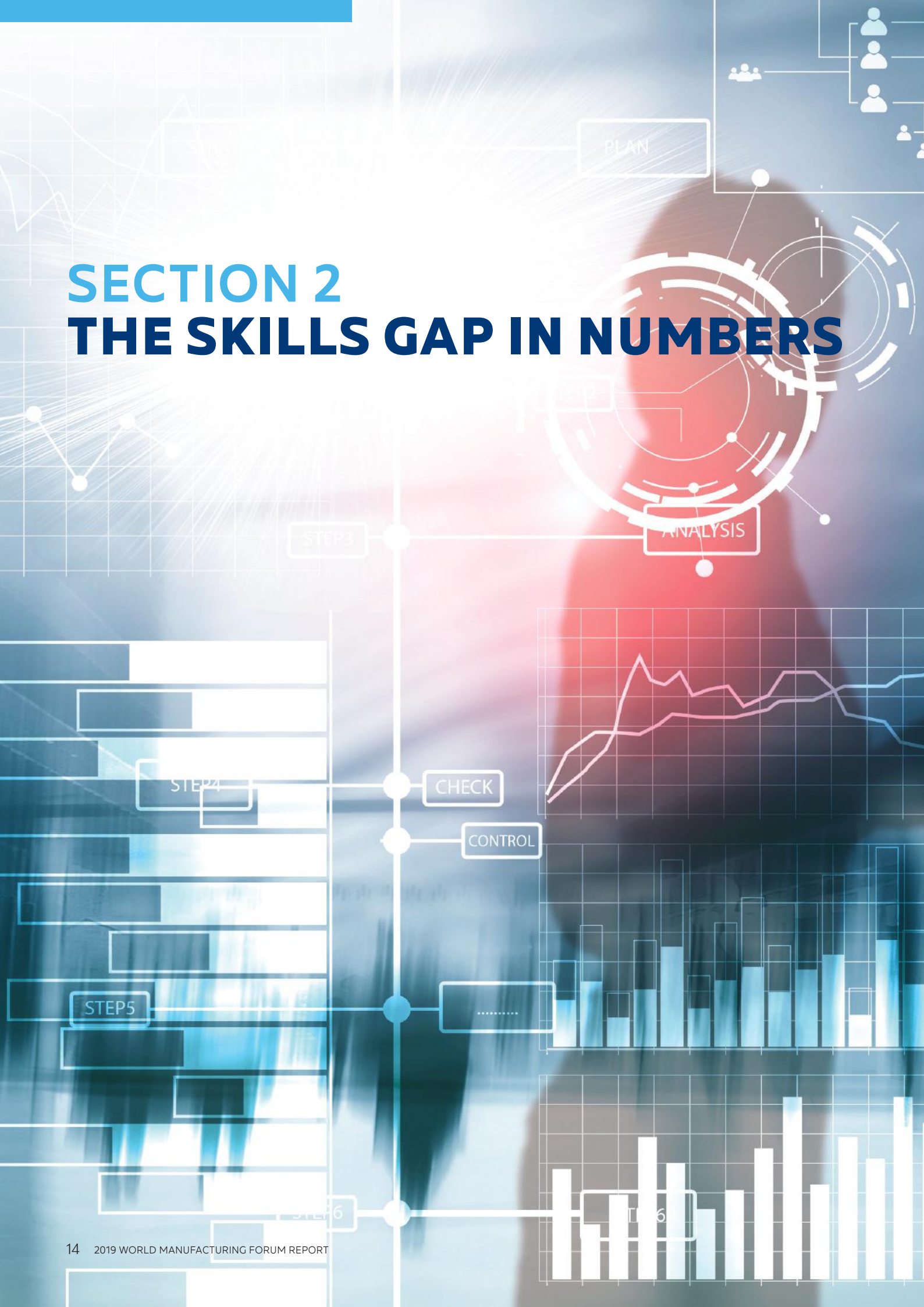
Prof. Johan Stahre
Chalmers University of Technology, Sweden

Human capital can be seen as a set of valuable knowledge, abilities, and skills carried by employees. This capital should always match the firm's investments in technology. Human capital is used in corporate activities that contribute to the creation of value for the success of the firm as well as of the employee. In the Era of Industry 4.0, human capital investments should be considered the most critical set of decisions and assets for the success of any organisation.

An organisation's capacity to absorb and leverage new technologies depends on the skills of its workforce. In order to continue to create sustainable value according to the emerging value creation paradigms, the workforce ability to recognise, assimilate, and refine the values in new technologies is what truly creates competitive advantages, not just technology acquisition. The key is the combination of human capital and technology. Thus, the absorptive capacity of any organisation and its workforce requires the strategic management of human capital. Are traditional human resources (HR) departments up to this task? They are now responsible not only for staffing the firm with the right skilled workers but they also need to foresee and plan for possible changes in human capital investment while the whole organisation is on a rapid digital transformation journey. Strong collaboration between HR, IT, and organisational decision-makers is required. Hence, Industry 4.0 technology adoption should not be relying on "silo" decisions, made by technical departments. Instead, strategic digital skills investments should strongly engage the HR department to proactively deal with present skill gaps or skills shortages in the corporate workforce that could limit the full exploitation of acquired technology capabilities. Reciprocally, recruitment and education decisions can easily derail a great digitalisation strategy, unless the HR staff deeply engage technical experts in the planning and execution of the hiring and reskilling processes.

In the Fourth Industrial Revolution, success will involve the strategic management of human capital to leverage a rapidly evolving technical development. Human capital investments are becoming expensive, as talent pools in areas such as Europe, the U.S., and China continue to shrink due to ageing workforces. Adding to the challenges, new skills are often required immediately in the labour market for fast-changing and new jobs. Policymakers and industry leaders have only recently realised that the current educational and training systems actually struggle hard to keep up with the rapid changes of the skills-threshold for the emerging Workforce 4.0. Consequently, organisations are facing several challenges such as finding a skilled workforce at the needed skill level and industry is often blaming policymakers and educators for lack of proactivity. This situation challenges HR departments to not just maintain their present workforce to meet current skills needs but to support continuous learning focused on future skills needs. Thus, HR departments need to anticipate the introduction of new technologies, requiring upskilling and reskilling programmes to be planned. Learning curves must also be anticipated to reap the benefits of new technologies and create competitive advantages using, for example, the Hyper-Cycle of Emerging Technologies. Roadmaps can also help to align and communicate technology adoption strategies linking market opportunities to corporate investments in human capital as well as in technologies.

In the coming years, the matching between investments in human capital and technical capital will be crucial. The economic and social sustainability of any firm will rely heavily on its ability to anticipate shifts in skill demands triggered by the Fourth Industrial Revolution. Strong internal collaboration between HR and IT/OT experts will be necessary to manage human capital. Maintenance of current workforce capabilities, as well as a long-term ability to acquire and develop the right skills for the future workforce, may be the best way for companies to stay competitive.



SECTION 2
THE SKILLS GAP IN NUMBERS

Throughout the next decades, the skills required for success in the manufacturing workplaces will be vastly different from those needed now due to the influence of new technologies and automation. In this context, defining skills of the previous era is necessary but they are no longer sufficient since, "manufacturing needs more skilled workers for new types of jobs."[3]

Skills are a Key Challenge for the Future of Manufacturing

According to a recent report from the National Association of Manufacturers (NAM), "...attracting and retaining a quality workforce is considered as one of the most important challenges of the current business landscape..." and more than twenty-five percent of manufacturers in the U.S. had to turn down new business opportunities due to a lack of workers during the first quarter of 2019 (See Figure 2). The most common response from companies when asked why there are not enough workers is that there is a fundamental skills gap and workers do not have a complete skill set in today's high technology manufacturing workplace.[4]

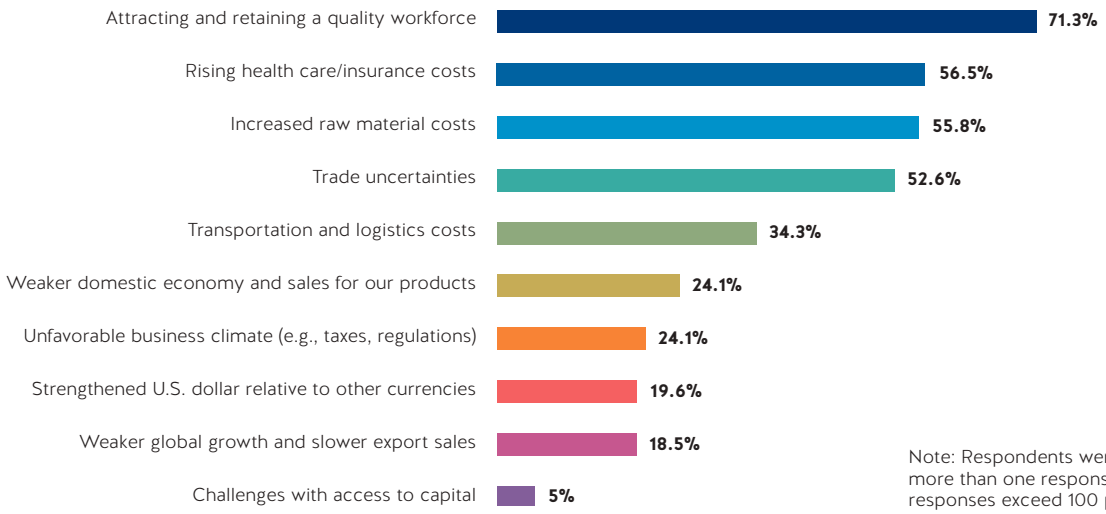
Furthermore, the European Investment Bank's 2017 Survey revealed that European firms find limited availability of skills to be a key investment impediment.[6] As shown in Figure 3, seventy-two percent of European companies find it to be an obstacle to investment, with a subtle increase compared to the previous 2016 EIB survey.[7]

The term *skill gap* refers to the difference between the actual skills possessed by the employees and the skills required on the job. In this regard, the skills gap provides both the employees and the company the opportunity to identify the missing skills and work to learn what is needed. Identifying skill gaps is essential for companies to ensure that the workforce is well-trained, knowledgeable and better equipped to perform the job. Therefore, a well-trained workforce equipped with the skills required to adopt AI technologies and automation will ensure that our economies enjoy strengthened productivity growth and that the talents of all workers are harnessed.[10]

Figure 2

PRIMARY CURRENT BUSINESS CHALLENGES, FIRST QUARTER 2019[5]

(Source: National Association of Manufacturers)

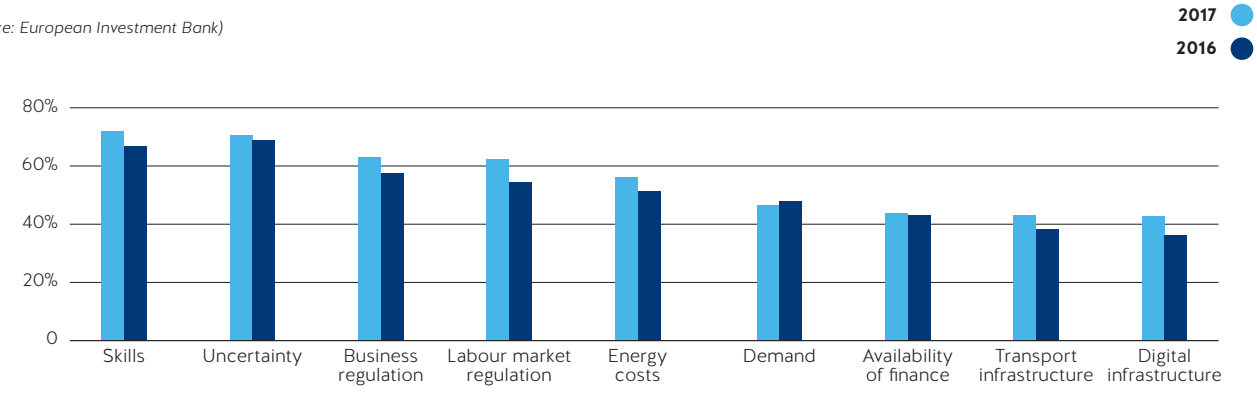


Note: Respondents were able to check more than one response; therefore, responses exceed 100 percent.

Figure 3

IMPEDIMENTS TO INVESTMENT IN COMPARISON (EU AVERAGE)[8] [9]

(Source: European Investment Bank)

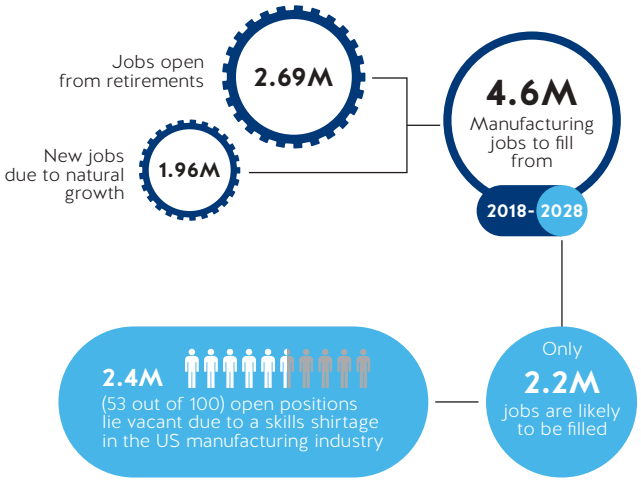


Therefore, it is of paramount importance for the manufacturing industry to address the problem of the skills gap phenomenon. To that end, in this section we will examine key messages concerning the skills gap, extracted from statistical research presented in the most recent and relevant reports all of which provide clear insights that will help to us better understand the evidences of the skills gap and its underlying causes as well as the impacts on business, economies, and society.

Figure 4

PROJECTION OF UNFILLED MANUFACTURING POSITIONS DUE TO SKILLS GAP

(Source: Deloitte & The Manufacturing Institute)



*Calculated on the basis of 52.7% of the skilled manufacturing positions that are unfilled (per the 2018 survey)
**Retirement age 66

EVIDENCE OF THE SKILLS GAP

This subsection highlights the fact that the skills gap exists, and illustrates evidence of changing jobs in manufacturing, lack of required skills, difficulty in finding talent, and an increase in STEM degrees and graduates as deterministic factors of skills gap.

The Future of Manufacturing Will Observe New Roles and the Skills Gap Will Continue to Widen

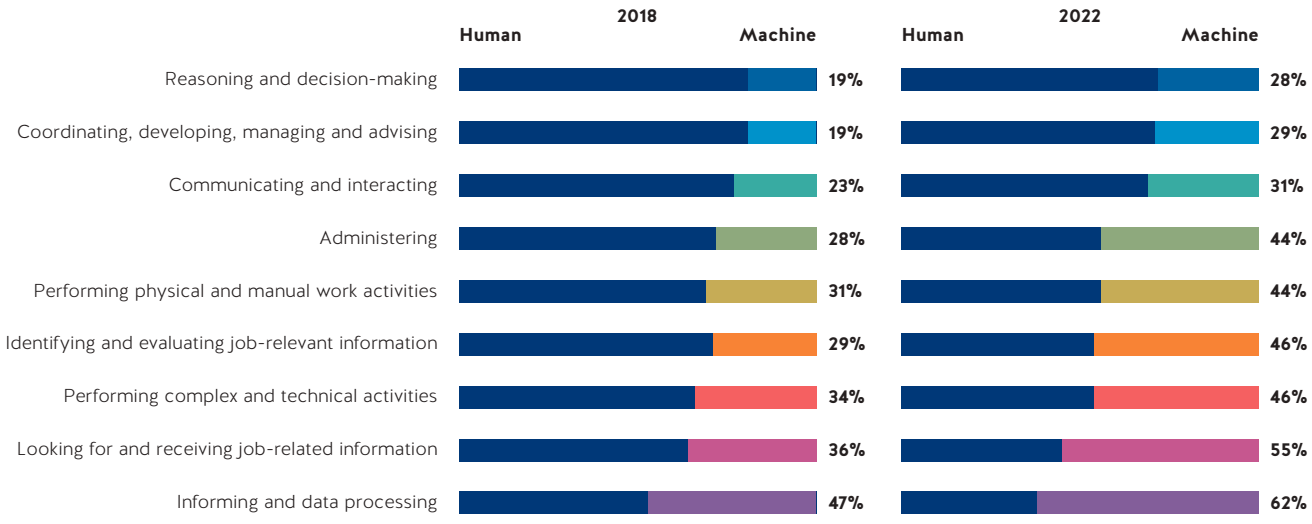
Based on a recent study conducted by Deloitte and The Manufacturing Institute, the skills gap will continue to widen eventually leading to a predicted 2.4 million unfilled positions in the U.S. manufacturing industry between 2018 and 2028 due to lack of necessary cross-disciplinary skills (See Figure 4).[11] Considering the importance of technological and cross-disciplinary skills to be prepared for a rapidly changing workplace and to ensure continued participation in society, the skills gap is a very important alarm bell.

Furthermore, as evidence of changing job profiles in the manufacturing industry, in its 2018 Survey on the Future of Jobs, the World Economic Forum illustrates an expected significant shift on the frontier between humans and machines regarding existing work tasks between 2018 and 2022 (See Figure 5).[12] However, this finding is tempered by a net positive outlook for jobs focused on emerging tasks which are expected to offset declining jobs. Accordingly, the future of manufacturing will observe new roles that are more adapted to the new division of labour between humans, machines and algorithms.

Figure 5

RATIO OF HUMAN-MACHINE WORKING HOURS, 2018 VS. 2022 (PROJECTED)

(Source: World Economic Forum)



There is a Widening Gap Between Job Openings, New Hires, and Positions Remaining Unfilled Due to the Lack of Qualified Candidates

Looking at the current business landscape, the manufacturing industry has plenty of jobs but simply not enough people to fill them. Recent figures from the U.S. Bureau of Labour Statistics illustrate a widening gap between job openings and new hires as thousands of positions remained unfilled due to lack of qualified candidates (See Figure 6). Similarly in 2018, the NAM highlighted that with close to half a million unfilled vacancies in the manufacturing sector, about three quarters of manufacturers cited the skills gap as their top concern.[13] Another recent survey by ManpowerGroup reported that forty-five percent of employers had trouble filling open positions due to a lack of available talent.[14]

Further, Deloitte and the Manufacturing Institute's 2018 study on the skills gap noted that the average time to fill an open job position is rising, illustrating the difference in number of days to fill a job position in different categories for manufacturing companies between 2015 and 2018 (See Figure 7). It is apparent that skilled jobs are becoming increasingly difficult to fill.

Figure 6

MANUFACTURING OPENINGS AND HIRES (CUMULATIVE % CHANGE SINCE JUNE 2009)

(Source: Bureau of Labour Statistics)

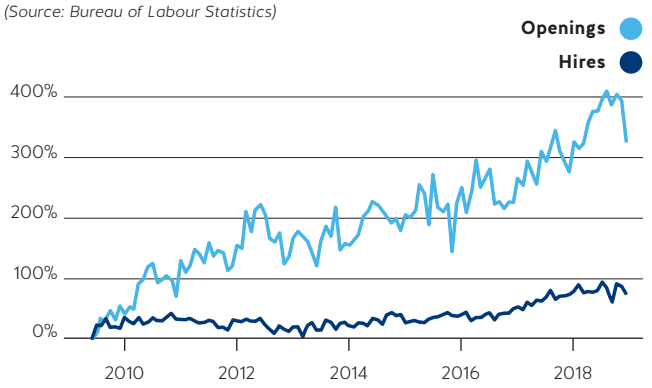
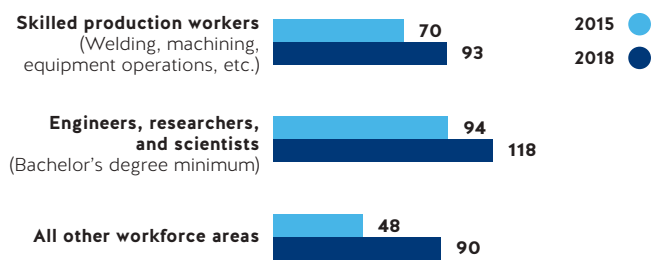


Figure 7

NUMBER OF DAYS TO FILL A JOB POSITION, BY CATEGORIES, 2015 AND 2018

(Source: Deloitte & The Manufacturing Institute)



Talent Shortages Have Been Pushed to Their Highest Levels Due to Changing Skills Needs

As a result of the strengthened global economy over the past decade, hiring demand is now stronger as employers are more optimistic about the future of manufacturing. However, as illustrated in Figure 8, talent shortages have been pushed to their highest levels in 2018 due to changing skills needs.[15] Moreover, another recent survey by the Association for Talent Development (ATD) highlighted that more than seventy-five percent of manufacturers report a moderate-to-severe shortage of skilled workers, and the problem is expected to grow. Additionally, fifty-six percent of talent development professionals observe skill mismatches in current workforcer roles due to changes in company strategy, goals, markets or business models.[16]

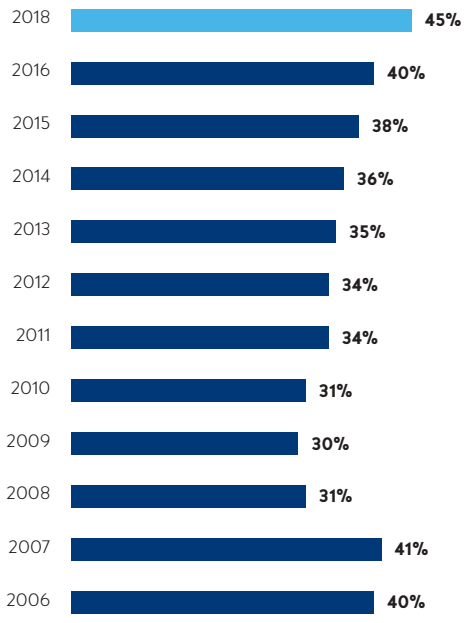
With Careers in Manufacturing Becoming More Attractive in Recent Years, the Number of STEM Graduates is Increasing

Science, Technology, Engineering and Mathematics (STEM) education is one of the key factors for increasing the innovation potential in manufacturing. With careers in

Figure 8

GLOBAL TALENT SHORTAGE

(Source: Manpower Group)

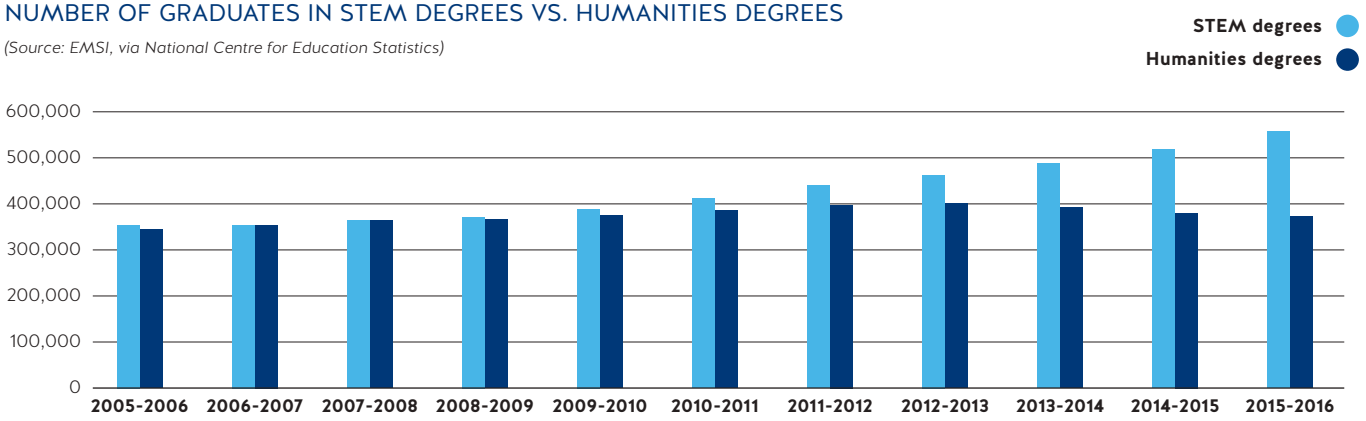


manufacturing becoming more attractive in recent years in addition to expanding advanced technologies due to innovation, highly skilled workers are and will be needed to fulfil the requirements of changing job profiles.[17] For this reason, as demonstrated in Figure 9, there is an increasing interest in achieving STEM degrees compared to past years.

Figure 9

NUMBER OF GRADUATES IN STEM DEGREES VS. HUMANITIES DEGREES

(Source: EMSI, via National Centre for Education Statistics)



The increasing number of graduates in STEM fields indicate that students and universities are aware and responding to market needs. However, according to Pure Michigan there will still be a shortage of 274,000 STEM professionals by 2018 since eighty percent of the fastest growing occupations depend on the mastery of STEM fields.[18]

UNDERLYING CAUSES

The skills gap exists due to several underlying causes which will be examined in this subsection. These causes include the introduction of advanced technologies and automation, challenges in the education system, the disconnect between institutions and companies, lack of efficient training programmes, misperception of manufacturing jobs, ageing populations along with shifting and lack of versatile skill sets in workers, among others.

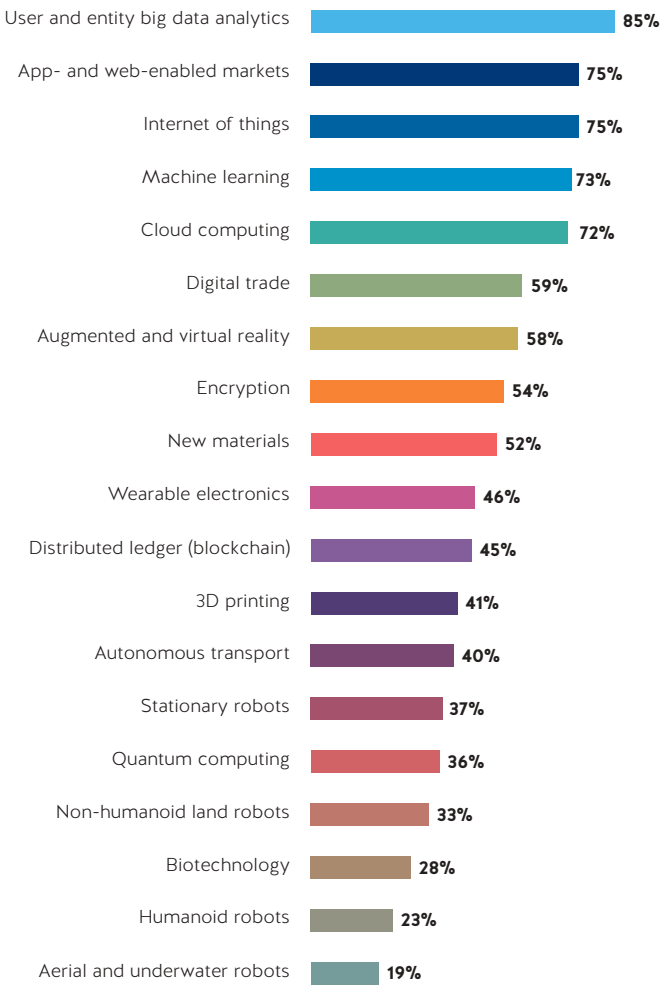
Due to the Introduction of Advanced Technologies and Automation, Manufacturers Face a Huge Challenge in Employing People With the Required Skills in Evolving Workplaces

Today, the manufacturing industry is experiencing the ever-shorter cycles of technology advances which, in turn, leads to a rapid change in the very nature of the manufacturing jobs that need to be performed and hence in the skills set of workers. A common complaint and worry among manufacturers today is that they face a huge challenge in employing people with the required skills to apply and maintain these technologies as current workforce training and experience will become obsolete over time due to faster changes than ever before. New careers requiring advanced degrees and technical skills will then emerge to address the resulting skills gap. According to the World Economic Forum, by 2022 more than 130 million new roles will be the result of a new division of work between humans and machines.[19] The technologies that will drive this paradigm shift in the manufacturing industry are illustrated in Figure 10 by an estimated proportion of companies likely adopting such advancements by 2022.

Figure 10

TECHNOLOGIES BY PROPORTION COMPANIES LIKELY TO ADOPT THEM BY 2022 (PROJECTED)

(Source: World Economic Forum)



Social Sustainability of Future Manufacturing
Challenges & Strategies

Prof. David Romero,
Tecnológico de Monterrey, Mexico

Prof. Johan Stahre
Chalmers University of Technology, Sweden

The basis of any enterprise is economic viability and sustainability. Manufacturing enterprises are also paying increasingly close attention to the environmental sustainability of their businesses. Only recently, social sustainability has gained attention as a competitive advantage. Timing may be right, as severe demographic challenges are starting to affect industrialised regions such as Europe, the U.S., and China. The effects of increasing elderly populations are worsened by the lack of young talent, altogether threatening industrial operations. Adding fuel to the fire, the Fourth Industrial Revolution continues to disrupt our present notions of industrial work. Labour market challenges now call for a radically different future workforce. We need a workforce that carries new sets of skills, knowledge, and values. How will companies be able to attract new employees, while retaining their ageing workforce? How can older workers and office staff sustain their competitiveness? Several important answers lie inside the companies' social sustainability strategies.

There is awareness that targeted social sustainability measures will be key for attracting and retaining a skilled workforce. Unfortunately, social sustainability is probably the least defined and understood dimension of sustainable development, ranging from "social equity" to "workplace ergonomics." When being one of three "triple bottom line" factors, social sustainability impact was obvious and much broader than work-related issues. The United Nations' Sustainable Development Goals (SDGs) have broadened the definition of the concept even further. Nobel Laureate Amartya Sen suggests six dimensions for social sustainability: equity and equal opportunities, promotion of diversity, social cohesion, quality of life, democracy and accountable governance, and maturity. Specifically, the social sustainability of future manufacturing needs to be addressed, not as an idealistic or altruistic abstraction, but as a highly pragmatic and competitive business and recruitment weapon. The creativity, ingenuity and innovation capabilities of the workforce will set the new base-lines for competitive advantages. Put into the context of the Fourth Industrial Revolution, social sustainability in manufacturing means that the workforce should sustain human well-being, supported by a combination of robotics, automation, and digital technologies (such as artificial intelligence). Consequently, social sustainability in future manufacturing is key for taking on the risks of the skills shortage, skill gaps, and skill mismatches in a redefined industrial world of new competitive advantages.

The meaning of social sustainability in manufacturing should be well understood in order to assess and plan a "social sustainability strategy" for a company. In this strategy, the internal and external stakeholders should be readily identified and the main factors influencing worker well-being in the company context should be named. This could include leadership commitment to socially sustainable workplace enhancement; loyalty and identification to company values; duly integrated social care and work life commitment; and clear communication of missions towards social sustainability.

While a strong commitment to social sustainability efforts has been shown to benefit companies' economic growth, the direct causality links are complex to visualise. It is natural that improved well-being and trust among employees significantly simplifies retainment of personnel and attraction of new workforce hires. It can also be assumed that successful social sustainability actions provide a good context for skilling and reskilling the workforce, to meet new requirements from the Fourth Industrial Revolution. Some of the main objectives would be to:

- Handle the skills shortage – ensure that enough skilled workers are available for the labour market. Address the effects of demographics of a certain society and problems in the talent pipelines of certain professions. Recruitment of more skilled workers into specific industrial sectors or professions will be required to achieve social sustainability.

- Manage skill gaps and shortfalls – make sure that enough workers have reached the skill and competence levels needed in the industrial sector. This requires further training of the existing workforce and improvement of the educational systems for the future workforce in order to achieve social sustainability.

- Manage skill mismatches – create a workforce with the overall skill levels and skill sets needed to address the specific supply and demand of skilled workers for an explicit industrial sector in order to achieve social sustainability.

The suggested risks of future manufacturing, triggered by demographic challenges and further increased by a rising Fourth Industrial Revolution, require strong "social sustainability strategies" crafted as a combination of:

- Strong leadership in companies – devoted to addressing social sustainability challenges.
- Cross skilling actions – to spread workforce skill sets for work mobility and polyvalence.
- Upskilling actions – to update the workforce on the latest working methods, tools, and technologies. To match them with the expected competence levels and skill sets by industry.
- Reskilling actions – to sharpen workforce skill sets and keep them competitive in their profession and industrial sector.
- Expert skilling actions – to make the workforce the best at something.

Finally, six scenarios showcase different "social sustainability strategies" that can contribute to face the challenges of social sustainability of the future of manufacturing around the world:

- Scenario 1 – the case of an ageing population: Skill shortage risks may emerge, and therefore, it may be required to upskill parts of the workforce if the retirement age is extended. At the same time, cross skilling and reskilling other parts of the workforce may be necessary to support industrial sectors with the highest skills shortages.
- Scenario 2 – the case of a country with a poor educational system: Skill gap risks may emerge. The educational system must be improved to better prepare the future workforce.
- Scenario 3 – the case of non-popular but needed professions: Skill shortage and skill mismatch risks may emerge. This requires motivating enough current and future workers and students to enrol in vocational training programmes, to serve labour market demands (e.g., the STEM crisis).
- Scenario 4 – the case of a poor training system in the industry: Skill gaps and skill mismatch risks may emerge, rapidly leading to an unqualified workforce. As a result, the labour cost of a certain profession will rise quickly. Therefore, traditional workforce training programmes should be evolved into a culture of life-long and continuous learning.
- Scenario 5 – the case of a shift in the nature of an industrial sector due to e.g. "servitisation trends." Upskilling of the workforce will be required in order to avoid skill shortages and skill mismatch risks.
- Scenario 6 – the case of increased specialisation and sophistication in an industrial sector: Due to the advanced and complex nature of their products, services and product-service bundles (e.g. smart, connected products and systems), the expert skilling of the workforce will be required in order to avoid skill shortages and skill mismatch risks.

In conclusion, social sustainability in manufacturing is key to industrial success- even to companies' survival. We are in a situation where demographic challenges threaten to undermine the competitiveness in major parts of the global industrial sector. Social sustainability awareness and actions in line with well-known requirements of human well-being could be supported by emerging digitalisation technologies and the present situation should be seen as a great opportunity. Combining emerging technological advances, social sustainability awareness, and efforts for human skill development, the manufacturing industry should enable us to take a leap into a socially sustainable Fourth Industrial Revolution.

There are Significant Challenges in the Education System which Prevent the Future Skills Gap from Being Closed

A new 2019 study from Microsoft UK found that fifty-eight percent of teachers think the current education system fails to prepare students for a digital future which therefore contributes to the widening skills gap.[21] Despite the recommendations and need for workers to be agile life-long learners in the workplace, students are not being prepared to be successful in a competitive business world due to a lack of future skills content in schools and universities. The skill sets that are increasingly important across every role are acquired through practice and experience, and not in classrooms (See Figure 11). Therefore, the education system needs to reform to better meet the needs of students in equipping them with the required skill sets for their future career.

One of the most important implications of these challenges in the current education system is the disconnect between institutions, employers, and job seekers.[22] Workplaces are evolving due to the increased competition that values innovation, creativity, communication, imagination and emotional intelligence, urging workers to use their soft skills to better adapt to changing technologies and organisational structures. However, institutions are not revising their curricula accordingly to match needs of employers. Hence, companies are unwilling to pay higher wages for employees that are not ready for evolving jobs while individuals expect education programmes to provide them with the needed skills to get prepared for their future career. Evidence suggests that, for to bridge the skills gap, we should give priority to tackling the disconnect between institutions, employers, and job candidates.

Misperception of Manufacturing Among Teenagers and Parents Affects Early Career Choice

One key highlight and recommendation from the *2018 WMF Report* that stood alongside our recommendation to focus on skills was to also *Cultivate a Positive Perception of Manufacturing*. The effect of these misconceptions start from the phase of early career choice since many parents do not have current knowledge of manufacturing and available opportunities. Consequently, a recent survey revealed that parents have trouble understanding

Figure 12

PARENTS' PERCEPTION VS REALITY OF THE MANUFACTURING JOBS[23]

(Source: American Welding Society)

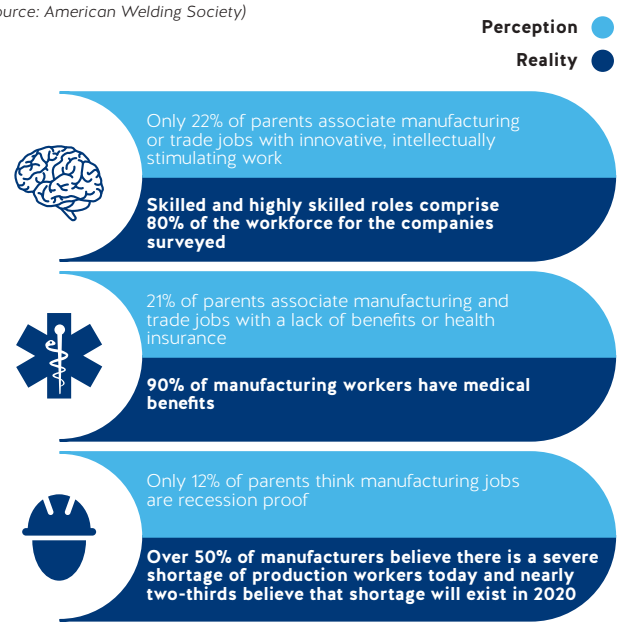


Figure 11

THE RISING IMPORTANCE OF NEW SKILL SETS[20]

(Source: Accenture)

Importance: ● **High** ● **Medium** ● **Low**	**Complex Reasoning**		**Creativity**		**Socio-emotional Intelligence**		**Sensory Perception**	
	Importance in 2017	Change since 2004	Importance in 2017	Change since 2004	Importance in 2017	Change since 2004	Importance in 2017	Change since 2004
Management & leadership	●	▲	●	▲	●	▲	●	▲
Empathy & support	●	▲	●	▲	●	▲	●	▲
Science & engineering	●	▲	●	▲	●	▲	●	▲
Analytical subject-matter expertise	●	▲	●	▲	●	▼	●	▲
Relational subject-matter expertise	●	▲	●	▲	●	▲	●	▲
Process & analysis	●	▲	●	▲	●	▲	●	▲
Physical services	●	▲	●	▲	●	▲	●	▲
Technical equipment maintenance	●	▲	●	▲	●	▲	●	▲
Machine operation & manoeuvring	●	▲	●	▲	●	▲	●	▲
Physical manual labor	●	▲	●	▲	●	▲	●	▲

Note: Complex Reasoning includes critical thinking, deductive reasoning, active learning and a set of higher-order cognitive capabilities. Socio-emotional intelligence involves active listening, social perceptiveness, persuasion, negotiation and service orientation. Sensory Perception incorporates a wide range of sensory capabilities that have been stimulated through our increasingly intimate relationship with digital technologies

the potential of a career in manufacturing (Figure 12).[24] According to the survey, more than twenty percent of the 1,035 surveyed U.S. parents view manufacturing as an outdated and dirty work environment, and almost half of all respondents did not see manufacturing as an engaging, challenging or exciting profession. Further, one in five parents believe manufacturing jobs only pay minimum wage salaries, lack benefits, and won't provide their child with innovative and intellectually stimulating work. Nearly ninety percent of the parents estimated the average hourly wage for manufacturing jobs at $22 USD an hour or less. However, the real industry average stands at $34 USD per hour. This is not the only proof that parents' fears are largely unfounded. Dispelling common beliefs, today's manufacturing environments are mostly in laboratory-like settings and are clean sterile environments - not dirty shop floors of past times. Moreover, the manufacturing industry offers career opportunities for every education level, and technological advancements yield to well-paid careers. Current manufacturing enterprises also use very sophisticated technical equipment to produce a variety of products ranging from semiconductors that power virtually every high-tech product, to very technical medical device products that have the power to save lives.

Figure 13

TOTAL HOURS WORKED IN EUROPE AND UNITED STATES, 2016 VS 2030 ESTIMATE, BILLION

(Source: McKinsey)

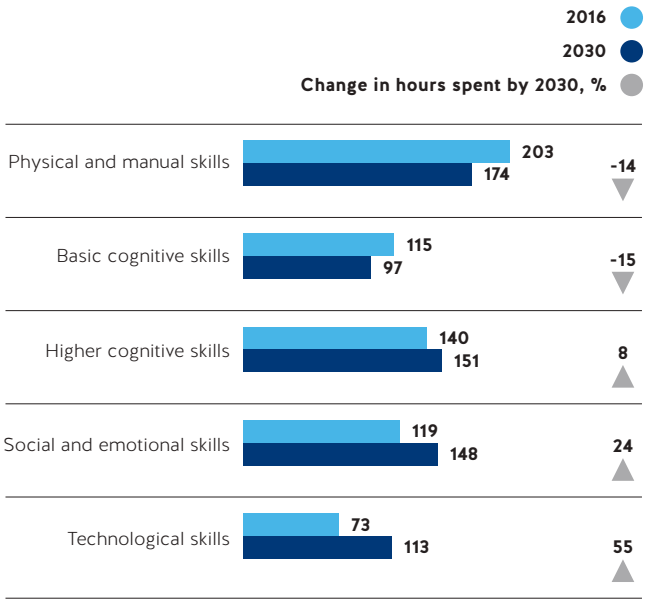
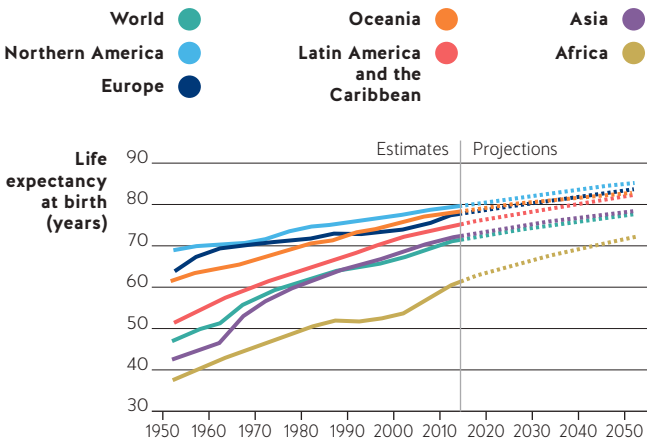


Figure 14

LIFE EXPECTANCY AT BIRTH BY REGION, BOTH SEXES COMBINED, FROM 1950 TO 2050[28]

(Source: United Nations)



The Manufacturing Industry is Still Focusing on Traditional Just-in-Time Hiring Strategies Instead of Acting as Builders of Essential Skills for the Future of Manufacturing

Manufacturing will create many more high skill jobs in the future, supporting a stronger wage growth and a healthier labour market. This will serve as a crucial testbed to see whether new technologies can complement human skills in new and better jobs, rather than simply displace workers. Considering record talent shortages in the manufacturing industry, employers should now shift their focus from traditional just-in-time hiring strategies to acting as builders of essential skills for today and the future. To achieve this, a combined effort by companies, education institutions and government to reboot education and training will be required for essential upskilling and reskilling. A 2018 study by McKinsey reveals the need for a paradigm shift in hiring and training strategies by highlighting the estimated change in the composition of skills for manufacturing jobs between 2016 and 2030.[25] According to the projections, the demand for workforce skills will significantly change (Figure 13) with increased role of automation and artificial intelligence, which will lead to evolving workplaces since people will frequently interact with ever-smarter machines. To adapt to these changing trends, companies need to have a new mindset for building the future workforce and collaborating with educational institutions and industry associations. Currently, many companies think in isolation about their retraining programmes. However, in the future, universities and institutions will play a more active role in filling the needs of the labour market, by putting a stronger emphasis on courses that teach data science and other advanced technologies as well as support students in acquiring relevant soft skills to be successful in competitive business markets.

Ageing Workforce as a Part of the Solution for Bridging the Skills Gap is Essential

As highlighted in the most recent OECD Employment Outlook 2019 report, populations are ageing fast in OECD countries. In 2015, there were twenty-eight people aged sixty-five and over for every one hundred people of working age, and this ratio is projected to double by 2050.[26] The ageing population (Figure 14) directly affects the workforce and available skill sets in the wider economy since one of the current key challenges is the loss of skills from

one generation to the next.[27] With tens of millions of ageing workers approaching retirement every year and also considering the serious decline in birth rates in the U.S. and Europe, the workforce of the future is in serious jeopardy. Most of the skills in manufacturing workplaces are gained over years, and it is not easy for new workers to replicate these skills without side-by-side training. Therefore, the ageing workforce leads to an increase in the already existing skills gap concerning manufacturing and fabrication. In this context, making older workers a part of the solution for bridging this gap is essential. For example, by mentoring the younger workforce effectively to address specific knowledge transfer would help to solve the issue at hand. Such an evolution in the roles of older workers would support companies to retain the existing skills base while sharing knowledge with the next wave of recruits. Thus, the relationships between younger and older workers are critical to addressing the skills gap problem.

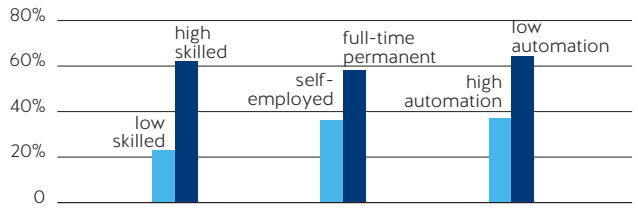
Adult Training Should Better Target the Disadvantaged

Again highlighted by the 2019 OECD Employment Outlook report, participation in training by low skilled adults across OECD countries is forty percentage points below that of high skilled adults. Figure 15 illustrates these numbers relevant to the participation in training by skill level, employment status, and risk of automation. This could be the result of multiple barriers to training disadvantaged workers such as lack of time or money to train, unwillingness to be trained in jobs that are at a high risk of automation, and the tendency of employers to invest in training higher skilled workers where the return on investment is expected to be higher. Thus, adult learning systems should be improved to provide all workers, including those most vulnerable to the changes that lie ahead, with adequate opportunities for retraining throughout their careers.

Figure 15

ADULT PARTICIPATION IN TRAINING BY SKILL LEVEL, EMPLOYMENT STATUS AND RISK OF AUTOMATION[29]

(Source: OECD)



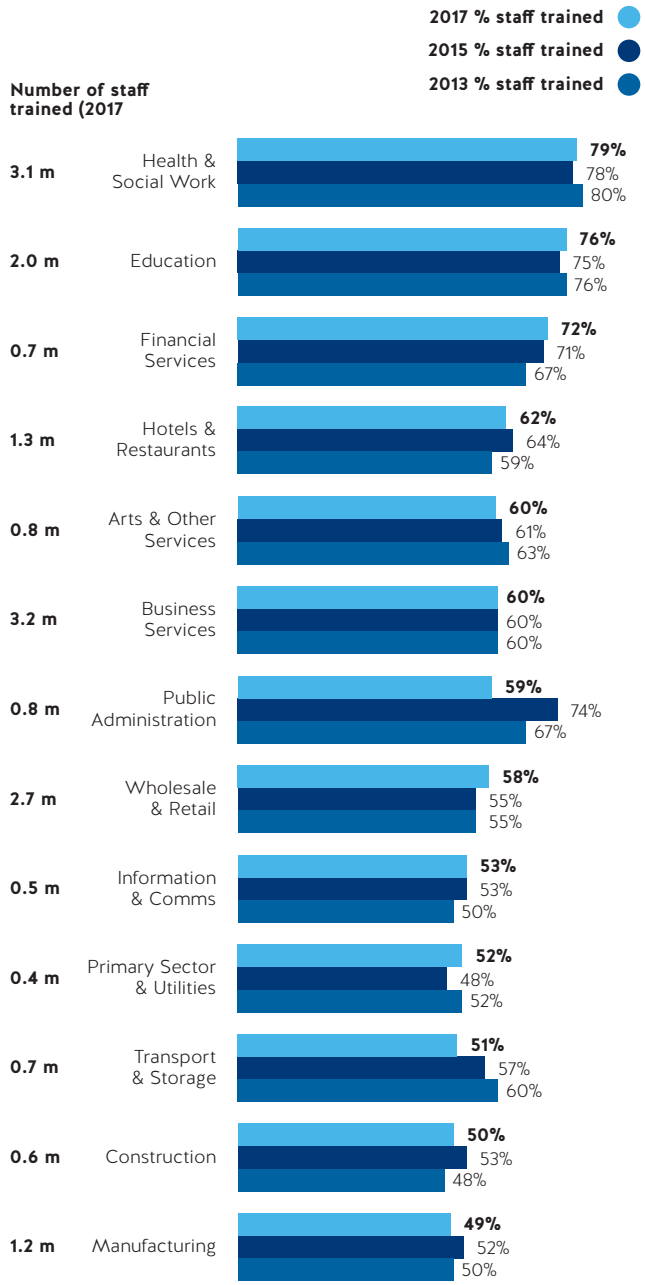
Insufficient Retraining of Workers Leads to a Lack of Skilled Workers and Inhibits the Full Use of Advanced Manufacturing Technologies

Industry 4.0 technologies will not only improve how manufacturing works but also will change the way workforce is engaged in creating value since manufacturing stakeholders must constantly evolve with the pace of technology. The highest levels of productivity could be achieved with a workforce that is engaged in the process, therefore making technology extremely efficient. As a result, manufacturing companies should invest more in training on a long-term basis and shape technologies in ways that make workers most productive. Additionally, recognising the training and skills gap and accordingly cross-training workers in jobs will continue to engage them. Governments and policymakers should push organisations to feel responsibility toward society and causes other than just

Figure 16

PROPORTION OF STAFF TRAINED BY SECTOR, 2013 - 2017

(Source: UK Employer Skills Survey 2017)



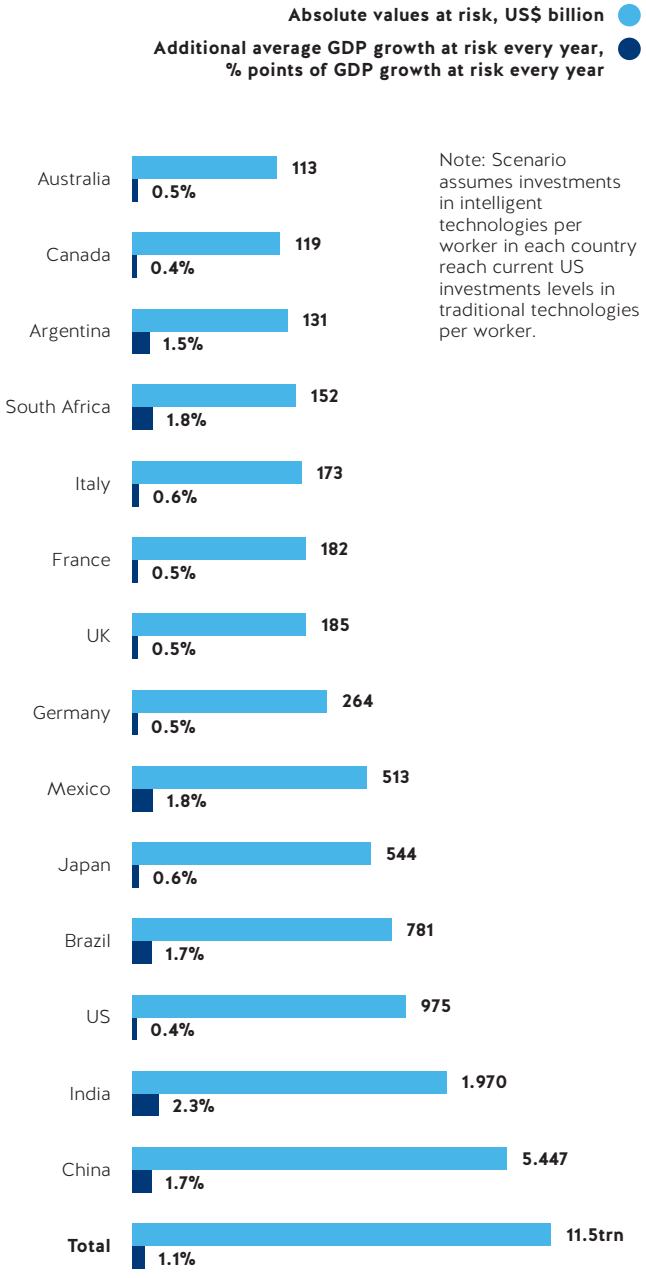
their shareholder, invest in education on a long-term basis, and involve all actors to create other life-long learning opportunities besides training such as education updates with universities and other educational outlets.

However, the 2017 Employer Skills Survey of the UK illustrates that manufacturing is one of the sectors with the smallest proportion of trained staff as highlighted in Figure 16. This situation is similar in other countries as well illustrating that this training gap should be improved to better address the skills gap challenge.[30]

Figure 17

POTENTIAL COST OF THE SKILLS CRISIS

(Source: Accenture)



Note: Scenario assumes investments in intelligent technologies per worker in each country reach current US investments levels in traditional technologies per worker.

IMPACTS OF THE SKILLS GAP

This subsection presents the impacts of the existing skills gap on the competitiveness of the manufacturing industry as well as on society itself.

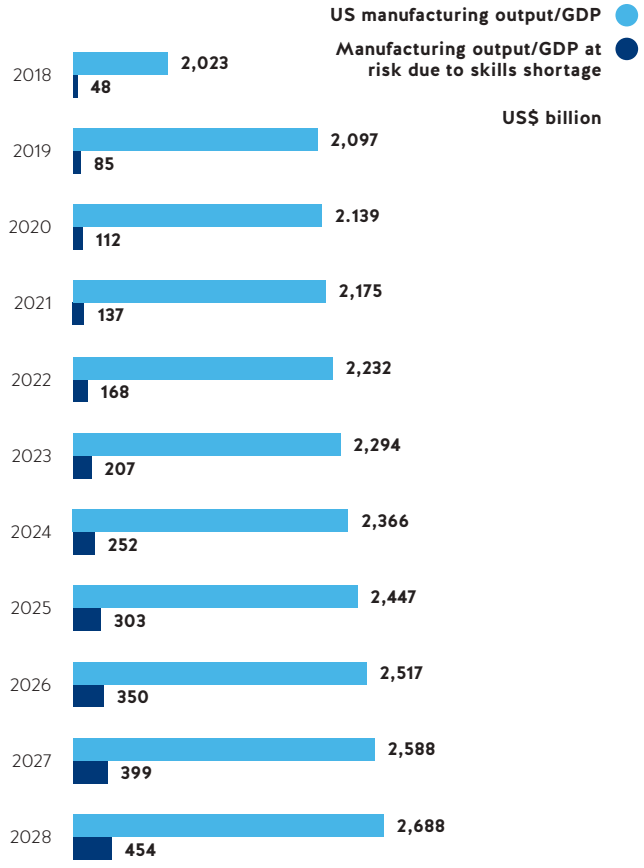
Skills Shortages Will Cause the Potential of Digitalisation to Go Unrealised Leading to Significant Negative Impacts on GDP Growth in Developed Economies

The changing size of the economy is an important determinant of future employment dynamics. When the economy grows rapidly, the growth often results in increasing skill shortages simply because training systems and education cannot respond to employers' demand for workers and skills quickly enough.[31] A growing skills shortage could prevent the potential of digitalisation from being realised. Over the next ten years, in G20 countries alone, the unsatisfied needs of the technological era could cost as much as $11.5 trillion USD in GDP growth (See Figure 17).[32] The impact in the U.S. is expected to be similar as the skills shortage could put 454 billion USD of manufacturing

Figure 18

IMPACT OF SKILLS GAP ON GDP IN US[33]

(Source: Deloitte)



GDP at risk in 2028 alone, and $2.5 trillion USD within a decade (See Figure 18).

Inability to Meet Customer Demands is the Biggest Concern caused by the Skills Gap and Impacts Competitiveness

While the manufacturing industry in developed countries is now booming, it needs to overcome the skills gap which could cause several issues for companies. Among many other impacts, the inability to meet customer demand is the biggest concern caused by this ongoing problem. With more of the current workforce retiring, businesses are losing highly skilled workers faster than ever before, pushing companies to focus on hiring younger talent. However, manufacturing companies are unable to find suitable workers to fulfil skilled job roles within the industry. This is due to the fact that training systems and the technical education systems have not yet evolved to keep up with the advancements of the industry along with automation's impact on the job market (See Figure 19). The talent shortage will cause a significant negative impact on fulfilling customer demands, leading to decreased productivity, slower production times, increased operating costs, and other issues concerning business performance. Above all, according to a recent U.S. News & World Report article, the skills gap could affect the ability of companies to stay competitive in the global market.[35] Eighty-seven percent of the respondents to a recent survey of the Association for Talent Development mentioned that the skills gap did indeed affect their performance, with customer service, growth, and service delivery being significantly impacted.[36]

Companies are Trying to Reach New Talent Pools and Bring More Diversity into the Workforce

The failure of the current business landscape to address the demands of shifting skills could exacerbate social tensions and thus lead to an increased variety of skills and wages among society. This situation pushes companies to consider actively recruiting from underrepresented or overlooked talent pools such as formerly incarcerated peoples, people with disabilities, workers returning from career breaks and older workers thereby promoting inclusiveness in the workforce. In that regard, Figure 20 shows the results of a 2018 survey carried out by ManpowerGroup which reveals that thirty-six percent of the recruiters are being more flexible about education and experience requirements for jobs and thirty-three percent consider different demographics, age ranges or geographies in their hiring decisions, and more than thirty percent increase salaries and benefits.[37] Further, Figure 21 demonstrates what actions employers are taking to overcome talent shortages, with top options being: provide additional training, adjust education and experience requirements, recruit from new talent pools, offer higher salaries, and additional benefits among others.

Figure 19

SHARE OF JOBS WITH A HIGH POTENTIAL OF AUTOMATION[34]

(Source: PwC/OECD)

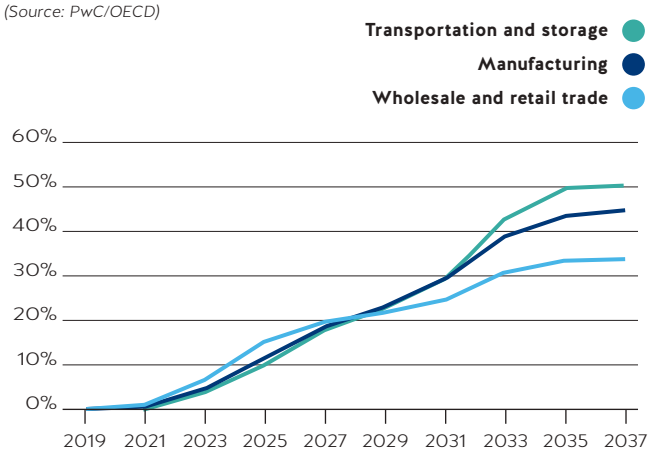


Figure 20

REACTION OF COMPANIES AGAINST INCREASING SKILLS GAP

(Source: ManpowerGroup)

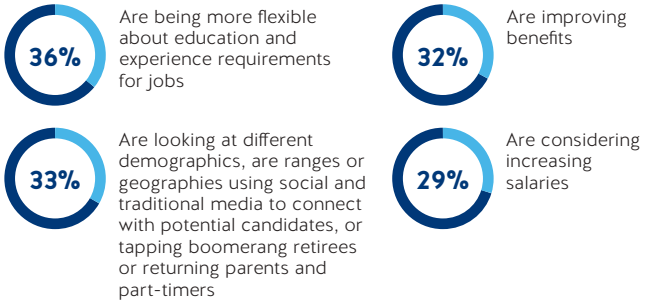
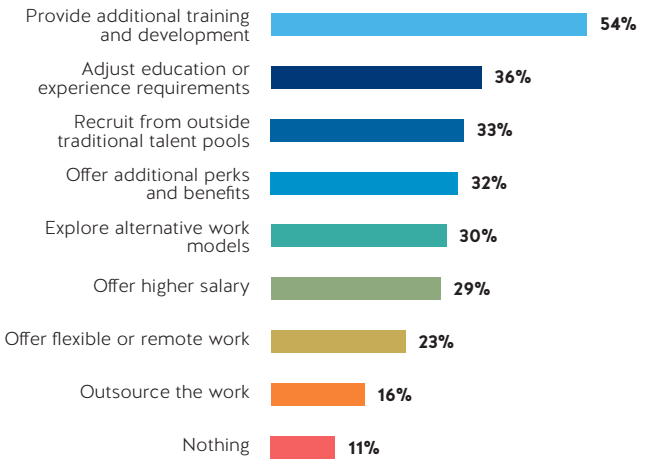


Figure 21

WHAT EMPLOYERS ARE DOING TO OVERCOME TALENT SHORTAGES

(Source: Manpower Group)



Manufacturing to Digital: The Pirelli Way
Commitment, Change, and Culture

Ing. Davide Meda
Pirelli Head of Manufacturing

Pirelli was founded in Milan in 1872 and today stands as a global brand known for its cutting edge technology, high-end production excellence and passion for innovation that draws heavily on its Italian roots. With nineteen production plants in twelve countries and a commercial presence in over one-hundred and sixty, Pirelli is among the world's major producers of tyres and associated services and the only one focused solely on the Consumer tyre market, which includes tyres for cars, motorcycles and bicycles. Pirelli has around 31,500 employees who come from different countries and have a wide variety of different skill sets. This diversity is encouraged by Pirelli, which recognises the professional excellence of its many specialised individual functions and puts great effort and investments in the upskilling of its young talents.

In September 2016 Executive Vice President and CEO Marco Tronchetti Provera stated during an interview, "The success occurs if resources are used in the right direction. A fundamental element for the competitiveness of a company is the relationship with the development of technologies and with science. Today, talking about Industry 4.0 and digitalisation is an everyday topic, in Pirelli and in any company that wants to be competitive. An appropriate use of digitisation is worth the competitiveness and the future of a company." A change like that, which has a deep impact on the organisation, cannot happen without a strong commitment from the top management to every single corner of the organisation, a radical change of Pirelli's way of thinking and working within its plants and the right culture focused on data and predictive analysis to be faster and more efficient in creating value from the data itself.

Commitment, change and culture. These are the three words which the programme "Manufacturing to Digital: the Pirelli Way" has been based since the beginning in 2017 with the aim to improve products' quality and processes' efficiency by developing new 4.0 integrated systems based on the use of the "data" through an embedded "data-driven culture" starting from the shop-floors where the majority of data is stored. It all started in Stuttgart, Germany during a worldwide workshop where Pirelli Manufacturing and Quality Senior Managers coming from headquarters and plants were invited to take part. Here begins a strong commitment which leads to the awareness that becoming "digital" is not just a passing fad but it is a question of survival.

During this workshop the management decided to build a strong and clear organisation called the *Smart Manufacturing Office* both at central level (HQ) and at the plants. In parallel, each plant created specific roles as change agents – so called Smart Manufacturing Officers and Smart Manufacturing Champions - with the aim of creating a clear governance of the program's roadmap. With the creation of new roles, Pirelli – through the Pirelli Professional Academies – ensures adequate managerial and technical training in order to complete their upskilling and to transfer to them the culture necessary to succeed in spreading the "data-driven culture" through the organisation.

All Smart Manufacturing Officers and Champions went through an intense training of three weeks in order to attain the following competences: coding, data exploration, programming, web app development and advanced statistics. In less than one year, Pirelli can count on a team of hundreds of Smart Manufacturing Officers, Champions and Data Experts – these numbers are going to increase in the following months - which are the "armed arm" of the digital transformation within each of the group's nineteen plants. These investments aim to anticipate the needs of the market, manage the complexity of the business, constantly improve the level of its services and effectively reach the final consumer, Pirelli is globally committed to a transformation and renewal plan that aims at the digitalisation of planning, production and distribution processes and consumer profiling.

SECTION 3
SKILLS FOR THE FUTURE OF MANUFACTURING

With the increasing complexity of manufacturing systems, connectivity, exploding number of integrated sensors, etc. the skill level and required depth of knowledge about system integration is and will be changing rapidly.

The previous section reported on the real and perceived skills gap in the manufacturing domain and provided some alarming numbers that highlight the importance of this topic for the future of manufacturing. In this section, we will take a closer look at the various skills that are projected to be essential and required to be successful in the future, smart, and digital manufacturing environment. For this report, we brought together different perspectives, including small, medium, and large manufacturing companies, governmental agencies, non-profit organisations, as well as individual experts, and think tanks to provide a comprehensive and accurate view on this important issue. However, while the digital transformation of manufacturing is still in an early stage, the presented results are to some extent based on a prediction of what the future of work may look like. Furthermore, given the diversity of manufacturing and associated careers, there may be certain jobs that require a very specific skill set that is not adequately represented in this section as we generalised the findings in order to serve the majority of our constituents.

Traditionally in manufacturing, the skills required were structured in *technical skills*, also referred to as hard skills, and *soft skills*. Technical skills include, for example, operating a CNC machine, welding pipes, and designing an electric board, etc. Soft skills on the other hand describe skills such as attention to detail, three-dimensional thinking, and the ability to work in interdisciplinary teams; just to name a few. When managerial and design tasks are included in the manufacturing field, additional technical and soft skills are included, such as proficiency in CAD systems and creative problem solving respectively. The high-level structure in technical and soft skills is broad enough to fit most skills and as such, can continue to serve as a vehicle to structure the skills required today and tomorrow. It is important to note that the manufacturing community needs to avoid a too narrow definition and categorisation in order to keep the collected skills flexible and agile.

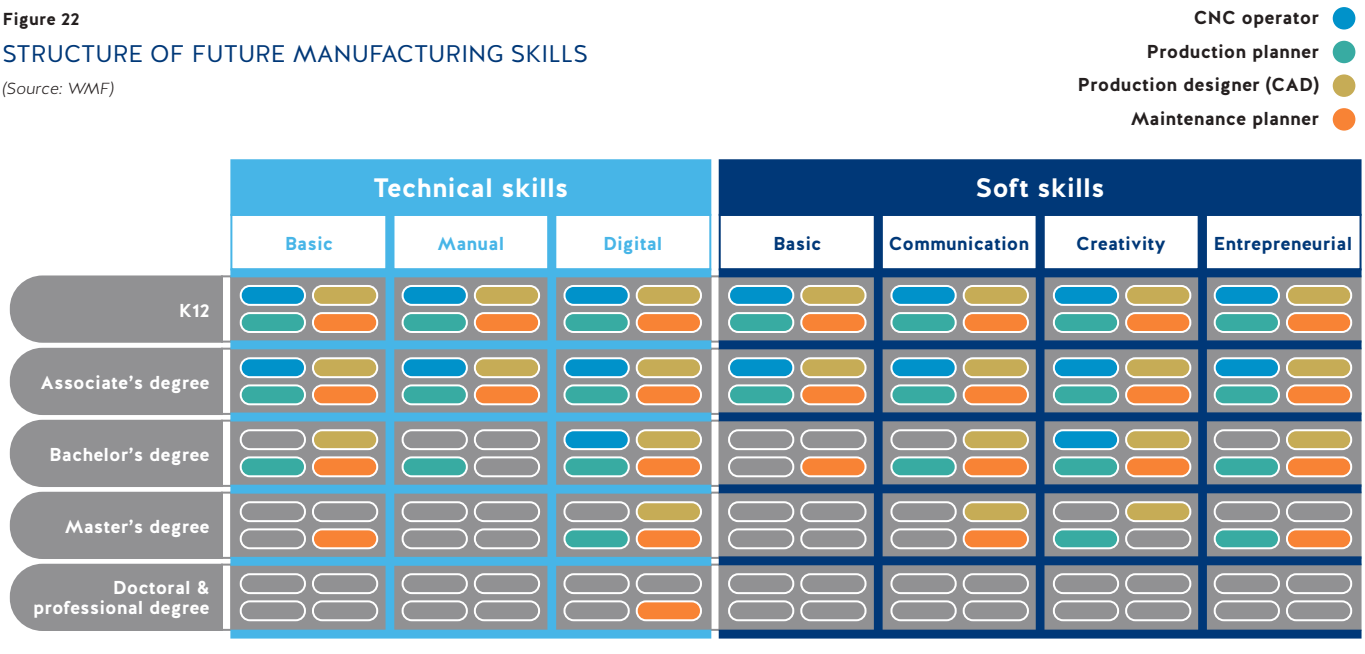
However, while the flexibility and general applicability is sometimes favourable, it also does not allow for a clear depiction of the ongoing shift in required skills. To accurately and transparently illustrate the ongoing transition, we have to increase the granularity of the structure further. We recommend to approach this with a two-dimensional strategy: split the high-level technical and soft skill categories further to provide a more granular structure while keeping the general notion of technical and soft skills. At the same time, we can include an *educational dimension* to further elaborate on the proficiency of a certain skill. While it can be argued that the educational dimension is artificially creating differences between workers, it is imperative that the educational level reflects the amount of time that is required to acquire and master a certain skill. For example, in the case a skill is associated with a two-year associate's degree from a technical college, this does not mean it cannot be acquired in another way, including self-study. However, the time and effort necessary to acquire the skill is comparable. Therefore, educational level is a good indicator to showcase the requirement different skills impose on the worker. In this case, we use the resultant matrix depicted in Figure 22 to indicate selected examples of shifting skills requirements for certain common manufacturing positions graphically.

It is important to introduce three sub-categories for technical skills: *basic, manual and digital*. Basic technical skills include a rudimentary understanding of mathematical and physical phenomena, mechanics, and statics, etc. In the past, many manufacturing jobs, especially on the shop floor, required skills and experience in manipulating physical parts. This includes, but is not limited to, manually grinding the surface of a metal part to the required tolerance and operating a lathe without CNC controls. Today, this has already shifted towards operating advanced machine tools, and thus programming complex CNC programmes. Furthermore, this involves troubleshooting complex machine tools, often

Figure 22

STRUCTURE OF FUTURE MANUFACTURING SKILLS

(Source: WMF)



without direct feedback on what went wrong. Feedback is provided indirectly through sensor data output and coded feedback from the machine. However, there are still many manual tasks that shop floor workers have to fulfil, including maintenance of mechanical parts, replacing cutting tools, or loading/unloading machines. This could change even more in the future, where the shop floor worker will serve as more of an operator of high-tech machinery and the skills required are shifting towards the interpretation of large amounts of data and deriving insights. The worker will require fewer manual skills and more abstract digital skills, such as understanding the state of the work piece in the machine based on sensor readings instead of "touching the part" to identify potential quality issues. On a high level, we can project an ongoing shift from more manual skills towards more digital skills that will be required of the manufacturing shop floor worker of the future.

On the soft skill side, we can safely project a general increase of importance and impact of soft skills on the value-add in manufacturing careers. Interpretation of data and problem solving, that was mentioned under the digital side of the technical skills, has a strong connection to soft skills that are increasingly required of all levels of manufacturing workers. This grey area between the two skill categories is sometimes referred to as *meta skills*. We can sub-divide soft skills in four different categories: *basic, communication, creativity and problem solving and entrepreneurial skills*. It can be argued that these categories overlap to some extent. However, they actually reflect the different dimensions of the future skill set the most. *Basic soft skills* are for example negotiation skills, empathy and intercultural competences. *Communication skills* are becoming increasingly important on the shop floor and beyond as processes and problems are more complex and multi-disciplinary in nature. Therefore, effective communication among various stakeholders of various backgrounds (incl. education, culture, position, and level of expertise) is required to solve these kinds of problems. *Soft skill creativity* is included as many of the problems that will emerge in the future of manufacturing will be new challenges with no historic data or experience available on how to solve these issues. In this context, creativity is understood as creative problem solving which will be one of the key skills required in the future manufacturing setting. *Entrepreneurial skills* refer to the entrepreneurial mindset, not necessarily the skills to create new startups. The entrepreneurial mindset includes skills such as initiative and self-direction, risk-taking, flexibility and adaptability. It has to be noted that communication skills and creativity are often also attributed to the entrepreneurial mindset – however, separation for these key soft skills is necessary. The promotion of an entrepreneurial mindset can also be an additional vehicle to promote manufacturing careers among younger generations such as Millennials and GenZ.

The classic division between technical and basic skills is diminishing and the meta skills located at the intersection are becoming increasingly important. Meta skills are often referred to as inter- or cross-disciplinary skills and are included in new areas of technical expertise. These areas can be in assembling complex systems together with a collaborative robotic system that needs to be programmed or development of a CPS as a product-service system to satisfy variating stakeholder needs along the whole lifecycle. As these examples imply, meta skills are intertwined combinations of classic skills that are more than the sum of its parts. However, those are often very case specific and thus nearly impossible to cluster in pre-determined categories such as presented in Figure 22. These key skills will be revisited in the top ten skills section discussed at the end of this chapter.

Before we can deeply explore specific skills that can be considered top skills in the manufacturing careers of the future, it is crucial to briefly revisit an established paradigm that needs to be reinvented: *Life-Long Learning*. In the future of manufacturing, society will see rapid development and fast lifecycles in products, machines and manufacturing systems. The time when an operator received training for a specific machine tool and was then able to productively provide value to the manufacturing operations for years or even decades is over. The manufacturing community will not only see a rapid change of parts and products to be produced with variating requirements but also, the upgrade cycle of machine tools, especially with regard to the software/interface side. Effective operators will be required to constantly learn and adapt to the changing conditions and requirements put forth by the digital side of manufacturing. While we chose machine tool operators as an example, this will be true for most if not all manufacturing roles – from the product designers that need to adapt to new features in their interface and new DFMA capabilities, to the maintenance operators that need to inform and familiarise themselves constantly with new AI and Machine learning algorithms to improve predictive and preventive maintenance strategies.

It has to be noted, that many of the future requirements for manufacturing professionals will require the same type of skill as in previous years, yet, at times the level of proficiency of the skill changes dramatically. For example, the technical (digital) skill system integration was relevant before and continues to be relevant. However, with the increasing complexity of the manufacturing systems, the connectivity, exploding number of integrated sensors, etc. the skill level and required depth of knowledge about system integration is and will be changing rapidly.

The following will explore selected skills that identified through interviews with global experts and previously published reports and literature. We chose to present ten rather specific skills to provide our constituents with a better understanding of the interdisciplinary and variety of future skills. One reason is that there are several high-quality publications available that provide a yearly update on the top general skills required in the future. Those generally are applicable for manufacturing as well, yet, manufacturing has some rather unique skills that deserve attention and might inspire our readers to think beyond established boundaries.

The WMF's Top Ten Skills for the Future of Manufacturing

1. ***Digital literacy*** *as a holistic skill to interact with, understand, enable, and even develop new digital manufacturing systems, technologies, applications, and tools*
2. *Ability to use and design new* ***AI and data analytics*** *solutions while critically interpreting results*
3. ***Creative problem solving*** *in times of abundant data and technological opportunities in smart manufacturing systems*
4. *A strong* ***entrepreneurial mindset*** *including proactiveness and the ability to think outside the box*
5. *Ability to work* ***physically and psychologically safely and effectively*** *with new technologies*
6. ***Inter-cultural and -disciplinary, inclusive, and diversity-oriented mindset*** *to address new challenges arising from a more diverse manufacturing workforce*
7. *Cybersecurity,* ***privacy, and data/information mindfulness*** *to reflect the rapidly increasing digital footprint of the manufacturing value chain*
8. *Ability to* ***handle increasing complexity*** *of multiple requirements and simultaneous tasks*
9. *Effective* ***communication skills*** *with humans, IT, and AI systems through different platforms and technologies*
10. ***Open-mindedness towards constant change****, and transformation skills that constantly question the status quo and initiate knowledge transfer from other domains*

1 *Digital literacy as a holistic skill to interact with, understand, enable, and even develop new digital manufacturing systems, technologies, applications, and tools*

It is imperative for future manufacturing workers on the shop floor and beyond to be comfortable with new digital technologies. Not only will workers be required to develop a basic level of understanding of new digital manufacturing technologies, tools, applications, and systems that enable them to interact with those systems but workers will also be increasingly required to enable and develop new digital solutions themselves. For example, machine operators might have to adapt the application of an analytics software tool to process and visualise the increasing amount of process data in order to do their job. They are experts on this specific machine and understand best what insights are required for value-adding applications in, for example, predictive maintenance or tool wear prediction that make manufacturing operations more efficient. While this is certainly different from developing new software and applications from scratch, it requires a basic understanding of coding and data analytics that was not necessarily part of the job description in the past. In the future, more interpretation of digital information is needed as manufacturing processes are becoming more complex and the operator has to rely on data and secondary information instead of, "seeing and feeling" themselves

2 *Ability to use and design new **AI and data analytics** solutions while critically interpreting results*

In the future, manufacturing will produce significantly more data. On one side, this offers many opportunities for optimisation and better prediction that will allow processes to become more efficient and effective. On the other hand, this increase in available data exceeds the capacity of human operators to understand and interpret the data without sophisticated tools. These tools to provide insights from large amounts of data, particularly big data, are mainly based on machine learning and AI. Both AI and machine learning have made significant progress throughout the last years, however, many of the algorithms were developed for domains other than manufacturing. This leads to the challenge that, while very effective, they often do not consider manufacturing specific challenges in data, such as small sample sizes and unbalanced data sets. Furthermore, many new tools work as black boxes and do not provide insights with regard to causality – which is a requirement for many manufacturing applications. Therefore, in the future, manufacturing workers need the skill to work with and critically interpret the results provided as an output of big manufacturing data solutions. An increasing number will further need to develop more expertise in data pre-processing to enable the analysis using machine learning and AI algorithms, therefore, developing new data analytics applications for their specific manufacturing use case. This emerging requirement is connected to ethics in the case of AI solutions. In a narrow sense, this is less relevant for core manufacturing applications compared to biometrics solutions or such. However, in the broader sense, this will become relevant once AI solutions are used to determine human resource relevant KPIs or are responsible for safety or privacy functions within a company.

3 ***Creative problem solving** in times of abundant data and technological opportunities in smart manufacturing systems*

While problem solving is a recognised skill that has been relevant throughout time, the new realities of future manufacturing operations make this ever more prominent. With the ability to not only automate physical processes that are dangerous, strenuous, and repetitive, but also increasingly automate cognitive tasks, the human operators' focus and value will shift more towards tasks that cannot easily be automated. Solving complex problems is a key aspect of this. Similar to physical automation, in cognitive automation the first tasks that will be automated using AI and machine learning are repetitive tasks, such as monitoring the tool wear and operations of a CNC milling system. However, other tasks, such as system level problems and process optimisation are difficult to automate. Human ingenuity is best prepared to develop creative solutions that address root causes of smart manufacturing systems, taking the input of supporting analytical tools into consideration when appropriate.

4 *A strong **entrepreneurial mindset** including proactiveness and the ability to think outside the box*

An entrepreneurial mindset goes beyond the ideas and concepts for starting a new business. An entrepreneurial mindset refers to the skills needed to successfully manage innovative ventures. This mindset is characterised by creativity, proactiveness, and the ability to think outside the box to identify, develop, and act on new ways to deliver value to stakeholders and society at large. Value can be created in ways including new business models addressing new product and service requirements through advanced manufacturing technologies, digitalisation, and materials. This skill includes an active interest in the overall strategy of the company and the willingness to work in and with areas outside of their own core expertise when needed.

5 *Ability to work **physically and psychologically safely and effectively** with new technologies*

This skill addresses the need for human workers to be willing to and capable of working with robotic/automated systems and AI. This includes interacting with CPS or other highly-automated and autonomous systems, collaborative robotics, and human augmentation technologies such as exoskeletons, and AI-powered AR. The manufacturing community is currently in a transformative state where new robotic systems, AI powered solutions, and Operator 4.0 technologies are being introduced to the shop floor for the first time. Manufacturing workers need to develop the skill to work effectively in such an environment while being physically and also psychologically safe. For example, when wearing an exoskeleton, the system might have a delay in reaction that causes some human operators stress as it feels like there is a lack of control. Being able to work with these systems and at the same time ensuring that the human operator is empowered instead of reduced to a human-robot is a skill that needs to be carefully developed.

6 ***Inter-cultural and -disciplinary, inclusive, and diversity-oriented mindset** to address new challenges arising from a more diverse manufacturing workforce*

Manufacturing is not disconnected from global developments such as increased migration, an ageing workforce and more diverse economies. While some countries experience certain phenomena more than others, most countries face the challenge of an increasing gap in the number of manufacturing talent (see chapter two on the skills gap in numbers). This will lead to more diverse manufacturing environments in terms of gender, ethnicity, and physical ability and require more inclusive and thoughtful work environments. Therefore, future manufacturing workers need an inter-cultural and -disciplinary, inclusive, and diversity

oriented mindset to address new challenges arising from managing a more diverse group on the manufacturing shop floor and beyond. This includes, for example, migrants with different language requirements, disabled workers, and under-represented groups. While some aspects might be addressed with technology, such as multi-language operating systems or training materials using visuals and AR, the skill to navigate such a diverse environment as well as efficient and effective communication will be key to sustainable operations in manufacturing companies.

7

*Cybersecurity, **privacy, and data/information mindfulness** to reflect the rapidly increasing digital footprint of the manufacturing value chain*

The digital transformation in manufacturing leads to more data and information, integrated digital communication through platforms, as well as the digital thread from design to manufacturing, use and recycling. This offers tremendous opportunity; however, it also brings about new challenges that require a certain skill set for future manufacturing workers. Manufacturing workers need to be mindful of data and information and understand that these are highly sought after resources that need to be handled with care. Constant connectivity becomes a norm in daily life and this is no different on the shop floor, R&D, or an engineering design office. Yet, data and information from the production line can cause significant problems in the wrong hands, such as industrial espionage or insider trading. In the worst case, this can have significant economic or even deadly consequences. Imagine a criminal element gaining illegal access to a company's CAPP/CAM system. The infiltrators could change parameters with the objective to produce parts that fail at a different rate as originally designed, and alter the quality monitoring process to allow the altered parts to pass. These parts, for example, structural components in a fighter jet or civilian aircraft, could then fail when exposed to a certain stress during the operations of the systems, with deadly consequences. The skill of being mindful of such possibilities and an understanding of the procedures and possible pitfalls will be increasingly sought after and ultimately be a requirement for future workers in a digital manufacturing environment.

8

*Ability to **handle increasing complexity** of multiple requirements and simultaneous tasks*

Manufacturing processes become increasingly complex and interconnected, while continuously providing more information and connectivity. The Industry 4.0 mantra of "batch size one" pushes the customer order decoupling point further and further into the manufacturing value chain. The manufacturing workers of the future will have to cope with this increasing complexity and develop the ability to handle multiple, often conflicting requirements and simultaneous tasks. These can include requirements such as environmental impact, customer value, and process efficiency. They will have to do so while being constantly connected without getting distracted, overwhelmed, or burnt out. This puts a strong emphasis on the ability to multitask and prioritise as necessary and requires an understanding of the priorities of the whole operation, not only of the specific process. For example, an operator that all of a sudden has to juggle the environmental impact of the lubrication with the energy use of their CNC milling system that manufactures one of a kind parts to customer specification. The specifications can change up to the time when the machine starts the subtractive process and does provide real time data to the customer and subsequent processes.

9

*Effective **communication skills** with humans, IT, and AI systems through different platforms and technologies*

The future manufacturing shop floor and worker is characterised by connectivity and exchange of data and information in addition to the physical parts and products. In this environment, effective communication skills are key. Effective communication in this environment includes humans, IT and AI systems, as well as all other stakeholders. IIoT platforms and other technologies enable real-time communication and exchange of data. However, the ability to break down a complex problem and explain it to others, within or without disciplinary borders, is a key skill, as workers will change jobs frequently making fast and effective knowledge transfer is more important than ever.

10

***Open-mindedness towards constant change**, and transformation skills that constantly question the status quo and initiate knowledge transfer from other domains*

The last key skill is one that is difficult to capture in words. However, this skill might be one of the most important factors for successful manufacturing operations in the future. Technology lifecycles have shortened dramatically and with it the face of the shop floor and the tools used in manufacturing. New technology implementation projects will be the new normal and constant change a reality manufacturing workers will have to cope with. Workers will have to be open to learn constantly and adapt to changing conditions. The notion of having fully mastered a subject will be a thing of the past, and this puts a strain on manufacturing workers. The support system among the peers will become a key element where mentoring or reverse-mentoring systems are avenues to address this constant change. New workers, or digital natives, might mentor a seasoned technician on the use of a new cloud-based visualisation tool on a tablet, while the technician trains the younger colleague in safety procedures of the laser cutting process.


Production Rate

Emerging Roles

The rapid proliferation of new technologies has and will continue to transform roles within manufacturing. This section will outline examples of roles that the WMF believes would increase in importance in the future. While the list of emerging roles is not exhaustive, the following examples show that the advent of Industry 4.0 is not only augmenting the nature of existing manufacturing roles such as lean managers but also leading to the creation of completely new roles such as collaborative robot experts and industrial big data scientists. It is therefore imperative that educators and training providers ensure that there is adequate training to prepare workers for these emerging roles increasingly required by the job market. Companies equally should place emphasis on transition opportunities for existing workers to take on new or augmented roles within the organisation, providing the workforce education and training programmes needed to support such transition.

		
ROLE	**Digital Ethics Officer**	**Lean 4.0 Engineer**
DESCRIPTION	■ The rapid pace of digital technologies such as artificial intelligence have profound ethical implications for organisations, including fair usage of data, strict compliance to regulations, and mindfulness on how deployed technologies impact the society. The digital ethics officer oversees the development, implementation and monitoring of ethics and compliance programmes (policies, procedures, meetings, training and audits)	■ Industry 4.0 technologies have a great potential to augment or complement the existing lean practices in manufacturing. Advanced data analytics for instance can provide information not previously available to better understand and respond to customer needs or improve process efficiency. Companies who are able to capitalise on the synergies of two approaches can also expect significant reduction in costs versus those that either approach achieves individually.[1] The Lean 4.0 Engineer is able to identify how the integration of Industry 4.0 technologies and various lean methods can provide value to improve operational excellence.
MAIN RESPONSIBILITIES	■ Lead the development of systems and frameworks for the responsible use of technology and data throughout the organisation ■ Analyse the internal and external environment to understand risks and repercussions of different drivers to business activities ■ Ensure compliance with the digital ethics code through regular audits, as well as timely assessment and resolution of complaints ■ Collaborate with stakeholders to build ethical frameworks for the use of emerging technologies, in the absence of established standards and laws, to be viewed as the leader in the space	■ Identify types and forms of *physical* and *digital* waste ■ Redesign processes end-to-end to improve them with the introduction of Industry 4.0 technologies and organisational innovations ■ Avoid and prevent *digital* waste that may come into existence in the digitalisation processes ■ Serve as a change agent for Industry 4.0 and lean integration at all the organisational levels
TOP SKILLS AND COMPETENCIES REQUIRED	■ Proactiveness and receptiveness to new developments in the technological, legal, regulatory and ethical landscapes. ■ Strong communication skills to interact with people from different levels of the organisation as well as external stakeholders ■ Transformative leadership with the ability to inspire others towards a common cause	■ Expertise on lean principles, practices, techniques, tools ■ Expertise on key Industry 4.0 technologies ■ Established use of industrial analytics ■ Ability to simulate manufacturing systems and processes ■ Outstanding leadership skills complemented by forward and holistic thinking and participatory approach

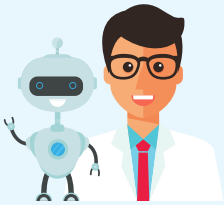
in Manufacturing

Industrial Big Data Scientist

- Generating value from data from manufacturing processes is both a challenge and opportunity. The amount of data generated from a wide range of sources such as sensors is increasing at an unprecedented rate paving the need for as structured approach to collect, analyse, store and share data. Data, if captured and used correctly, has profound benefits for manufacturers such improved process efficiency and reduced time to market. The industrial big data scientist is a central figure in analysing and manipulating data to unlock its value for the company, such as generating insights leading to new business models.

- Collaborate with the production and other company functions to see how data can be exploited to support decision making
- Design and create models to mine, analyse, and manipulate data to solve complex problems
- Conduct tests to validate data to ensure it is correct and complete
- Use visualisation or other tools to communicate results of analyses to different stakeholders

- Capacity to identify data sources and work with large sets of both structured and unstructured data
- Deep knowledge of data mining, machine learning and predictive analytics
- Ability to summarise and present insights to executives and other users
- Creative problem solving and ability to manage complexity
- Knowledge of the manufacturing domain and Effective communication skills



Collaborative Robots Expert

- Already, industrial robots are revolutionising production resulting to significant levels of efficiency. In the years to come, collaborative robots which can be easily programmed and are able to interact and support factory personnel in different work settings are expected to become more widespread. The collaborative robots expert ensures smooth interaction between humans and robots, and work to maximise capabilities of robots to support in various processes.

- Observe work processes to continuously identify opportunities where cobots can be deployed to improve business processes
- Define, install, configure, and maintain “co-bost” integrated with factory/ enterprise systems
- Deliver technical support and training to workers to work optimally with co-bots

- Deep know-how of programming
- Ability to understand and use AI
- Ability to exploit intuitive user interfaces and human-cobot collaborative modes
- Strong acumen for problem solving & process improvement
- Entrepreneurial and User oriented mindset with ability to anticipate user needs

IT/OT Integration Manager

- Cost synergies and increased operational performance are only some of the factors driving the convergence of operational technology systems (OT) with IT systems. The IT/ OT Integration manager facilitates the interactions between IT systems and production environments to enable real time decision making, reinforce security of assets, and increase the organisational capabilities to capture new business opportunities.

- Develop the required infrastructure such as applications and secure networks to optimise data flows
- Formulate and monitor guidelines to ensure the integrity of data and connected assets
- Coordinate actions and providing technical support to IT and OT teams

- Strategic leadership to gain the commitment of IT and OT actors and handle multiple requirements
- Capability to design and build an Industry 4.0-oriented and data-driven architecture
- Experience of network and data communication systems
- Knowledge and ability to apply standards and monitoring their evolution
- Security and safety management

Digital Mentor

- Workplaces are continuously being transformed by newer technologies changing the nature and execution of tasks. For this reason, IT know-how such as the use of digital peripherals to communicate virtually or to support other tasks have become indispensable. The Digital Mentor helps personnel across the organisation to be comfortable working with technology. Special focus may be given to boost the confidence of older workers who may be hesitant to learn how to use new digital tools.

- Conduct regular trainings on the use of essential IT hardware and software to personnel
- Provide training on use of virtual, augmented reality, and other wearable devices
- Educate employees on importance of data mindfulness or privacy

- Knowledge and proficiency of digital tools or peripherals
- Empathy and patience towards others
- Intercultural mindset and openness to diversity
- Strong communication/ listening skills

[1] *Boston Consulting Group (2017). When Lean Meets Industry 4.0 Next Level Operational Excellence Retrieved from: https://www.bcg.com/publications/2017/lean-meets-industry-4.0.aspx*

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Cross-Functional Development as the Base for Successful Future Manufacturing: A TRUMPF Case Study

Andreas Witt
Head of Software Development, TRUMPF Werkzeugmaschinen

Victoria Beinert
Executive Assistant to Head of Software Development, TRUMPF Werkzeugmaschinen

With regard to innovative skills for the future of manufacturing, TRUMPF was already ahead of its time in 2014. That year, TRUMPF began developing the TruLaser Center 7030 as the first fully automated laser cutting machine in TRUMPF history, by using agile methods and finalising the development within only two years. A record-breaking achievement that could only be done by discovering innovative paths with respect to internal collaboration methods. Software development and the manufacturing department needed to find a new way of working hand in hand: cross-functionally.

Communication is the real deal.

Before elaborating about the success story of cross-functional teams, let's start by defining the issues that can come up when cooperation and communication between software development and machine-based manufacturing fail. The value chain in industrial manufacturing is built on order preparation being software-based and the physical production process being machine-based. The actual parts-manufacturing-process needs to be monitored (software-based). However, for monitoring to work well, it must be closely connected with the sensor technology of the machine (machine-based). You might already see the challenge: how can a software developer come up with a perfectly fitted solution for a machine, when there is rare communication between the machine-engineering and software development department? Both parts can create the most beautiful piece of software or machine, but without them being in symbiosis, the output for the customer will never live up to its full potential.

Previously, towards the end of a project, project management would realise that even though all the axis were moving perfectly, and the laser would cut well, the customer would eventually not be able to easily programme new functionalities such as microjoints into the machine if he needed to. The required feature was still missing in the CAM system because software development and machine-construction had not discussed topics like these. Now let's think about a machine development project for an upcoming trade show, of course, under time pressure. Then, as soon as an issue like missing features in the CAM system was discovered, software developers had to quickly come up with an acceptable set of functions for the machine to be launched on time at the trade show. Communication lacks like these caused tendency and pressure within the organisation where it could have been avoided. The highest goal for a machine-building company such as TRUMPF has been and will always be to provide the customer with a well-functioning machine, no matter the internal processes.

Very soon after the start of the TruLaser Center 7030 project it became clear that the traditional approach of developing a machine would not work. The team tried to combine proven processes in new ways. However, reality kicked in quickly: more radical steps needed to be taken in order to achieve the goal of designing a machine that could sort automatically. They broke out of comfortable routines and developed completely new technologies whenever state-of-the-art offered no sufficient solutions. Former borders between departments could no longer play a role as this would have obstructed the successful development process. Hence, cross-functional teams between software development and machine development were set up. The core team was made up of more than one hundred employees from service, sales, product group, development, purchasing, production and project organisation departments. While the software teams were experienced in the application of the agile method "Scrum", it was all new for machine construction teams. Intensive coaching and a few excellent scrum masters brought the teams together. The agile approach, focusing on cross-functional expertise which was applied during the development of the TruLaser Center 7030, guaranteed that software-based order preparation and monitoring perfectly matched the physical manufacturing of the parts. The key benefit of a TruLaser Center over any current state of the art laser cutting

TruLaser Center 7030

machine is that manufactured parts exit the machine fully sorted and neatly stacked by part type. In addition, the skeleton of the metal sheet that remains after the cutting process is automatically discarded. The pallets containing the sorted parts can be extracted from the machine into storage while the machine is still running. All of this combined implies that production is possible without operator intervention during night shifts and even on weekends. The "Smart Gate" is one essential feature enabling 24/7-production. It supports the processed parts during the cutting process and therefore controls the exact position for automatic extraction. Furthermore, it is a prime example of how the intimate, cross-functional collaboration between software development and machine development guaranteed the success of the TruLaser Center 7030: Machine engineers on the team had planned to build two smart gates into the machine as physical stability of the parts would have been easier and cheaper to achieve. However, this approach would have increased complexity in the programming a hundredfold. Formerly, in the traditional development process, this approach would have been revealed much too late and would have cost time and money to adapt. The development of the TruLaser Center 7030 is a paradigm for machine development which led to all following machines being developed in a similar way.

In conclusion, it can be said that the most important skill for successful future manufacturing at TRUMPF is the ability to transform a formerly very classical organisation into a business that facilitates collaboration and communication between different departments. Machines are complex systems with various stakeholders. Only through agile, interdisciplinary teamwork without borders the success of projects can be ensured. Through machine engineers and software developers starting to evolve mutual understanding for their needs, challenges and tasks, they can generate their products and services at a similar pace. Further skills needed for success are communication skills, high flexibility in thinking and working together, self-organised work and speed. It is the customer who benefits the most: At the end of the day, he receives a machine that supports his specific processes and needs to a maximum.

"Skills for Advanced Cosmetic Manufacturing in Italy"

How an SME value chain invests in multidisciplinary skills for the cluster of the future.

Luca Fumagalli
Assistant Professor, Politecnico di Milano

Graziano Fumarola
Chief Operations Manager, Ancorotti Cosmetics

Giovanni Righini
Professor, University of Milan

Marco Piacentini
Managing Director, Eurofins Biolab Cosmetics & Personal Care IT

More Than Just Makeup

The global definition for makeup is in fact, "Cosmetics & Personal Care" which clearly shows that there is much more than just beauty behind it. Daily, everyone comes into contact with many products from this vast category. Many have to do with cleaning and perfuming, perhaps to enhance the way we look, or simply to protect our body while keeping it in good condition, as well as adding or covering its natural odor. Cosmetics & Personal Care products are daily companions since we can track back human existence: the oldest makeup trousse was found in Africa, dated approximately 167,000 B.C. As for modern times, cosmetics appeared at the beginning of the twentieth century and since then their industry has never been seriously impacted by economic crises.

A Best Practice Cluster Investing in Advanced Cosmetic Manufacturing

The Italian cosmetics manufacturing supply chain, with its 15.5 billion Euros of income (2017, Teha), is worldwide acknowledged for its break-through technical solutions, its high customisation and its outstanding creativity. These elements allow the Italian cosmetic industry to be highly competitive on the global market. In Italy, the cosmetics supply chain has its complexities, being the result of an integrated network of small and medium companies, each contributing to a different step towards the creation of final products. While global cosmetics sales have never experienced a real contraction, the easier and easier access to final consumers has favored the creation of new brands, has increased the level of competition and has pushed authorities to enforce tighter controls on cosmetic products safety and on the reliability of the accompanying claims. The current scenario represents an opportunity to foster Italian OEM and ODM cosmetics companies. Particularly in Lombardy Region, where the heart of worldwide makeup manufacturing beats, a selected cluster is bringing together institutional investors and leading companies to implement Industry 4.0 solutions. Also, local authorities and research and education institutions are joining their forces to develop highly specialised skills, promoting a favorable ecosystem and thus driving system-level innovations at scale. In this context, from a research and innovation agreement with Lombardy Region (2016), an Observatory on Advanced Cosmetic Manufacturing has been launched as a landmark for studying a new generation of models and processes in the cosmetics value chain. The observatory aims at developing highly replicable applied research for the benefit of the entire cosmetic supply chain. The Observatory is based in the city of Crema (Italy) supported by several leading companies: Ancorotti Cosmetics, Eurofins Biolab, Lumson, Omnicos Group and Regi, with the management of REI – Reindustria Innovazione and the collaboration of Politecnico di Milano and the University of Milan.

Collective Impact and Positive Perceptions of Manufacturing

The AD-COM Observatory (www.ad-com.net), after an initial phase devoted to business process mapping, has set up collaborative actions between university researchers and businesses, according to specific objectives monitored over time. It focuses on developing productivity with real-time simulation that exploits models and algorithms to promote process optimisations, such as scheduling of the production or warehouse management. In addition to research, relevant communication actions and other networking events are organised. These are useful to create awareness on identified gaps, to promote and support a positive perception of manufacturing and to activate opportunities of virtuous exchange in a professional environment. It is believed that the key to the success of an interconnected supply chain is the positive atmosphere from which also small entrepreneurs can benefit.

Essay

Domenico Cicchetti
Chief Executive Officer, Omnicos Group

Giovanni Broggiato
Vice President, Lumson

Alessandro Ratini
Chief Executive Officer, REGI

Ilaria Massari
General Manager, REI – Reindustria Innovazione

Social Welfare Creation, Rethinking Skills, and Organisational Contexts

Cosmetics is a creative and stimulating world. In terms of employment, companies have annual growth rates of around eleven to twelve percent. In the North of Italy, the background of professionals employed in the cosmetics industry is not only in biochemistry but also in mechanics and in advanced process management.
The analysis of current and missing skills for Industry 4.0 solutions has been performed to identify the specific competences and organisation of human capital in companies. This aims at making the organisations ready for the implementation of Industry 4.0 technologies, in line with the concept of human-centric manufacturing.
Dealing with 4.0 technologies applied to cosmetics manufacturing processes, companies requires critical judgement and a lot of creativity. The inventive capacity grows when enterprises attract both industrial designers and technicians, able to effectively take care of production, maintenance and planning. The industry produces a relevant employment of women and young people. This is mainly explained by the attitude of the companies to offer dynamic jobs and attractive perspectives for the future. Employees appreciate the deep spirit of innovation, connected to the boost to the product personalisation and the craft heritage.

Totally Safe Cosmetics and the Rise of the "Natural" Beauty Industry

The Cosmetics & Personal Care value chain is strongly impacted by the social system and in turn strongly impacts on it. For this reason, sustainability is a keyword: Social Sustainability, Environmental Sustainability, Ethics, Corporate Sustainability, Industrial Sustainability, all these concepts come together in leading the way for future global Cosmetics & Personal Care value chain. Science and emotions (driving the market) are required to cooperate to build reliability and confidence in global consumers. In a world that is more and more ruled by fast sharing of information, it is mandatory to be transparent, understandable and accessible. To match market expectations, the challenge is to be efficient and effective in fast design, prototyping and large-scale production to offer real-time and accurate information about raw materials, packaging, production processes, final products to the entire value chain.

That is the goal of the partner of AD-COM Observatory, Eurofins Cosmetics & Personal Care, part of Eurofins Scientific Group, the world-wide largest company in Life Science Testing: to offer integrated testing solutions by merging analytical and clinical science to guarantee reliability and trust to all Cosmetics & Personal Care value chain players.

AD-COM Advanced Cosmetic Manufacturing
*AD-COM (www.ad-com.net) is a research and innovation agreement with Lombardy Region, that gave birth to the **Observatory on Advanced Cosmetic Manufacturing**, as landmark for study the new generation of models and processes in cosmetic value chain. It is based in the city of Crema (Italy) and powered by some of the leading companies of the cosmetic cluster: **Ancorotti Cosmetics, Eurofins Biolab, Lumson, Omnicos Group** and **Regi**, with the management of **REI – Reindustria Innovazione**, in collaboration with two Universities **Politecnico di Milano – Technical Universities of Milan**, and **University of Study of Milan.***
AD-COM is co-funded by the POR FESR 2014-2020 (European Commission, Italian Government, Lombardia Region).

SECTION 4
SKILLS ASSESSMENT AND DEVELOPMENT

Each country, sector, company, team or individual must be able to thrive in future manufacturing. To this end, developing a strategy and roadmap toward the skills of future manufacturing is a crucial and urgent priority for all stakeholders. Skills assessments work to achieve this goal by providing a clear and methodical process of understanding and appraising the skills and competencies of people. Assesments can be conducted through many mediums as is later discussed in this chapter. However, the overall goal remains the same: to gain an accurate gauge of the level of skills possessed by workers. Skills assessments are a valuable tool that can help us to understand where growth is possible rather than a test that simply points out weak areas.

SKILLS ASSESSMENT

Skills Assessments Represent a Key Step to Determine the Current Situation and Available Competencies, Identify Needs for the Future, and Plan the Transformation Process Toward a Desired Vision

Skill assessments can help policymakers map the skill strengths and weaknesses of worker segments, communities, regions, and make evidence based decisions about education and training, labour, industrial and innovation policies.

Skill assessments can help manufacturing companies uncover learning and development needs, prepare purposeful workforce plans and use budgets effectively. It can also positively impact attractiveness, as well as engagement in the company. Although manufacturing companies may implement strategic skills assessments individually, there are also clear advantages to taking coordinated actions on an industry-and/or value chain-wide scale.

It can also can help individuals understand where they stand and, when matched to personal goals, professional profiles and career aspirations, to identify any further learning for personal and professional development.

It is important to underline that the assessment of skills should not be considered as a "once in a lifetime" exercise but it must be viewed as part of a broader system and continuous collaborative process involving multiple actors at different levels, with the aim of creating and diffusing changes towards continuously evolving, socially sustainable digital transformation objectives.

SKILL ASSESSMENTS AND SUSTAINABLE HRM

The Extent and Speed of Changes Triggered by New Technologies Require More Strategic, Holistic and Sustainable Human Resource Management (HRM) Solutions

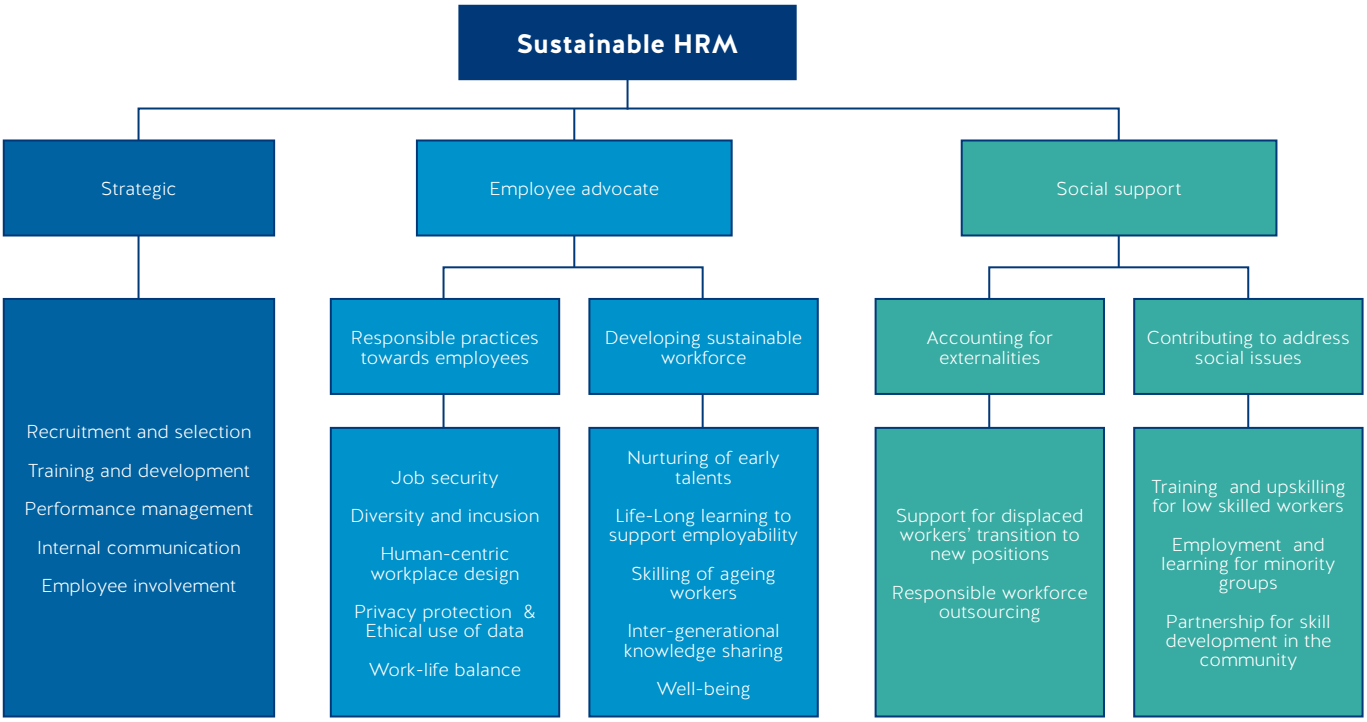
As stated by executives surveyed by McKinsey in 2018, companies cannot afford to wait for others to find a solution for skill problems, but instead must take the lead in exploring and exploiting new approaches." There must be collaboration with governments, education/training systems and other stakeholders, to close the gaps and address development needs, in order to achieve future strategic objectives as well as human and societal well-being.[38]

In this respect, strategic Human Resource Management

Figure 23

EXTENDED PEOPLE MANAGEMENT ROLES IN DEVELOPING SUSTAINABLE ORGANISATIONS

(Adapted from Podgorodnichenko et al., 2019)



has long recognised that human capital is a key source of competitive advantage. Accordingly, in order to achieve superior performance, organisations must effectively acquire, develop, retain, motivate and provide employees with opportunities to best apply their skills to processes aligned to the company's strategic goals and changing environmental conditions.[39] However, a strategic HRM approach may be not enough to address present and future challenges, but an extension toward sustainable HRM is needed (Figure 23).[40] Sustainable HRM considers people to be a pivotal asset and embraces, "a logic for renewing, regenerating and reproducing people and social resource.s"[41] Indeed, it promotes a more contextual, inclusive and long-term view to people management. Through co-creation with internal and external stakeholders, it aims at contributing to the enhancement of human, social and economic outcomes within the organisation and beyond organisational boundaries.[42]

PHASES OF THE SKILL CYCLE

Within sustainable HRM, manufacturing companies can enhance their employees' preparedness for the future and leverage people's strengths by going iteratively through the four macro-phases of the skill cycle (See Figure 24.)[43]

1. *Skill mapping* aims to provide the organisation with a forward-looking overview of the necessary skills to fulfil its future targets. Skill mapping can be done for the organisation as a whole or for a specific department or job family. Anticipated changes in technologies, processes and tasks as well as design decisions about the future organisation of work must be considered. The required proficiency level for existing or new roles is defined in this phase as well.

According to Chartered Institute of Personnel and Development, "...internally generating a skill and competencies framework that builds in business relevance while also drawing on external standard models represent a good practice."[44] As an example, Figure 25 shows the links between the EU e-Competence Framework and companies' skill management. In this respect, it must be highlighted the absence of a general reference framework that is capable of capturing the main skills needed in future manufacturing and that can be used as a common source of information by all manufacturing stakeholders.[45] [46] [47] [48]

2. The second phase is *skill diagnosis*, meaning an assessment of the current situation of the skills and equivalent proficiency level that employees possess. A skill gap analysis is also essential in this phase, in order to highlight workers' strengths and potentials, identify and prioritise the gaps between the type and level of skills that employees possess in comparison with those required in future.

Figure 24

SKILLS LIFE CYCLE

(Source: Spitzer et al., 2013)

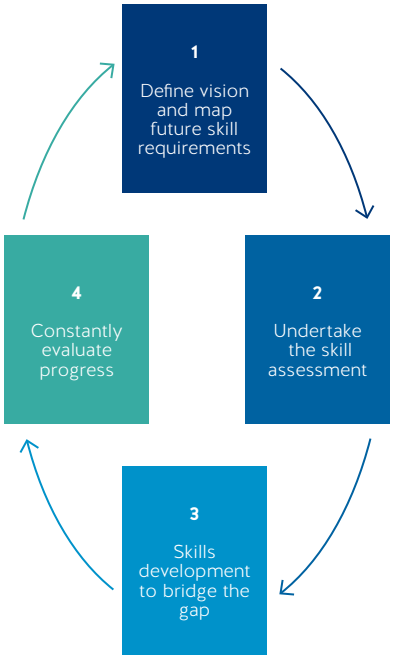
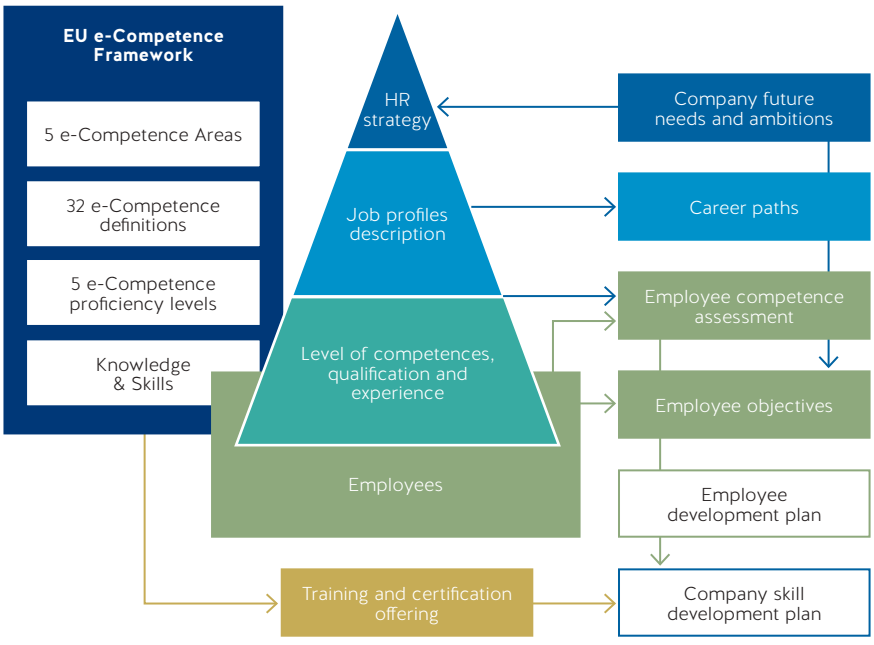


Figure 25

EUROPEAN E-COMPETENCE FRAMEWORK AND LINK TO COMPANY COMPETENCE MANAGEMENT

(Source: e-competence framework)



3. *Skill development* is the third phase and deals with the formulation of the plan to bridge the skill gap, scheduling and implementation of learning and developmental activities in the short, medium and long term, so as to improve the types and/or proficiency level of people skills, according to the previous two phases.
This phase will be discussed in depth in the later skills development section of the report.

4. The last phase is the *monitoring of skills*, namely the continuous evaluation of the results achieved by skill development, the transfer of leaning into job activities, and the impact on individual, organisational and community outcomes.

KEY CHARACTERISTICS OF AN EFFECTIVE SKILL ASSESSMENT

Although skill assessments can take many forms in different manufacturing companies, some characteristics that can influence its effectiveness can be identified.[49] Specifically, skill assessments should:

1 *Have commitment from top management and be linked to the strategy*

Launching a skills assessment cannot be taken lightly. Commitment from the senior management team is crucial to have a good fit between people and manufacturing digital transformation strategies.[50] When both areas mutually support one another, organisations can harness synergies and achieve better outcomes. Overall, empirical evidence supports the complementarity relationships among HRM practices, organisational innovation (e.g., teamwork) and technological innovation in influencing the effectiveness and sustainability of manufacturing companies.[51] Moreover, engaging with stakeholders, including operational managers, worker groups and their representatives, is vital and they need to be engaged early in the process.

2 *Be proactive and agile*

As higher agility and flexibility are required, the focus is shifting toward more rapid assessment, development and deployment of training solutions.[52] Indeed, it is important that the process is forward looking, dynamic, agile and continuous. It should be subject to frequent feedback and review to remain relevant in a rapidly changing environment. For instance, at Airbus SE there is no more a single annual review of competencies and learning needs, but, according to the company, leaders and employees should do it for their own benefit at their own rhythm.[53]

3 *Have people at the centre*

The decision to learn ultimately resides within people who are the future designers, managers and users of digital manufacturing systems, and key agents in successful, socially sustainable digital transformations. Indeed, workers must be active participants able to influence the whole process. Workers must be fully aware and empowered to participate, co-determine their work, the assessment of skills and their learning activities.[54]

It is also important to recognise that people may have different needs, motivations and aspirations, and they may experience diverse barriers to participate, learn and use what they have learned on the job. Indeed, a targeted approach should be adopted to foster fairness and inclusion.

Overall, evidence shows that when there are positive incentives, leader and peer support, a learning and innovation culture that promotes proactiveness and initiative and learning opportunities then motivation to learn and application of skills on the job are generally enhanced.[55]

4 Combine the individual and collective view

It is important to underline that traditionally the focus of skill assessments has been on individuals. However, manufacturing companies should no longer be seen as "tailoristic" structures where individual skills are "inserted" or in which, given the organisational processes, individual's skills come into play as "gears of a mechanism." But flat organisational structures and decentralisation of power have made autonomous and diverse teams on the field increasingly crucial.[56] Consequently, a collective view on competences has emerged alongside the individual view.[57] The two "ways of seeing" should be considered as complementary, as "each approach 'selects' and 'deflects' attention from specific aspects."[58]

5 *Allow to identify the right mix of interventions*

The combination of formal, non-formal and informal learning can be leveraged in order to foster skill development. Job-rotation, communities of practices, reverse-mentoring, involvement into industry-academia projects, apprenticeships, redesign processes and workspaces to foster knowledge sharing, can all be useful options. Moreover, not all skills can be developed internally, but gaps can also be closed via recruitment from outside the company or via collaboration with technology and service partners.

6 *Have a cost-benefit analysis including social impacts*

The results must be actionable, such that they can be easily transferred into strategic actions and, thereby, have an

impact. In this respect, it is worth conducting a cost-benefit appraisal, to check whether the intended benefits outweigh the expected costs. During the appraising of the business impacts, the potential social impacts should be considered as well, as those round out the picture of total costs and benefits.

SKILL ASSESSMENT TECHNIQUES AND TOOLS

A variety of methods, techniques and instruments have been proposed for skills assessment, which can be employed either individually or in combination one with another to measure skills. In the following sub-sections, some of them are briefly presented, and their main advantages and disadvantages are illustrated, as well as some examples.

Depending on the assessment goals and target groups, ethical, legal and regulatory requirements, organisation circumstances and available resources, manufacturing companies must find the right mix of methods and balance between using solutions already available on the market and creating their personalised ones. Manufacturing companies may also take advantage of external specialised consultants.

Self-Assessment

Self-assessment tools allow individuals to self-evaluate their skills, often with surveys or online questionnaires. Self-assessments can be used to raise employee participation, accountability, and stimulate self-reflection. Since employee development is first and foremost personal development, employees who appraise their own skill level may become more motivated toward learning and empowered to take control of their improvements.

An example is provided by the "Online-Kompetenz-Check-Industrie 4.0" tool by the IMPULS Foundation of the Mechanical Engineering Industry Association (VDMA).[59] The online tool enables a general self-assessment of the necessary skills of engineers for Industry 4.0. Target groups are companies, employees and students.

The "DREAMY4Skills" by the Manufacturing Group of Politecnico di Milano School of Management can be used to evaluate hard and soft skills of managers and operators of manufacturing companies embracing Industry 4.0.

Another example is the Council of European Professional Informatics Societies' free online tool to assess ICT skills, based on the European standard e-Competence Framework. The e-Competence Benchmark provides professionals with a personal skill gap analysis that compares their competencies against those required for a range of European professional profiles.[60]

Assessment Tests

In knowledge-based assessments, individuals respond to carefully designed test items, while in performance assessment, individuals are monitored by a human observer or a software while being engaged in solving authentic, real-life problems.

For instance, Scientific Management Techniques offers a validated skills assessment programme, using portable hands-on assessment machines and a task-oriented methodology.[61] Manufacturing companies can also set up online programming tests using platforms like Qualified, HackerRank, Codility, and choosing to test employees in one specific programming language or over multiple ones (Python, R, etc.).

Further, psychometric tests are a standard and scientific method used to measure personality, interests and cognitive abilities, such as numerical reasoning or abstract reasoning.

As an example, in the digital area, the Mindset for Digital Agility Quotient measures digital skills as, "...understood as soft skills needed to act and interact in an agile and adaptable way in increasingly 'digital' workplaces, which require speed, flexibility and the ability to feel at ease with digital technologies and complexity."[62]

There is also an emerging trend to gamify testing or to use online gaming apps to test a range of abilities. While these tools engage employees in a fun, positive experience, sometimes they are less rigorous from a psychometric perspective. Moreover, this type of assessment is also relatively expensive to design, test and implement, so adoption remains limited at present.

Interviews

The interview method is a very flexible but time-consuming method that consists of asking questions face-to-face to both workers and managers in either an individual or a team setting. Interviews can also collect "felt needs" of training to improve either the person or the group.[63]

Multisource Feedbacks

For developing employees, techniques such as multisource feedback involve the collection of ratings from multiple sources about the effectiveness of an employee on a set of skills and their potential for future roles. In a 360-degree assessment, people all around the employee provide feedback, including the employee themselves, managers, peers and team members and customers. Multisource feedback is usually recommended to developing and strengthening teamwork and accountability, while reducing bias and discrimination tendencies that may affect single source ratings.

For assessing teams' collective competences, the TEAM

BOOSTER tool by PerformanSe focuses on the team as a whole, unlike other approaches which often focus on the individuals and their roles within the team. The results are shared collectively with the entire team, which takes charge of its own agenda for change and builds its own development plan.[64]

Assessment and Development Centre

In assessment centres employees are involved in several interactive exercises that simulate job related situations, and multiple assessors evaluate their skills on several dimensions and task lists.[65] Simulations provide the opportunity to observe complex behaviours of people as they interact with others, solve problems, and act upon their analyses. Among the variety of different exercises, role-plays, group discussions, case studies, and in-basket exercises (e.g., structuring different tasks via digital media) are especially common.

Human Analytics and Artificial Intelligence-Enabled Assessment

Companies should begin to use human analytics for an array of human resource issues, moving from basic data reporting towards more predictive analytics.[66 67] Specifically, seventy-one percent of respondents to the CIPD survey 2018 are using some data for skill development but only fifty-five percent consider their company to be effective in tackling this challenge (Figure 26).[68]

Thanks to the increasing availability of data regarding employees' activities from sensors, smart devices and advanced human machine interfaces, real-time information on individuals' and teams' performances and an evolving classification of their skills and proficiency levels can be obtained.[69] Consequently, in past years, there has been an increasing interest in new solutions employing a diversified set of data in assessment processes, and an extension of the analytical techniques to include artificial intelligence.

As an example, Visi-Skill by Experis, "...captures technical and soft skills of employees, analyses current roles and generates an AI dashboard of skills changes over time, projecting the evolution over a one to three-year period. AI uses semantics to analyse people within the organisation and/or prospective candidates, assessing whose skills most closely align with the current and future skills demands."[70]

The FLEXA platform, created by MIP Business School and Microsoft, is an AI platform acting as a digital mentor that assesses hard, soft and digital skills, determines where there are gaps and provides a personalised learning pathway in line with professional and personal interests.

In 2018, Coursera for Business launched an AI-powered skill benchmarking tool through which companies that subscribe to its training programmes can see their employees'

Figure 26

USE OF DATA TO TACKLE HR CHALLENGES

(Source: CIPD and Workday, 2018)

	Importance of this challenge to your organisation	Effectiveness of organisation at tackling the challenge	Agree data is used to tackle this challenge
Attracting and retaining high-performing/talented individual	74	55	66
Understanding workforce performance and productivity	73	56	75
Developing workforce human capital (knowledge and skills)	72	55	71
Understanding workforce culture and behaviours	70	56	69
Managing basic workforce operations (for example full-time equivalent employees, workforce distribution over geography)	67	64	74
Understanding the impact of modern and future working practices on the workforce (for example automation, outsourcing)	66	48	63
Delivering the talent management strategy	64	49	68

Base: global HR (n=1,288)

scores, how their employees' skills measure against their competitors', and what courses would help fill any gaps.[71]

The use of analytics and AI is still emerging and its privacy, legal, ethical and organisational implications are not fully understood yet. For instance, practices and tools designed to serve equality and fairness in assessment, can instead entrench biases against minorities who are not well represented.[72]

THE SME PERSPECTIVE

SMEs are vital to present and future manufacturing and society. Even though the SME landscape is diverse, it is still possible to say that often they tend not to have enough information, financial and time resources, demonstrate occasional skills assessment, and more difficulties with recruitment of skilled workers, and organising training.[73] Moreover, often SMEs consider that most of existing consulting services, management tools and training offers do not fit well into their requirements.

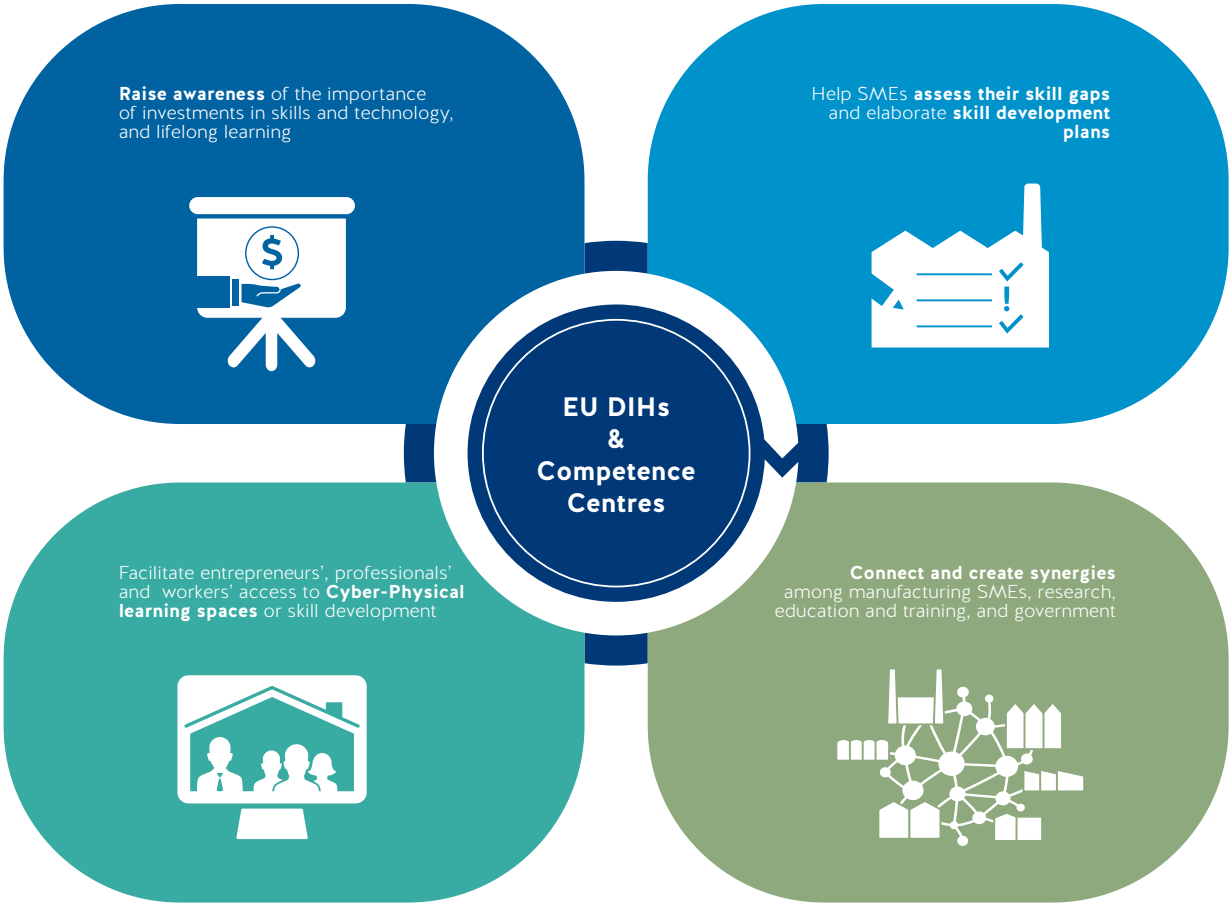
Industrial associations, clusters and competence centres can play a pivotal role in supporting SMEs all along the skill cycle and the assessment process through simple and practical instruments, easily accessible, affordable and quality services on strategic issues, and fostering SME cooperation in skill development rooted in the local ecosystem.[74] SMEs can find a range of services related to digital jobs and skills, from assessing skills needs, to training, financing and networking opportunities.

In this respect, the pan-European network of Digital Innovation Hubs is a key European initiative aimed at engaging SMEs to facilitate their digital transformation. Digital Innovation Hubs act as one-stop-shops where SMEs can find a range of services related to digital jobs and skills, from assessing skills needs, to training, financing and networking opportunities.[75]

Figure 27

SUPPORT TO SMES

(Source: WMF)



MADE: The Competence Centre on Cyber-Physical Systems

Filippo Boschi
Innovation Transfer and Research Assistant
MADE - Politecnico di Milano

Technological aspects have been the dominant part of what has been referred to as the Fourth Industrial Revolution. Few voices, on the other hand, have focused on the evaluation of (new) professional, technical and specialist skills and the related training that will be affected by digital transformation. This is a central aspect as the development of human capital will play a crucial role in the reindustrialisation of Europe; moreover, the quality and availability of highly skilled workers, who facilitate a shift towards innovation and advanced manufacturing, can be considered as one of the most critical driver of global manufacturing competitiveness.

Industry 4.0 implies, in fact, a systemic change in the manufacturing jobs. This is not about the introduction of one new technology, linked with an incremental adaptation of work systems, but about a multitude of new technologies and applications with different degrees of technical maturity and systemic effects. The introduction of these new technologies and the growing digitalisation and automation of manufacturing processes will require present and future industry workers to have their technical skills improved. In particular, workers will be required to have skills in digital techniques, computing, analytical thinking, machine ergonomics and manufacturing methodologies[1].

Manufacturers, therefore, should be actively investing in their workforce through retraining effort and upgrading employees' current skill sets. A proactive and strategic effort is needed to manage reskilling and upskilling to mitigate against both job losses and talent shortages.

In addition, it is fundamental to better understand what skills are readily available within the adult population and where the greatest skill gaps exist. This needs to be complemented with information about which skills are in greatest demand in the labour market and how to provide the appropriate reskilling pathways toward new employment opportunities.

In this context, the Italian Government released the National Plan Industry 4.0 for creating a distributed system to disseminate the concept of Industry 4.0, focusing not only on the implementation aspect but also on the development and enhancement of human capital.

This ecosystem is based on the combined and complementary effect of different Competence Centres spread throughout the Italian territory.

The Competence Centres (CC), following a public-private partnership model, are technical partner of SMEs. The CC objective is to work with the support of national universities and companies to carry out a series of activities such as: training and awareness creation on new manufacturing technologies, application of testbeds and teaching/learning factory based on Industry 4.0 aspects, creation of advisory services to guide the technology transfer for SMEs.

In particular, MADE, the Competence Centre initiated by Politecnico di Milano, consists of thirty-nine companies, divided between technology providers, consultants, system integrators, training experts and Inail; the Universities of Bergamo, Brescia and Pavia complete the partnership.

MADE has the mission to be considered as innovation centre able to address the manufacturing sector towards the knowledge and the adoption of Industry 4.0 technologies and allowing companies understand how the solutions available at the state of the art can be usefully used to improve their competitiveness. For these reasons, the methodology of "experiential learning," where the instructional theory and foundations are delivered across

technology-enabled environment using a teaching/learning factory approach has been implemented. MADE is a reality-conform production environment where every worker gets the opportunity to experiment with physically real equipment based on real industrial sites and to exploit a tighter integration with the Industry and society.

Following this approach, MADE is organised on 14 use cases focused on different technological areas. For example, user can test how a product can be designed by using augmented reality technologies, how to predict plant failures by using predictive maintenance policies, how to monitor machine performances while measuring energy consumption, or how to use big data to optimise the factory behaviour.

In particular, the activities offered by MADE can be divided into three macro-areas:

1. Business orientation, through the preparation of a series of tools aimed at supporting companies in assessing their level of digital and technological maturity through the use of specific evaluations and assessment activities;

2. Training activities using the approach of Teaching / Learning Factory as a framework for education / training paradigm for delivering manufacturing knowledge, skills and competencies in full accordance with the real business world and working environment, their constraints and future needs;

3. Implementation of innovation projects, industrial research, experimental development and technology transfer services in Industry 4.0.

Furthermore, based on different level of company awareness on digital manufacturing, a range of services to meet the needs of companies that are at different levels of maturity of Industry 4.0 understanding has been designed. It has been planned to provide a guide to those companies that are still very immature and to provide a training activities (through the learning/teaching factory approach) for those companies that want to learn how to use 4.0 technologies. Finally, for those more advanced companies that want to implement Industry 4.0, a set of consulting and innovation activities has been carried out.

[1] G. Angelo et al., "Education and Training, Digital Education Action Plan," in MIDIH -Manufacturing Industry Digital Innovation Hub -Grant Agreement No. 767498 Innovation Action Project H2020-FOF-12-2017, no. 767498, 2019.

SKILLS DEVELOPMENT

As previously discussed, there are many skills that are important to manufacturing that can be identified. Cutting edge education and life-long learning are crucial to progress towards this vision and meet the needs of the future labour market as previously discussed. This section focuses on how these skills can be fostered and developed.

Education and Life-long Learning are Crucial to Close the Skills Gap for Industry 4.0

Manufacturers are especially susceptible to the disruptive forces reshaping the future of work; examples include: technological advances, workforce demographics and more inclusive workplaces. To achieve and sustain successful performances in the long-term, they need a robust strategy to attract and retain employees, as well as support and implement education and training programmes. Yet, "... even though almost half of business leaders in our survey identify skills shortages as a key challenge, only three percent say their organisation plans to increase investment in training programmes significantly in the next three years. Companies can achieve more with less, but only if they are willing to innovate their training methods."[76]

When considering acquiring new skills and competences, there are different routes companies can follow; such as outsourcing activities, upgrading the workplace and infrastructure, recruiting new talent, or training existing employees. This section focuses on training and education by characterising different types of skill development strategies and methods for manufacturing organisations.

Figure 28

KEY FACTORS OF INFLUENCE FOR SKILLS DEVELOPMENT

(Source: WMF)

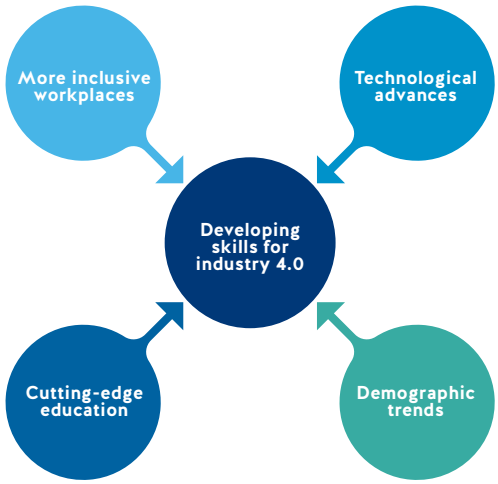


Figure 29

ACQUIRING NEW SKILLS AND COMPETENCIES

(Source: WMF)

Core skilling from prior education and work experiences (a.k.a. generic and transferable skills) is usually delivered through schooling and off-the-job training programmes. Combined with the right recruitment process, it should provide sufficient basic skills to get started in a new position. Technological advances and demographic trends (such as ageing and diversifying workforce) require more adaptable work environments and higher levels of collaboration between humans as well as between humans and machines. Therefore, the nature of generic and transferable skills is changing with more emphasis placed on soft skills, as discussed in chapter three.

These soft skills enable and enhance a person's ability to learn new technical skills which are becoming increasingly important. An employee with the ability to work with both front-end and back-end technologies is often preferred over a person with expertise only in one area. Multi-skilling (or cross skilling) can provide organisations with more flexibility and resilience, while increasing the intellectual capital and morale of the workers. During the expert interviews, it was noted that employees with higher education tend to learn

Figure 30

NEED FOR TRAINING IN ALL LEVELS OF THE ORGANISATION

(Source: WMF)

Figure 31

SKILLS DEVELOPMENT TERMINOLOGY

(Source: WMF)

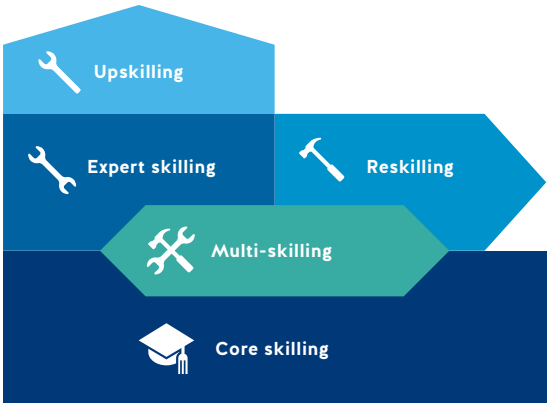
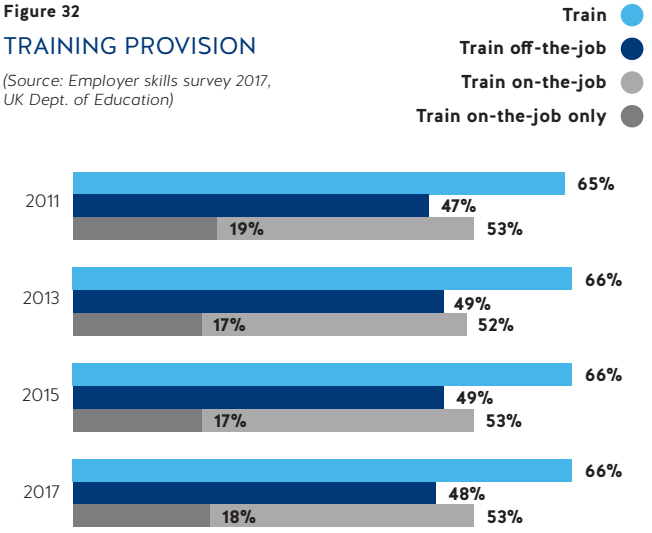


Figure 32

TRAINING PROVISION

(Source: Employer skills survey 2017, UK Dept. of Education)



faster and be more adaptable than those with secondary or vocational education.

While technological advances provide organisations with new opportunities for value creation, the real benefits can only be realised when the organisations also possess the right skills and expertise to make productive use of new technologies. Therefore, expert skilling is necessary to go in depth (as opposed to breadth with multi-skilling) and capitalise on these specific technologies. Such technical skills are often non-transferable and require vocational or on-the-job training, for example apprenticeships and internships, as they can only be obtained through hand-on practice and experience. While off-the-job training can deliver most types of core skills, on-the-job training is more effective for problem-solving and teamwork skills.[77]

Businesses Often Underestimate Employees' Willingness and Ability to Learn New Skills

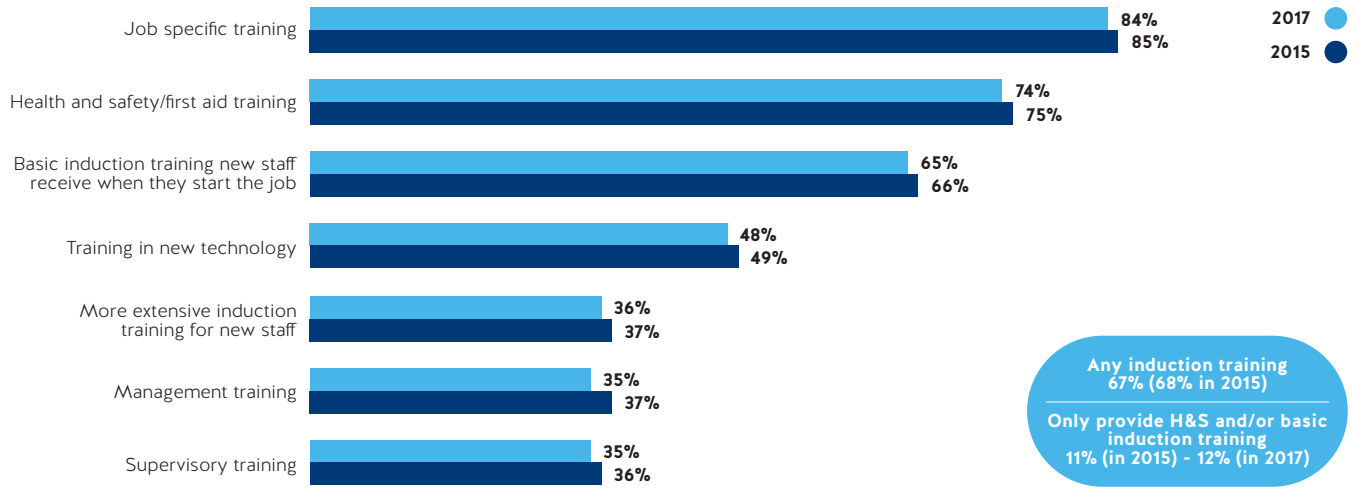
Job transition opportunities through reskilling are essential to retain workers and ensure their fitness with ever-changing work environments. Businesses often underestimate employees' willingness and ability to learn new skills.[78] The World Economic Forum notes that, "...only thirty percent of employees at risk of job displacement from technological changes received training in the past year, and those most at risk are often the ones who are least likely to receive any retraining at all."[79]

A direct way for organisations to acquire new capabilities is through hiring new talents already proficient in the latest technologies and work models. However, market and

Figure 33

TYPES OF TRAINING PROVIDED OVER THE LAST 12 MONTHS BY EMPLOYERS THAT TRAIN

(Source: Employer skills survey 2017, UK Dept. of Education)



technological changes are accelerating and becoming more disruptive than ever, making it challenging for educational institutions to keep pace and update their curriculum at such a fast rate. Thus, it is important that junior and senior workers alike regularly update and upgrade their knowledge and skills to keep up with these changes. It is not surprising that upskilling has recently become the central topic for the transition to Industry 4.0.

To support the aforementioned skill development types (basic skilling, multi-skilling, expert skilling, reskilling, and upskilling), various mechanisms can be used. After assessing the needs of their employee base, organisations must address these needs by carefully considering strategic investments in human and social capital, from recruiting and training new workers, to retaining and retraining the existing workforce through time- and cost-effective programmes. While the initial investment in skill development programmes is a major barrier, the benefits pay off in the longer term as productivity increases and workers stay with those organisations longer.[80]

Recent surveys show that a majority of employees receive either on-the-job or off-the-job training on various topics, most of which will be job-specific and health and safety related (See Figures 32 and 33). Despite the recognition that new technologies will change job requirements with additional knowledge and skills needed to productively exploit these technologies, "only three percent of executives intend to significantly increase investment in training and reskilling programmes in the next three years."[81]

Addressing the Skills Gap Phenomenon Should Not Be Seen as a Crisis Which can be Fixed, but as a Collaborative and Continuous Effort to Keep Up With Societal Change for a More Sustainable World

While it is critical to start addressing the skills gap phenomenon today, it should not be mistaken for a crisis which can be fixed once and for all with short- to medium-term actions. The role of governments is also essential in coordinating initiatives to create national and international strategies with visions and roadmaps to tackle the skills gap as a societal and evolutionary phenomenon. This requires continuous and long-term efforts involving all manufacturing stakeholders. Both universities and companies play an essential role in preparing young people for future jobs as well as the current workforce for the on-going digital revolution, equipping them with, "...the right type of skills to successfully navigate through an ever-changing, technology-rich work environment, and give all workers the opportunity to continuously maintain their skills, upskill and/or reskill throughout their working."[82]

Starting with skill development in higher education, universities are faced with the challenging task to equip the new generation of industrial engineers and leaders with the skills discussed in the previous section. Modern curricula need to go beyond the traditional focus on technical subjects to deliver up-to-date knowledge in a fast-changing world as well as broader professional skills. Industrial and systems engineering, "...aims to design, analyse, improve and install systems integrating people, materials, information, equipment and energy," bringing together multiple disciplines "to specify, predict, and evaluate the systems' performance."[83] In addition, the engineering curriculum should be rich with practical projects, integrate professional skills such as teamwork and communication, feature active and experiential learning, and constantly improve.[84]

E-Learning and M-Learning Create New Learning Opportunities Accessible Anytime, Anywhere

Digital technologies are not only drivers of societal and industrial change, but also tools and enablers STEM education. Technological advances in information and communication technology (ICT), most notably computers and mobile devices, have increased the accessibility to course material outside the traditional classroom setting as well as increased learners' autonomy in their own learning.

Teaching facilities and course design are also evolving. Classrooms in the developed world are often equipped with audio-visual systems (such as screens, projectors and speakers) and, in some cases, interactive technologies (such as touchscreens and augmented reality) as discussed later in this chapter with Learning Factories and digital technologies used in industrial training programmes. Many universities use an online learning management system to facilitate course preparation and delivery. Such a system provides a platform for tailoring teaching and learning activities to meet individual student's needs.

The impact of ICT and the Internet on training programmes delivery is tremendous, most notably with the emergence of online learning platforms and massive open online courses (MOOCs). While early e-learning systems mostly focused on managing the training processes–and some still do–adding little to no value to the actual learning process, recent developments in e-learning systems enabled more effective course delivery using learner-centric approaches.

E-learning and m-learning enable communication and collaboration remotely thereby creating possibilities to study at anytime, anywhere, and bringing learners and educators closer together. E-learning and online courses are often accessible via mobile devices, enabling the rise of m-learning. New forms of learning methods are emerging with increasing peer-to-peer exchanges and the use of social media to enhance interactions between learners.

Global Learning Platforms and E-Learning Must be Integrated with Institutional Strategies to Align With the Company's Needs and Offer Customisable Programmes, Certifications, and Career Advancement Opportunities

Many organisations have developed their own global

learning platform with on-demand, modular programmes to enable company-wide strategies for skills assessment and development. Along with certifications and salary incentives, these initiatives empower employees with career advancement opportunities and increase their performance, in turn resulting in improved organisational capabilities and competitiveness. However, it is important to note that such online learning platforms and e-learning should not be considered as a full replacement for traditional teaching methods, especially accounting for cultural differences when in-person training is still preferred over digital medium. The flexibility and independence provided by e-learning must also be balanced with meaningful learning outcomes and learning experience often requiring a mix of teaching methods, such as mentoring and classroom-based training. In addition, e-learning must fit with institutional strategies (rather than implemented ad-hoc) to ensure that it fits with the company's needs, and is integrated with other essential features for feedback, continuous learning, performance assessments, and certification systems.

Learning Factories Act as Knowledge Transfer Platforms Between Industry, Education, and Research

Most universities also have computer labs, design studios, workshops, robot labs and other high-tech facilities to offer a more applied learning experience. A good example is the Learning Factory model which provides a platform for knowledge transfer between industry, education and research. In addition, with the growing maker culture, more informal learning platforms, such as Makerspace, FabLab, Hackerspace, are emerging in many cities worldwide. Often developed in collaboration with local businesses, universities and municipalities, they make new technologies accessible to a broad audience to facilitate the dissemination of digital skills through peer-to-peer and project-based learning activities such as programming, prototyping and others.

Learning Factories and Industry 4.0 test-beds have been introduced in many industrialised countries, as exemplified by the German-Swedish Testbed for Smart Production initiative.[85] They are composed of state-of-the-art processes and technologies replicating a small-scale industrial site, creating ideal teaching environments for university students to experience industrial settings with multi-disciplinary teams and without any costly disruptions to manufacturing operations. Thus, it is a low-risk approach while still realising the benefits of a real industrial environment. It is also highly beneficial for companies involved as they can access state-of-the-art academic knowledge and facilities to identify and develop new solutions which they can then integrate in their own facilities. However, few universities have the financial resources to install these facilities as they require high-cost equipment and experts to be exploited effectively. Therefore, project-based learning remains a popular alternative.

Industry-university collaboration is a powerful mechanism for education, but it also creates additional benefits in advancing industrial practice and generating new knowledge for both parties. Today, most engineering programmes (both undergraduate and graduate) include industry projects whereby the students gain access to real industrial challenges and hands-on experience while solving real-world problems under the guidance of industry experts. In this context, manufacturing companies can actively engage in delivering education through project-based learning and collaborative research projects.

Digital Technologies Such as VR, AR and 5G Can Bridge the Skills Gap by Providing Real-Time Process Data, On-Demand Operator Instructions, and On-the-Job Training Opportunities

Governmental funding agencies in various countries are encouraging collaborative research projects to make productive and innovative use of digital technologies in the manufacturing industry. For example, using virtual reality (VR) as a cheaper, safer and realistic training environment to train workers in performing dangerous or advanced tasks such as complex assembly without prior practice or knowledge.[86] Another example is the use of augmented reality (AR) to provide real-time process data and adaptive instructions to maintenance experts performing new tasks without prior training.[87] Such usage of digital technologies can fill the skills gap by creating new opportunities for on-demand and on-the-job training, blurring the lines between working and learning (continuous learning mindset). Mobile technologies, including wearable devices, and 5G connectivity are further enabling access to essential process data and relevant experts as needed; e.g. communication systems to connect to nearby colleagues for additional support on specific technical issues.

Similarly, internships, apprenticeships and job shadowing allow expert skilling through on-the-job training, usually taking place in early career development. They allow more experienced workers to pass on their skills to the new generation, while also developing and strengthening the organisational culture. This knowledge transfer model is particularly suitable given the ageing workforce. Older workers often hold pockets of knowledge, but not necessarily the digital skills to combine this knowledge with new models of production. Bringing together two generations of engineers can facilitate the transition to digitalised and automated operations.

Continuing education and professional training are also pivotal in realising the cultural transformation needed for a successful and socially sustainable manufacturing ecosystem. Adult learning is an important channel for reskilling and upskilling to fit the future of work. However, time and financial constraints are amongst the main barriers to adult learning (See Figure 34). Manufacturers need to support such training programmes by providing the right environment to promote adult learning. Working closely with research and education organisations, industry can shape the curriculum to meet their needs and ensure the training programmes fit their work culture. There are

Essay

Learning Factory on Global Production
Use Case Augmented Go & See

Prof. Dr.-Ing. Gisela Lanza
Christoph Liebrecht, M.Sc.
Karlsruhe Institute of Technology, wbk Institute of Production Science

The Learning Factory on Global Production (LGP) at the wbk Institute of Production Science is an interactive training centre designed to bring a networked, global production process to life. In the LGP the effects of location factors on the design of a production system become tangible starting with production network planning, the choice of location, the location-specific design of a production and supplier management.
The LGP shows how processes within production can be designed to make optimal use of the site profile, which level of automation is the right one, how it can be scaled, what an adapted, data-driven quality management looks like and how employees can be trained with the new technologies. Our workshops take place in a real production environment. Workshop participants optimise the assembly and testing of a real electric motor from the automotive sector of Robert Bosch GmbH. In 2018, we were able to pass on our knowledge and passion for global production to over 200 workshop participants in open and individual workshops. All workshops consist of practice and theory. The methodical knowledge imparted can be applied directly and thus consolidated and deepened over the long term. The case studies take place as one-day workshops while operative workshops are offered as two-day events.

Lean Management and Industry 4.0
The advancing digitalisation enables companies to adapt their products to customer wishes, while at the same time complying with the time and price conditions of mass production. Lean management continues to be the basis for the optimal design of a production system. Suitable methods and tools are necessary for the successful implementation and combination of Lean Management and Industry 4.0, especially when companies operate in a global production network.
The LGP offers an excellent opportunity to illustrate the theory of factory planning using a real manufacturing process. There are no limits to the creativity of the participants due to the flexible structure of the production process. The participants experience a moment of great knowledge realisation in each event creating the basis for implementing what they have learned in their own company.
The workshop participants master in different roles the challenges of the variant-rich assembly. They apply suitable lean management methods and tools along the PDCA cycle to analyse and design a lean production system in order to make the best possible use of specific location factors. In addition to the lean tools, workshop participants will have numerous digital tools at their disposal for direct use and analysis of the production. In subsequent shop floor meetings, participants reflect on the effects of the methods and tools used.

Use Case Augmented Go & See
One of these tools is the Use Case Augmented Go & See. Bottlenecks in production lines are often shifting and thus hard to identify. They lead to longer throughput times, higher work in progress and decreased output. Go & See is a well-established Lean practice where managers go to the shop floor to see the problems first hand. Mixed reality is a promising technology to improve transparency in complex production environments.[1] The introduced mixed reality Go & See application is based on Apple ARKit. The AR framework allows the development of powerful mixed reality applications that run on common devices such as Apples smartphones and tablets. This opens new possibilities to create powerful AR applications in the context of production that rely on the bring-your-own-device principle. The developed Go & See application uses natural feature tracking to recognise the work station and blend in the last eight cycle times and current buffer levels, as shown in Figure 1. The data to calculate the cycle times is collected using RFID tags on each product.[1] This approach serves the goal of teaching the participants a deeper understanding of critical production KPIs. Secondly, the participants get to see an application of Augmented Go & See, which they might adapt to their specific production context. Based on the experience of carrying out traditional Go & See as well as Augmented Go & See the participants directly experience the effects of these methods. In order to quantify the difference in impact of traditional Go & See and Augmented Go & See a case study has been carried out among participants of the Lean & Industry 4.0 training in the Learning Factory Global Production.[1]

[1] Hofmann, C.; Staehr, T.; Cohen, S.; Stricker, S.; Haefner, B.; Lanza, G.; 2019. Augmented Go & See: An approach for improved bottleneck identification in production lines. 9th Conference on Learning Factories 2019 (CLF). Procedia Manufacturing.

Manufacturing and Mature Economies: A Model for Workforce Solutions

Rob Luce
Vice President, SME Education Foundation

Developed nations, though equipped with industrial and educational infrastructures, face a current and increasing shortage of qualified, skilled and motivated workers. American manufacturers and smaller operations know this shortage is severe. The skills gap could lead to a shortage of as many as 2.4 million manufacturing workers in the next decade.

The SME Education Foundation has developed and implemented a model to meet workforce development challenges: The SME PRIME (Partnership Response in Manufacturing Education) initiative. SME PRIME is directly enhancing the talent pipeline by partnering with industry to develop manufacturing and engineering programmes in 47 high schools across the country. A collaborative model, SME PRIME brings together manufacturers and schools to address localised workforce needs and create opportunities for area high school students. The initiative provides modern, advanced manufacturing equipment; a tailored curriculum; and hands-on training experience to students and educators. These partnerships are critically important because manufacturing is losing large numbers of skilled workers as they retire – and the new generation needs to first be made aware of the opportunity in advanced manufacturing and then educated and developed with the necessary skills, knowledge and abilities needed to succeed. Anna High School, an SME PRIME School in rural Anna, Ohio, was highlighted in an extended feature in The New York Times recently, discussing the preparation of high school students for careers in robotics. The story prominently features the school and global manufacturer Honda, the manufacturing partner supporting that school. Through SME PRIME, students are gaining experience with robotics programming and operations, fulfilling manufacturers' need for people who can operate, troubleshoot, maintain and install robotics and automation technology.

Starkweather Academy, part of Plymouth-Canton Community Schools in Michigan and an SME PRIME school, partnered with a coalition of local manufacturers. One company, LINK Engineering, became involved to sustain its growth, recognising the critical importance of supporting and training the next generation of craftsman in skilled trade positions such as machinists, electricians, machine builders, fabricators, field service technicians and test technicians. Opportunities for all students exist in the new manufacturing environment. The diverse student population of Park High School in Racine, Wisconsin, another SME PRIME school, delivers knowledge, technical skills and the opportunity to earn credentials while learning in a hands-on environment – preparing young people for career pathways in advanced manufacturing. Educated as an electrical engineer, Park High School instructor Valerie Webb-Freeman helps young minds first grasp, then embrace, the potential opportunities being offered through technical programmes at the school. Those opportunities extend to every educational level.

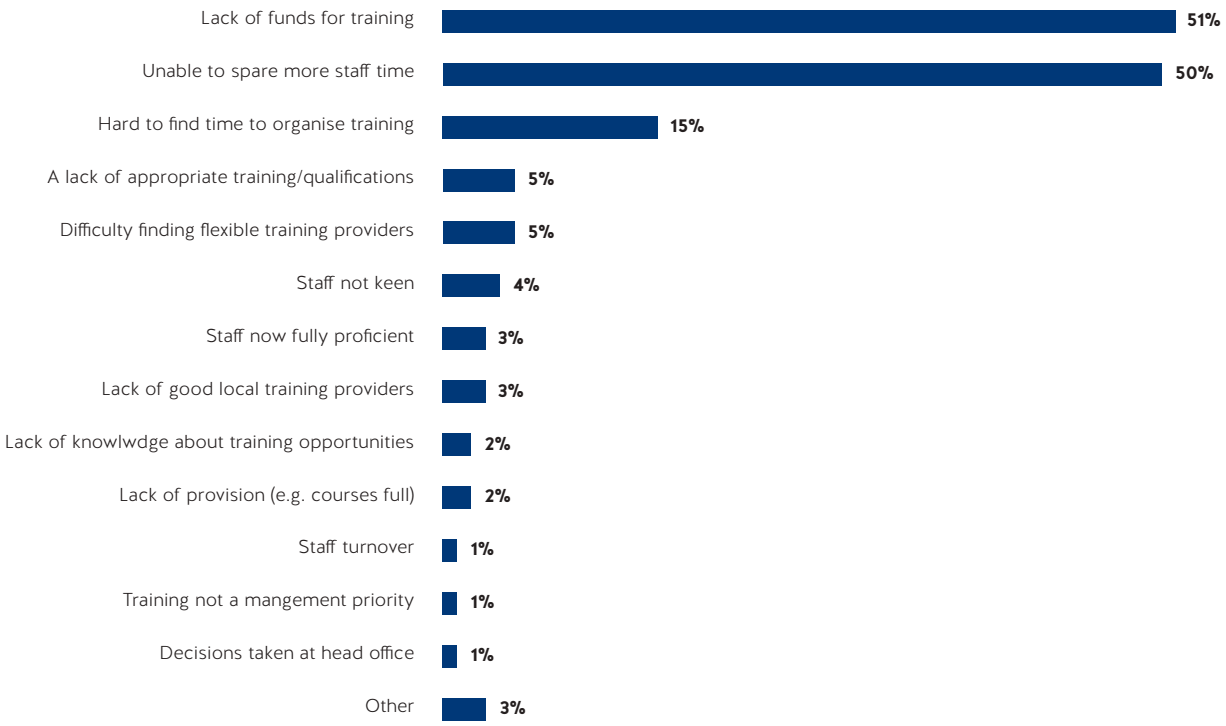
"Not every student will, or even should, go to college," Webb-Freeman says. "It's ok not to go – but I'm preparing my students to have that choice; to be prepared for a rewarding career or continuing education – or both." Part of her responsibility, says Webb-Freeman, is informing parents and students of the many paths, opportunities and careers available in manufacturing. "I want to attract everyone; I want to include everyone; to share my own experiences and expose them to an opportunity they may not have known about."

Rob Luce, vice president of the SME Education Foundation, noted in a recent Bloomberg Businessweek interview that, "Manufacturing is not a dark, dull, dying industry. It's a lucrative industry if you have the right skill set."The collaborative, cooperative partnerships forged by the SME Education Foundation through the SME PRIME schools initiative strengthen communities, contribute to the sustainability and growth of manufacturers, and create opportunity for students across the U.S. by building that skill set – and opening doors to fulfilling careers, continued education and unlimited professional achievement.

Figure 34

REASONS FOR NOT PROVIDING MORE TRAINING

(Source: Employer skills survey 2017, UK Dept. of Education)



three ways this challenge can be tackled and adult learning improved: more systematic diagnoses of the specific constraints that adults are facing, pedagogies that are customised to the adult brain, and flexible delivery models that fit in well with adult lifestyles.[88]

Time and Financial Constraints are Major Barriers to Adult Learning

E-learning, especially MOOCs, gained a lot of attention in 2012 and still remain one of the most popular learning methods today. This format of education provides freedom for learners to pursue new knowledge in their own terms and when they have the time. The quality and learning outcomes of online courses can vary greatly, especially since it can be a superficial solution to fulfil skills needs and not taken seriously by learners. In addition, the dropout rate is high as the learning content may not match the learners' expectation or abilities, and some courses do not provide opportunities to engagement with a community (e.g. forums or peer feedback). Finally, summative assessments can also be limited and not necessarily reflect actual learning performance. However, a lot of progress was made in online course design, and many companies are increasing its use to deliver learning opportunities matching their employees' needs and availability.

Life-long learning has been strongly advocated as a new mindset and corporate culture required to empower people to better navigate the complex systems charactering a globalised society and production. Equipping school pupils, university students, adult and elderly learners with appropriate competences and resources enables them to think critically about the co-evolution of technology and society, to take informed decisions for themselves and the societal well-being, and to contribute to sustainable development in the global context.

Inclusive Life-Long Learning Needs to be Fully Integrated in the Corporate Culture with Open Opportunities and Incentives to Encourage Employees in Seeking Training Proactively

With the risk of socio-economic inequalities widening and the fast-changing industry, the effects of the Fourth Industrial Revolution on various demographic groups must be taken into account to ensure fair and inclusive education and labour markets.[89] Notably, gender issues exist and must be addressed. As mentioned by the World Economic Forum, "...given how labour markets are currently segmented, the burden of job displacement and skills gap trends will likely fall disproportionately on women."[90] They hold many of the jobs likely to be replaced and are underrepresented in the fields most likely to see job growth. For example, only twenty-two percent of people working in artificial intelligence are women. In addition, gender preferences affect individual career aspirations, with women statistically being less attracted to STEM as they tend to go towards jobs that allow to work

with people rather than objects, and help others to benefit society.[91] Women are also more likely to perceive work-family balance as incompatible with STEM careers. Such gender preferences lead to a female underrepresentation in many engineering disciplines.[92] Finally, cultural norms and gender stereotypes surrounding STEM professions are additional barriers to the recruitment of young women. Therefore, it is crucial to take the opportunity presented by the on-going industrial transformation, "to hardwire gender parity into the future of work [with] proactive measures from business and governments to ensure women are equally represented in the highest-growth occupations and most in-demand skill sets."[93]

Ageing workers represent a growing demographic group and are an asset for employers as they accumulate experience and practical knowledge that help them with functioning in a known environment.[94] Older learners with a long career in manufacturing increasingly need to update and broaden their skills to keep pace with technological developments and to be more attractive recruits to transition to a new job in a late stage of their career. Finding the time and resources to pursue education programmes, as well as the lack of prerequisites for low-qualified workers, are major barriers to life-long learning.[95]

It is crucial to promote life-long learning as fully integrated in corporate culture, and to design ergonomic workplaces supporting older and disabled workers' productive capacities while minimising their vulnerabilities. In turn it helps to avoid detrimental effects on manufacturers' quality, productivity, workplace safety and workers' well-being, workability and employability. Organisations need to adopt proactive, solution-focused strategies (as opposed to a negative, problem-solving stance) enhancing individual resources, intergenerational learning, job satisfaction, and mental and physical health.[96]

While it is widely recognised that younger users are more comfortable with new technologies, the generational differences between the "digital natives" and previous generations can be addressed through sensible user interface design and tutorials. This age prejudice must also be overcome to avoid unfair privileged access to technologies by certain demographic groups; for instance, VR and AR have shown to be effective tools to enhance the learning experience for all, including older users.[97]

Various government programmes can give incentives for companies and universities to reach out more to disadvantaged and marginalised communities, including migrants and NEET young people (Not in Education, Employment or Training). Structures and policies are often required to avoid social exclusion which leads to further barriers to entering the workforce in addition to already unfavourable life career prospects. For instance, several European case studies were reported and demonstrated the effectiveness of cooperation between businesses with vocational education and training (VET) providers to deliver quality skills and attractive futures.

Forging Partnerships and Opportunities to Grow

While no single stakeholder is expected to tackle the skill gaps phenomenon alone, sixty-four percent of top executives in the private sector in the U.S. and fifty-nine percent in Europe believe that corporations should take the lead in trying to close the gap.[98] Delivering the skills needed for a successful and sustainable future of Industry 4.0 will requires partnerships between manufacturing stakeholders (industry, academia, and governments), continuously evolving training programmes making use of digital tools and new teaching methods in all levels of education, and life-long learning mindset in organisations. As such a pressing and pivotal issue in society today, we must work to foster collaboration and encourage skills development to drive progress forward.

Vocational Education and Training Systems and the Future of Work

Montserrat Gomendio
Head of the Centre for Skills, OECD
Ex-Secretary of State for Education, Vocational Education and Training, and Universities (Spanish Government)

In most countries, vocational education and training systems (VET) are undergoing major transformations, raising many questions about their design and purpose. Traditionally, VET systems attracted mostly students with low academic performance and equipped them with a rather narrow set of technical skills that allowed them to move to low skilled manual jobs. In contrast, students of better academic performance who aspired to attain high quality and well-paid jobs followed the academic track and then entered university. Over time this model has become obsolete, since low skilled jobs have started to disappear due to the impact of megatrends on labour markets (mainly automation due to digitalisation), and populations have gradually become equipped with higher levels of skills, so that a greater proportion of workers aspire to obtain high quality jobs. The fast expansion of access to university which has taken place over the last decades, has proven insufficient to deal with the new scenario.

Megatrends (digitalisation, globalisation, ageing and migration) are having a major impact on labour markets which, as a result, are changing very fast. The OECD estimates that around fourteen percent of jobs are at risk of full automation, which implies that workers will need to upskill in order to move to safer jobs. In addition, approximately thirty-four percent of jobs will experience the automation of those tasks that require routine low skills, thus experiencing a profound transformation that will make them much more demanding. In these cases, workers will need to acquire new skills to avoid being displaced from their current jobs. In this dynamic and challenging environment, the demand for skills have changed in two main ways: higher levels of skills and new sets of skills are demanded from workers. In addition, workers will need to upskill and reskill thoroughout their careers to be able to adapt to these rapid changes.

In this context, VET systems can play a major role given their strong links with the labour market which allows them to more easily track the changes that are taking place and to respond more efficiently by equipping people with the right bundle of skills. In order to achieve this goal, traditional VET systems need to change in a number of ways:

- Develop new courses that will prepare students to obtain good quality jobs that are in high demand; this will increase the employability and attractiveness of VET
- Attract students of all levels of performance
- Avoid dead ends in VET courses by creating bridges with the academic track and making real the possibility of moving into higher education
- Increase the amount of time that students spend training at work; this will make it easier for them to acquire the skills required by the labour market and will avoid the need for VET schools to constantly update equipment in order to track changes taking place in the working environments
- Equip students with strong foundation skills so that they can engage in life-long learning

In summary, we need vocational education and training systems that provide the right skills, are flexible enough to constantly adapt to changes in the labour market and are responsive to emerging demands. Achieving this closer collaboration with employers is key, since the offer of work placements will ensure that people are trained for jobs that are on demand, and will also facilitate the acquisition of technical skills which are relevant. Work-based learning will also allow students to acquire horizontal skills which have become crucial for employers, such as team work, the ability to adapt to change, to be creative and innovative, as well as social skills. Finally, partnerships between employers and VET schools can improve transition from school to work by allowing employers and potential employees to get to know each other; it contributes to the output of the training firm and it links training provisions to a direct expression of employer needs.

Essay

Promoting the use of work-based learning requires designing schemes that are attractive to students, because they learn useful skills and enjoy high employability and wages, and attractive to employers because they benefit from students' productive work and can recruit the best students. The design of work-based learning schemes, including decisions about wages, how participants' time is spent, needs to be adapted to both the employer and the learner. All of this requires some underpinning by mechanisms to bring together the world of work and the world of learning, to promote employer involvement in the provision and planning of vocational training.

It is important to understand the magnitude of the challenge. According to the OECD Survey of Adult Skills (PIAAC) over eighty million adults in Europe have weaknesses in basic skills – one in four adults. Since these adults are likely to have low skilled jobs, they are the most vulnerable ones. Vocational education can motivate people who might have become disengaged from school and more academic forms of learning, by allowing them to upskill mainly through work-based learning.

A common trend observed in many countries, is that adults are enrolling in VET courses in order to upskill and reskill. Thus, adult learning has become an increasingly important role for VET, since many adults wish to learn practical skills. In order to be attractive to adults VET systems may need to adapt to their specifc needs, by offering shorter courses and modular approaches, which allow the acquisition of skills at different stages.

CASE STUDY: SPAIN

In Spain, the VET system had low prestige, mainly because it could only prepare students for rather traditional low skilled jobs. Thus, it was widely regarded as a dead end that would prevent students from entering University. The lack of attractiveness was such that early school leaving remained at high levels for many years (around thirty percent), while a small proportion of students chose VET. In other words, students dropped out of school and obtained jobs in sectors such as the construction sector, rather than chosing VET. In this way, people could start working earlier without the need of obtaining a VET degree. After the economic crisis, the construction sector collapsed and many school leavers of a wide range of ages were left unemployed. As a result, unemployment rates soared and in 2011 they reached twenty-two percent. Young people were disproportionately affected and youth unemployment increased to fifty-three percent.

The Government introduced a series of measures to improve the attractiveness and employability of VET students. The first was to introduce a dual VET system in 2012 which makes it compulsory for students to spend a large proportion of the time training in a firm. The new model has been a success, since the number of enrolled students has increased rapidly over time, but numbers remain low compared to the traditional VET system. The second step was to make the modernisation of VET one of the main pillars of the education reform approved in 2013 (LOMCE). In order to make VET more attractive and effective, the academic and VET tracks were re-designed to make them more flexible, so that students could move from one to the other, and could make progress to higher levels of educational attainment (tertiary education); any signals that VET systems were more appropriate for low performers were eliminated; courses were modernised to include new modules which were in demand in the labour market and which required middle- and high-levels of skills; and work based learning and stronger foundation skills were promoted.

As a result of these reforms, from 2011 until 2015 enrolment rates in VET increased substantially (from 600,000 to 800,000 students, a thirty percent increase) and early school leaving decreased in parallel to historically low levels (twenty-six point three to twenty percent). This example shows how an effective redesign of VET systems can rapidly attract a large number of students, to the extent that it can have a profound impact on one of the major sources of inequality: early school leaving.

Education 4.0: Remote-Live Training Platforms to Accelerate the Digital Transformation of Manufacturing Companies

Dr. Dominic Gorecky
Switzerland Innovation Park Biel/Bienne AG

Despite the huge potential of the digital transformation for the manufacturing industry, companies, and especially SMEs, struggle with the introduction of Industry 4.0 enabling technologies. The following typical problems hinder the digital transformation in companies:

Lack of awareness: Companies have no or only little awareness about the on-going digital transformation and Industry 4.0 trends – or they do underestimate its influence on their own technology and business model.

Lack of corporate courage and leadership: Companies are aware of the on-going digital transformation and Industry 4.0 trends, but they do not have the courage, authority and/or control to push through partially radical transformations within their organisation.

Lack of corporate strategy: Companies have no strategic approach towards the identification and implementation of Industry 4.0. Practical methodologies and best practices are missing to address the on-going digital transformation and Industry 4.0 trends in the company.

Lack of rightly skilled talent: Ultimately, the lack of rightly skilled talent to implement and maintain modern technologies restrain companies in adopting Industry 4.0 solutions and becoming a relevant player in the digitalised ecosystem.

To overcome these hurdles, especially SMEs heavily depend on help from outside the company. The first three hurdles are typically addressed by consultancy firms but also national and regional networks and initiatives. They offer their support, sensitise on the subject of Industry 4.0, provide best practise examples, offer feasibility and cost studies and accompany the implementation of technical solutions.

One of the remaining, structural problems for companies that remains largely uncovered lies in the education and training of their workforce. The adaptation of education programmes for professionals at schools and trainings institutions requires a sufficiently long time, and thus the development of education programmes on digital technology can often not keep pace with the development speed of the technologies themselves.

New education methods are needed to create education programmes that prepare the digital workforce in a more timey, agile and demand-oriented manner. Education and training sessions must be provided to a greater extent on an ad-hoc basis, e.g. directly at the workplace and/or allowing workers to undergo self-studies. Education programmes must adapt to shorter-life-cycles of technologies by integrating new topics and training content in a “Plug&Play” fashion. The concept of a “Digital Classroom” allows access and exploration of new topics and training content at anytime and anywhere. It can be used as a complementary and more flexible approach to traditional training taking place only in the classroom.

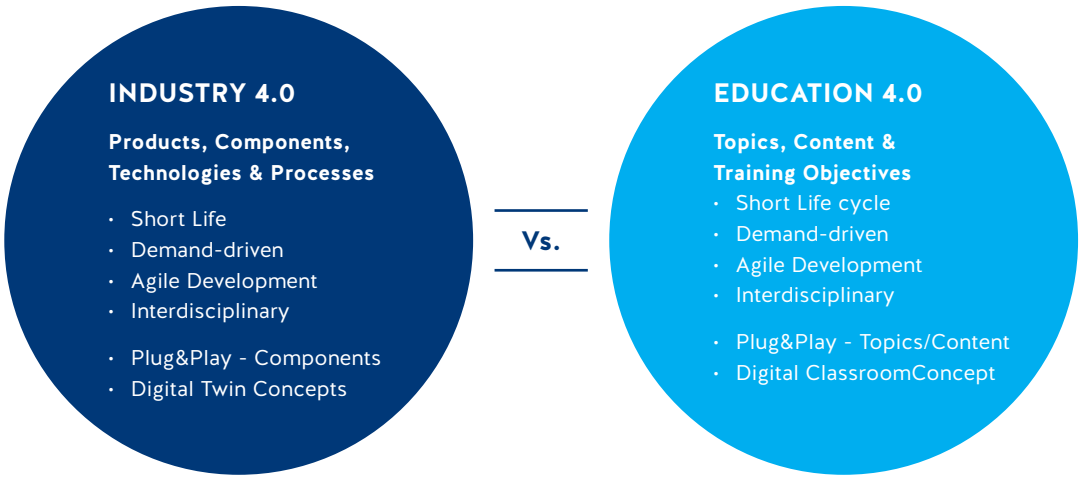


Figure 1: Comparison between the concepts and challenges of Industry 4.0 & Education 4.0.

In this context of "Digital Classrooms", special emphasis should be given to remote live-training platforms. A remote live-training platform offers easy access to real industrial workplaces with all their hard- and software components. The access to the workplace will be created via remote desktop connection and by using a camera live stream.

An example for a remote live-training platform is MyLiveZone (www.mylivezone.com). MyLiveZone is an online platform featuring a virtual programming environment for the remote-controlled workplaces including interactive cameras for live streaming. Currently it offers comprehensive training lessons for PLC programming, RFID implementations, cloud and edge solutions, data analysis as well as for the creation and simulation of digital twins.

Remote live-training is a promising approach to share knowledge about even complex technologies at any time, at any place, by anyone and without any specific resource requirements through the online platform. For the training providers, the costs and effort to scale training programmes can be drastically reduced, while the quality of the training can be standardised across the world. New training content can be integrated by the training providers and their community in a "Plug&Play" way. The trainee, on the other hand, will benefit from flexible access to any type of technologies at low cost – also in countries, where the technology is not available or easily accessible yet. This will ultimately lead to a democratisation of even complex and expensive technologies.

In future, remote-live training platforms can be integrated as part of a digital classroom training in novel education programmes, allowing a quicker and more flexible way for companies to train their digital workforce – and eventually overcome the last hurdle on their digital transformation journey.

Manufacturing 4.0: Most Required Jobs and their Evolutions – An Italian Perspective

Francesco Baroni
Country Manager Gi Group Italy

The evolutionary path of Italian manufacturing companies from a 4.0 point of view is in full development and presents complex situations; on the one hand, businesses that stand out on a global level and, on the other hand, organisations that are only in the first phase of assessment or, at most, experimentation. However, this complex scenario sees Italy as a protagonist despite the structure of the manufacturing sector, which is strongly characterised by SMEs that do not facilitate the adoption of new technologies and new business models if not within strongly export-oriented supply chains.

For it to be sustainable in the medium to long term, this evolution, or revolution, cannot ignore a significant contribution in terms of skills, training, upskilling, and reskilling both at the managerial level and the level of the most operative profiles.

At the management level, the impact of Industry 4.0 requires evolution, especially in terms of mindset. Companies increasingly need managers with cultural openness that are able to understand technological changes and translate them into process, product, and business innovation. These managers need to be able to enhance relationships with customers, suppliers, research centres and collaborators from an open innovation standpoint, demonstrating aptitude and willingness to learn continuously and, last but not least, be capable of communicating strategies and goals with empathy and clarity in order to attract the best talent and motivate change.

In terms of operations, the demand for skilled workers able to design, create, and implement machinery/systems increases in sectors where integration between software, electronic, and mechanical components becomes essential.

In recent years, requests for profiles from companies are constantly increasing and focus on several skill sets. At the same time, educational/school systems find it very difficult to keep pace both in the orientation phase and in the proposal of training courses consistent with the needs of the companies.

According to a study by the MECSPE Observatory, the most requested specialised profiles by 2030 will be ***Robotic Engineers*** (30.3%), ***Big Data Specialists*** (17.9%), ***Artificial Intelligence Programmers*** (13.8%), ***IoT Specialists*** (9.2%), ***Multi-channel Architects*** (7.7%), and ***Cybersafety Experts*** (6.2%).

According to our analysis, the most sought after roles to date are as follows:

- ***Senior Mechanical Designers/Project Leaders – Automatic Machinery and Plants*** 5-10 years' experience in the position without direct management of resources, for product design in the Automotive and Automation field. Experts in dynamic thermo-fluid are scarce
- ***Electronic Designers -Firmware Engineers, Electronic Software Developers-*** without direct management of resources for the development of software applications for the Automotive, Robotic, and Automation sector particularly with skills related to C++, C# language
- ***Electric/Electronic Engineers-*** with power electronics expertise
- ***Maintenance Managers and Process Equipment Coordinators-*** with advanced mechatronics and managerial skills. Workers to fill these roles are difficult to find, especially if a degree in Electronic Engineering is required since electronic engineers are more oriented towards Design/R&D
- ***Technical & Export Sales, Technical Support, and R&D-*** process industry in the field of chemicals, rubber, plastic, paper.

- ***Automotive Senior Buyers-*** with strong technical engineering content and strong interpersonal skills to manage relationships with internal customers and suppliers
- ***Senior Buyer/Supply Manager – semi-durable goods-***advanced management of the supply chain and supply chain logic for complex supply chains.

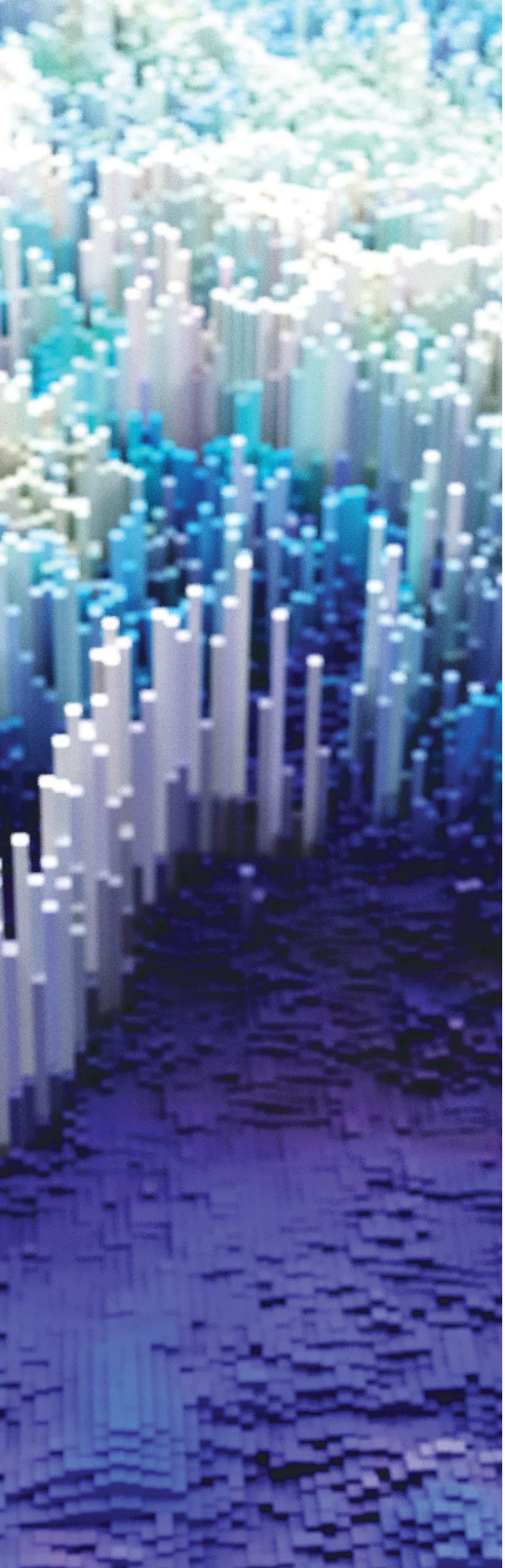
Concerning more operational roles, the most requested profiles are ***Automation Designer, Software Engineer, PLC specialist,*** and ***Mechatronic Assemblers***. Although the demand for these roles throughout the last decade has been high, over the previous two years, there has been a large surge. The main criticality in finding these type of skills lies in the fact that the training courses necessary to cover these roles effectively are mainly structured and, therefore, replaceable by customised training courses, only at the price of accepting low levels of performance in the first period of employment – as is the case of ***Developers*** in the ***IT field***.

The request for ***CNC Operators*** continues to grow, provided that they have the bases of setting/programming and equipping the machines. There is an increased need for ***Plant Operators*** who can make the first diagnosis in partial machine malfunctions by identifying the macro-area of intervention. All ***Production Engineers*** who are able not only to apply lean logic to various production environments but that can also make them evolve hand in hand with the evolution of the potential of the machinery assume a strategic role. An example of this trend is the role that ***Maintenance Engineers*** and ***Maintenance Technicians*** play, which is increasingly vital for companies characterised by 4.0. Therefore these workers are required to have a broader range of skills. Hence, a specific specialisation (mechanics, electronics, electrical engineering) is not enough; they need to have an overview that allows them to make diagnosis on machinery malfunctions characterised by the integration of electrical, mechanical and electronic components.

This brief overview of the professional skills required by industry strongly shows that without adequate human capital in terms of skills, inclination, and willingness to continuous learning, Industry 4.0 risks becoming a completely untapped opportunity.

For this reason and thanks to specialised professionals, GI Group supports companies to understand the impacts strategies and business models have on the mix of skills necessary to successfully face innovation in terms of 4.0 and how to find, in increasingly “candidate”- driven markets, talents with the right skills. It is not just a problem of identifying which skills are needed, but also how to train and manage them, in a context where the speed of change and uncertainty are the paradigms that most affect the evolution of companies and the human resources already present in the company. Additionally, there is a need to identify complex organisational solutions (outsourcing, apprenticeship, staff leasing) capable of combining the need for innovation and flexibility. These activities, conducted both nationally and internationally with great attention to territorial specificities, industrial districts, and supply chains, are carried out by enhancing collaboration with professional training centres of excellence, such as Professional Schools, ITC (Istituti Tecnici Professionali), and with Universities through a continuous action of observing skills and matching the needs of each company with candidates. Last but not least, by designing and managing highly customised vocational courses, Gi Group qualifies and makes profiles that would otherwise have low employability recognisable to help solve the quantitative and qualitative gap from which the manufacturing sector suffers.

SECTION 5
10 KEY RECOMMENDATIONS



The WMF is pleased to present our *Ten Key Recommendations* for the *2019 WMF Report*. We hope our readers are able to take these recommendations and work towards creating an educated and skilled manufacturing workforce now and in the future.

01

Create a Manufacturing Market with a Life-Long Learning Mindset

Workers should proactively seek out life-long learning opportunities

Create personal and professional incentives for workers to engage in training

Empower workers by letting them participate in training design

Undoubtedly, manufacturing workers are experiencing unprecedented changes in the nature of work and relevant skills within industry. Due to constant change and innovation, the skills required for current manufacturing needs are both evolving and changing. This directly impacts workers and alters both the relevance of their skills along with how they must approach the future trajectory of their careers.

In response to these changes, the manufacturing workforce, both present and future, must recognise the skills gap and understand that it is now a responsibility to engage in life-long learning and training. No longer are the days where life-long learning was something that was optional or supplemental and only few engaged in. Current workers must be prepared for a life-long learning mindset where they understand that constant learning, improvement and full change in skills is necessary.

Since this requires proactiveness and motivation from workers themselves, employers, educational providers and governments must emphasise how this provides personal benefits to workers. Net personal benefits such as job security, opportunity for promotion, skill accreditations, recognition, increased job satisfaction and more must be highlighted for works. It is human nature to feel motivated to perform well and efficiently if there is some type of personal gain. To create a market that is better suited to develop alongside evolving industry needs, stakeholders must work to increase this overall motivation for workers to pursue new learning opportunities. By combining personal and professional motivation the gains for not only workers is increased but also helps to overall uplift and improve society. Furthermore, when workers' current skills are assessed this should be decoupled from a review of their performance to avoid discouragement. By focusing on assessing organisational competencies and what skills can be learned or improved, worker morale will not be lowered but rather inspired to work towards new and improved performances for themselves and the overall industrial mission.

In order to encourage workers to develop this mindset and pursue new knowledge, they must feel they are in control of their education and choices. A participatory approach must be used to developing training programmes. If workers are forced into something they see as undesirable, they will be not only be less inclined to learn from the programme but it may affect their future views on training and life-long learning. Further, if programmes are created to be enjoyable then workers will be more incentivised to keep pursuing educational opportunities. It is key to ensure that workers associate life-long learning and training with positive attitudes and benefits to encourage this mindset to become prevalent and long-lasting. Both workers and companies need to be made aware by manufacturing stakeholders that a life-long learning mindset is beneficial for both parties. Additionally, when implementing these programmes, it is important to be aware and adapt to cultural differences and sensitivities. The success of life-long learning and fostering this mindset within manufacturing requires a delicate balance of making this effort not only productive but also positive for all workers.

Various actors aside from industry and workers can engage to help with this effort. Educational institutions can engage to help support life-long learning opportunities through efforts such as continuing education classes. Not only does this help to create a better workforce with relevant skills but it also helps to engage educational communities of students and alumni to feel more engaged and informed regarding the latest trends and developments. Further, organisations such as unions and industrial associations also have a key role in promoting this attitude to have workers proactively seek out training. These types of organisations can help to make trainings available on a larger scale through mechanisms such as programmes, online courses, resources and on-demand trainings. These efforts can highlight the role of technology with online courses, mobile learning and more. If measures are put in place for people to pursue training this will further encourage workers to engage. All actors must support workers in their endeavours to learn and better themselves and their skill sets.

02

Increase Investment in Workforce Education to Reach the Full Potential of New Technologies

Companies should treat workforce training and education as priority

Leverage human-centric skills that compliment technology

Provide a type of skills insurance for employees

With the rapid pace of change and innovation surrounding Industry 4.0 there is pressure for organisations to invest in new technology in order to match levels of technological advancement. However, investing in technology is only one component to reaching the full potential of new innovations. A key component to utilising technology to its fullest potential lies in human capital. It is crucial to invest in education, training and workers in order to reach the full potential of new technologies.

There is a circular and symbiotic relationship between workers and new technology which warrant the need for adequately skilled workers that can leverage the power of new technologies. Without skilled workers, new technology and advancements are not able to be used to their full potential. There is a critical need for having skilled workers to use and understand new technology if it is to be used to its full extent. Conversely, without technological advancements workers' skills will become more stagnant and lack progress necessary to keep pushing innovation and progress forward. Therefore, skilled workers and technology both need to be invested in as they play a critical role in the success of each other.

Further, Industry 4.0 technologies are more human centric than technologies in the past and as a result require workers who have the correct skill level. Utilising people whose skill level is adequate for new technologies is a key component in leveraging the potential of those technologies. For example, in the age of robotics and automation there is a need for skilled workers who are able to programme, troubleshoot and understand the technology behind a robot rather than perform the repetitive tasks that are now being automated. The skill needed to fully utilise technology and improve processes is changing. Although new skills will be required of workers due to automation, it is key to note that automation will not replace humans but rather leverage different skill sets which humans excel at. Instead of engaging in repetitive tasks that are now automated, workers will be able to utilise key skills such as creativity, problem solving and critical thinking. This further highlights the critical need to invest in training alongside technological advancements.

Further, investment in workforce education can be bolstered with skills insurance in order to help fully utilise new technologies. Providing a type of skills insurance to workers encompasses providing resources to ensure that workers either possess or can learn a skill that will be utilised alongside new technologies. This signals to workers that there is value in what they are learning and helps to not only fully utilise new technologies but also encourages innovation by understanding that the skills they learn are valuable and worthwhile in both current and future contexts. By investing in human capital and ensuring that workers are skilled in order to work and fully utilise new technology more benefits and further innovation will be leveraged and produced pushing the world forward.

03

Enact Policies to Promote Manufacturing Workforce Education and Training

Policymakers should incentivise training through tax incentives, subsidies, and individual credits

Decouple policy from politics to ensure continuity of programmes

Ensure policy addresses the needs of all relevant stakeholders

In order to begin to tackle the challenge of the skills gap in the manufacturing sector, stakeholders must develop, implement and promote policies for education and training on global, national, regional and local levels. Effective workforce education policies are at the core of disseminating knowledge and elevating educational levels that help to diminish the skills gap that is experienced world-wide.

Policies to promote workforce education can include mechanisms such as tax incentives, subsidies and individual incentives such as educational credits. Policies that directly promote and positively impact workforce education help to set the agenda of what is relevant for skills and skills development. A government might provide a tax incentive for a company that is implementing harmonisation of skills at various levels throughout their organisation therefore highlighting the importance of skills harmonization and its role in the manufacturing sector.

These types of policies are beginning to take hold in governments throughout the world. For example, the state of Georgia in the United States offers a retraining tax credit that allows businesses to receive a tax credit of fifty percent of their direct training expenses which can include the cost of instructors, teaching materials, employee wages during retraining and travel. This allows businesses to offset investments in their employees and promote new skills, training and competitiveness.

These policies set the agenda of what is relevant and also show that there must be a joint effort between various levels of stakeholders in order to achieve a certain level of skills standardisation. A certain level of skills standardisation is necessary with regard to having some type of national skills qualifications where degrees and competencies can be recognised and insured as equal throughout various regions. There must be some harmonisation between different regions in order to meet and promote standards. However, policies cannot just be formed with government in mind. They must have input from all stakeholders in the form of industry, experts and educational providers in addition to government. By having well-formed policies with multiple perspectives and inputs, this will help ensure the success of policies and a broader impact. Furthermore, stakeholders, particularly governments, must advertise and promote these policies and incentives to make potential benefactors more aware. Without knowledge of an incentive, policy, or programme, success and widespread positive effects will be limited. Prioritising long term policies for economic growth and promoting their importance will signal to businesses and relevant parties that these incentives are relevant and worthwhile, therefore setting an agenda that highlights the importance of skills.

Additionally, these policies must be decoupled from politics to create long term stability for industry and initiatives. Even if a head of state, majority party, or political agenda changes, these policies must be kept in place if long term results and stable progress are to be seen. These policies must be kept active and not viewed through a political lens. Rather, government should treat them as consistent policy and bureaucratic work while constantly evaluating metrics to understand impacts and how to evolve programmes with the pace of innovation.

Furthermore, these policies need to address not only industry but also individual workers and educational providers. Enabling effective policies to address the skills gap challenge requires working with multiple actors and stakeholders at various levels in order to best solve the needs of the workforce. Without addressing all actors that are integral to skills development, policies will fall short of truly creating long-lasting solutions.

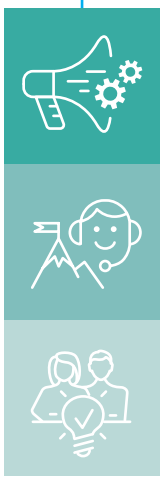
04

Excite People to Pursue Careers in Manufacturing

Promote manufacturing as a fast-moving and dynamic sector

Reach out to young people early on through engaging activities

Educate teachers and parents on the value of manufacturing related careers



In a highly connected world with vast knowledge and educational opportunities, people are faced with endless opportunities for careers. Despite having many options for career paths, people must be made aware of those career pathways that are not only exciting but also provide a bright and promising opportunity to meaningful work and a high quality of life. Manufacturing is a career pathways that offers great opportunity along with exciting and important work.

When dealing with skill shortages in manufacturing, one solution is to increase the talent pool available by encouraging more people to pursue manufacturing. Therefore, it is imperative that the manufacturing community works to help excite people to pursue a career in manufacturing. The global manufacturing community must better communicate that there are many job opportunities and convey that manufacturing is an important and exciting field to enter. However, we must first consider the question: in light of all of the positive and exciting aspects of a manufacturing career- why is manufacturing not being pursued in higher numbers?

A 2017 Deloitte study found that in the United States despite 8 out of 10 people believing that manufacturing is vital to society less than 5 out of 10 people believed manufacturing jobs were rewarding, clean and sage and more stable and secure than in the past.[99] Furthermore, less than 3 in 10 people would encourage their child to pursue a career in manufacturing. These alarming statistics signal the need for manufacturing stakeholders to dispel the theories and perceptions of the past and work to actively change public perception of the industry.

In order to excite people about manufacturing, it must be made clear that manufacturing has greatly changed with regard to careers, possibility, salaries and more from previous eras. No longer is manufacturing the dirty and unsafe shop-room floor that is depicted from in the nineteenth and twentieth centuries. It is also not the "outsourcing" activity that some think of. Exciting and important manufacturing is happening in local communities throughout the world and with that can come a sense of pride for a regionally or nationally produced product. Further, opportunities in manufacturing can also allow for international careers with entrepreneurial mind-sets to be utilised to spur creation and innovation. The largest amount of research and development is conducted in the manufacturing over any other sector.

One of the key ways to begin the campaign to promote manufacturing is to change parental and educational perceptions of manufacturing. If parents and educational providers have a negative perception of manufacturing this can greatly impact the number and quality of people that are guided or encouraged to pursue a career in manufacturing. Simply not enough people are pursuing these careers. As a result, manufacturing stakeholders must take concrete actions such as reaching out to educational institutions to inform people, particularly young students, of the opportunities that are available in the manufacturing sector. Stakeholders need to invest in recruitment and education through mechanisms such as manufacturing related activities, summer camps and exposure to experts. Starting early by creating fun manufacturing related activities to stimulate children can help to inspire the next generation of manufacturing leaders. Having manufacturing professionals engage with young students, parents and teachers helps to take away some of the perceived stigmas of pursuing a technical career in manufacturing. Additionally, this exposure can display that manufacturing is a career that allows for a great amount of pride since it is an important contribution to not only local communities but overall global progress.

Furthermore, societal and generational changes must be considered in order to excite people about manufacturing. Younger generations have a different world perspective as most have grown up with digital technology playing a large role in their life. Manufacturing can be marketed as an exciting path that combines the physical dimension with digital components. By highlighting the increased use of technology in manufacturing this can signal further attractiveness and more opportunity for young people.

In conclusion, manufacturing must be promoted in many areas of life and society in order to excite people about manufacturing careers. This must start as early as children in primary school and be as widespread as influencing popular culture to include manufacturing as a more commonly thought of and appealing profession.

05

Develop New Profiles with Technical Expertise Complemented by Generalist Know-How

Promote the importance of having both technical and generalist skills

Recognise that technical expertise can become obsolete and needs to be updated

Engage with technology to expand generalist know-how

In order to meet new needs within the manufacturing industry, there must be a shift to develop new profiles with technical expertise complemented by generalist know-how. This change means that we must encourage workers to gain skills that show their ability to understand many things across disciplines while also understanding something deeply. Knowledge is changing and developing right within the manufacturing sector and as a result workers need to be prepared to understand a broader view while still being able to understand and perform a skill with specialised knowledge. General skills need to include important elements such as working with a systems approach along with process engineering and skills. Having this type of profile will help to navigate changes as skills and knowledge are developing within manufacturing.

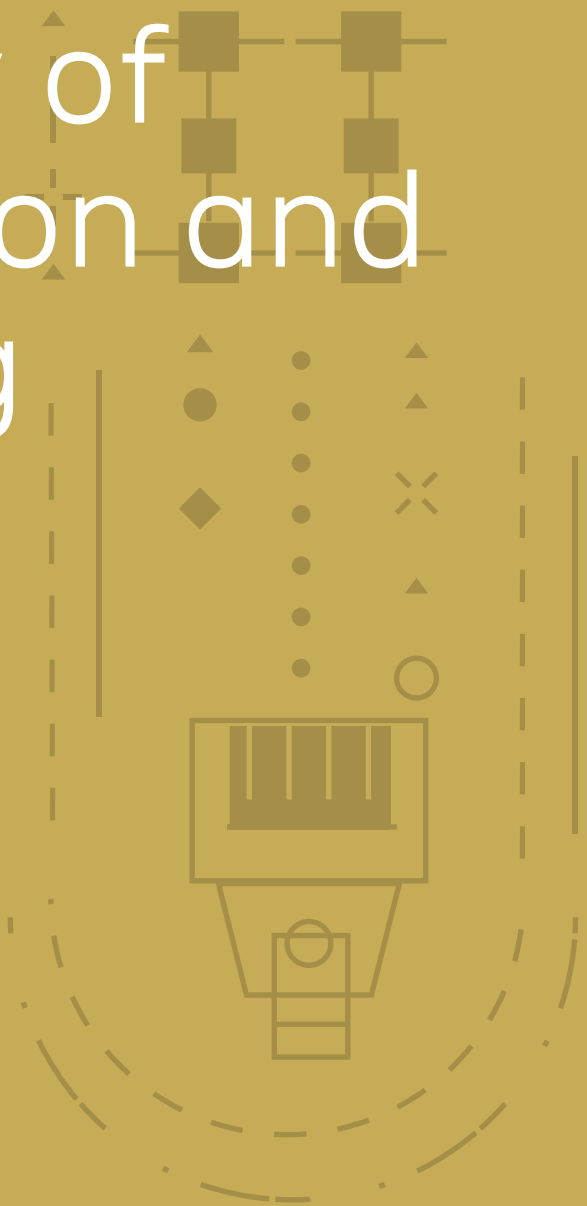
Due to this strong and fast technological evolution, workers will require more specialised skills and competencies in order to be able to work successfully with new technology. Technicians need to have stronger technical skills as the nature of work and manufacturing is becoming increasingly more advanced with new technologies. Within these skills however we must teach people how to continuously adapt to new systems, machines and programmes. By enabling workers to be quick thinkers and learners while remaining versatile they are more prepared for change and can even take part in new knowledge development. In order to have workers understand that they need to keep both their general skills and specialisations it must be made abundantly clear that there is expected change and deep knowledge will eventually have an expiration date. Even if someone is an expert, there is still a high probability that their specialisation will become less relevant without staying up to date with life-long learning and increasing overall breadth of knowledge.

Furthermore, it is important to note that the quantity of general know-how is getting larger due to the vast amount of information and variation among pertinent manufacturing topics. However, while the amount of information that is relevant to and can now be considered general is increasing, technology is allowing this information to be more widely and easily available. Technology can allow for people to learn and understand many more topics much more quickly and easily. If technology is utilised to help create these new profiles that encompass generalist know-how, it can help to lessen the skills gap instead of passing the issue onto someone else of the next generation. The time to utilise this technology to expand general knowledge is now.

Additionally, deep skills will always be needed and can be aided by general knowledge. In order to have the deep skills be communicated through cross functions, everyone needs to have a general know-how. By combining these two types of knowledge, the new manufacturing profile that will be relevant will greatly help to meet industry needs and spur progress. Workers, companies and educational providers alike must understand that having both wide and deep knowledge will serve all parties best when navigating rapid change.

06

Use Digital Technologies to Innovate Delivery of Education and Training



Utilise collaborative platforms to share knowledge and best practices

Use technology to help overcome physical, cognitive, and other barriers to learning

Leverage digital tools to make learning possible anytime and anywhere

While new technology has been a pivotal force in manufacturing that has caused a great amount of change, the same technology can be used to innovate the delivery of education and training to meet these newly created needs. The addition of technology can help to make education more customisable and adept to different learning styles. Every person has a different way of best capturing, comprehending and utilising information that they must learn. Since learning styles vary from individual to individual, technology can help to meet the needs of all learning styles. No longer do people exclusively need the traditional method of education where one sits in a classroom with a lecturer at the front. Technology can provide thousands of resources to learn about a specific topic or skills just from the simple screen of a smartphone. Innovative delivery mechanisms such as slides, videos, wearables and more can offer an array of different ways in which people can learn crucial skills. Along with these delivery mechanisms also comes the ability to use collaborate platforms that allow for knowledge sharing, best practices and know-how.

Utilising this technology can also adapt learning content to various needs of learners. Factors that may have once been barriers to accessing education or training such as language, physical ability or cognitive capabilities can be accounted for within learning content to meet the needs of students. Not only does this help to make education and training more accessible but it also helps to widen the talent pool from which the manufacturing sector can draw. Workers are also able to better assess what they may need to add to their skill set and what is important given the amount of access to education and knowledge.

Digital technology can even help to overcome the challenges associated with the ageing population in the workforce. For example, an ageing shop floor worker may not be able to something due to new physical constraints. However, with the use of an exoskeleton they can still physically perform this task while not putting themselves at risk or becoming obsolete. Similarly, technology can be utilised to help ageing workers learn in a more comfortable and accessible fashion in order to maintain relevant skills and knowledge. Even further, technology can be used to help retain knowledge (such as legacy systems) from older manufacturing workers that may be of great importance.

Further, the use of digital technologies can help to improve the education and training of workers in young generations. Technology can allow for flexible learning at individual paces to take place anytime, anywhere. The busy and fast paced lifestyle of many young students and workers in the twenty-first century not only influences available time and schedules but also lifestyle. Digital technologies can be used to adapt to shorter attention spans with micro-credentialing and mini-lessons. Learning can take place through a five-minute mini-lesson video that can be watched on a worker's commute home rather than traveling to an educational facility during a set time for a lesson. Flexibility in time and physical presence helps to make learning easily accessible given that educational opportunities can be delivered through digital technologies "on demand." By decoupling the rigid aspects of educational settings with learning, digital technologies can incentivise workers to continue educating themselves as it works with their lifestyle and schedule. Given that life-long learning was previously mentioned as a key recommendation that must be supported to help advance skills for the future of manufacturing, it is paramount that digital technologies are utilised to support this.

Finally, it must be noted that while digital technology must be used to help transform delivery methods of education and training it is not all-encompassing for manufacturing since there is such a physical component. Manufacturing is not a black box as we transform materials into some type of product through physical processes. While we must use these technologies, manufacturing stakeholders must remain cognisant that the overall goal of manufacturing is to make things. While we must employ these digital technologies- it must be done so in a way to promote and develop skills that keep continuously elevating and pushing industry forward.

07

Support Social Mobility Through Manufacturing

Enlarge the manufacturing talent pool by engaging underrepresented populations

Provide equitable access to education for all

Champion equal and non-discriminatory job practices

Manufacturing has been known throughout history as a powerful economic force that can uplift economies and increase quality of life for individuals. Manufacturing still has that power as it creates wealth and jobs in other sectors as a consequence. However, pursuing a career in manufacturing can also have a profound effect on social mobility. Education is an enabler of social mobility; helping people to reach higher positions and salaries that can great impact not only on their lives but future generations. Manufacturing is a field with a great amount of career diversity and opportunity, especially with new evolutions in the manufacturing field. By supporting education and engaging people outside the current scope of industry, stakeholders can help support social mobility and participation from under-represented populations in manufacturing.

First and foremost, it is important to support social mobility due to its profound societal effects. By uplifting populations, particularly those that are under-served or represented, education levels and the general state of well-being is raised across the board. By having a more equitable society, more people are able to have access to opportunities such as education and a safe and positive career. When more people are able to engage in these activities and pursue careers, then there is a much larger talent pool of people that are able to fill roles that are not currently able to be filled. This is particularly important in manufacturing as stakeholders are grappling with the skills gap and the lack of workers and talent that are available to fill crucial positions. Manufacturers must support social mobility by recognising under-represented populations in the industry and work towards engaging them and creating inclusive workplaces for all.

For example, companies should learn to value the skills of older people people who lose their jobs and/or are displaced by digitalisation. Because of their experience, these people usually have skills that are very valuable and therefore can provide value to companies and new workers. Hence, companies should always see the value of these groups.

Technology can be used to help support social mobility by bringing down physical, social and economic barriers. By utilising digital technology in education as was previously mentioned, the barrier to entry is greatly lowered for many allowing them to engage and seek opportunity within the field. Access to vocational and technical education can also lower the barrier to entry and elevate under-represented populations. The global manufacturing community must also work to actively provide opportunities and work to engage marginalised populations in order to make the field more diverse and equitable. In order to engage all peoples, industry must closely examine actions to make sure they are ensuring equitable access to opportunities. Something that is seemingly small, such as advertising a job description, can have an impact on access for people. If equal opportunities for jobs are to be available, we have to make sure they are also advertised in equitable places for all populations. Further, factors beyond salary for positions must be considered in manufacturing roles. Benefits such as holidays and remote work opportunities add more components to a role that may be crucial for some people.

To promote inclusion within manufacturing to lead to social mobility, actions such as mentoring can be taken. Having role models within a sector that help to promote the inclusion and provide advice can help to spur future involvement in the field. If people not only reap the benefits of opportunity from manufacturing but also feel included and represented, a great amount of social mobility can occur.

As a leader in uplifting lives, manufacturing must continue to strive to support social mobility. More than ever, manufacturing stakeholders need skilled workers to meet the changing needs of industry. If we work to uplift and engage all people, there can be overall gains in supporting social mobility and working towards a solution to skills gaps and shortages.

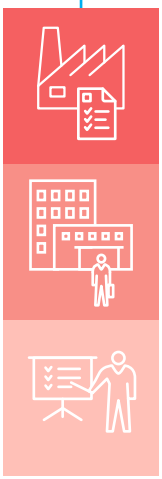
08

Ensure that Relevant Skills are Being Taught

Systematically involve industry in updating curricula in schools

Support real world experiences for students

Ensure teachers and instructors are up to date with industry developments



It is clear that manufacturing skills are changing, a skills gap exists and the manufacturing community must take action to ensure the success of the future of manufacturing. However, while in the midst large sweeping changes, it is vital to remember that all the actions with regard to skills must ensure that the right skills are being taught. To know that relevant skills are being addressed we need to deliver skills in response to industry needs. Relevance in this context is what is needed in order to be productive and keep pace with technology.

Open dialogue must be facilitated between industry, government and educational providers to understand what is needed and what capabilities are available within manufacturing. It is in the best interest of all actors to ensure that the skills being taught are not only necessary but help to drive further evolution. If all actors are able to work in tandem to ensure relevance of skills, then there will be a greater amount of success in producing skilled workers that can meet industry needs and are well-equipped for future careers. We must encourage a systematic involvement of industry in education in order to allow for highly correlated work that meets evolving needs. This cannot just be based on personal connections that happen on an informal basis but rather must have a distinct process that can be implemented and maintained on a larger scale.

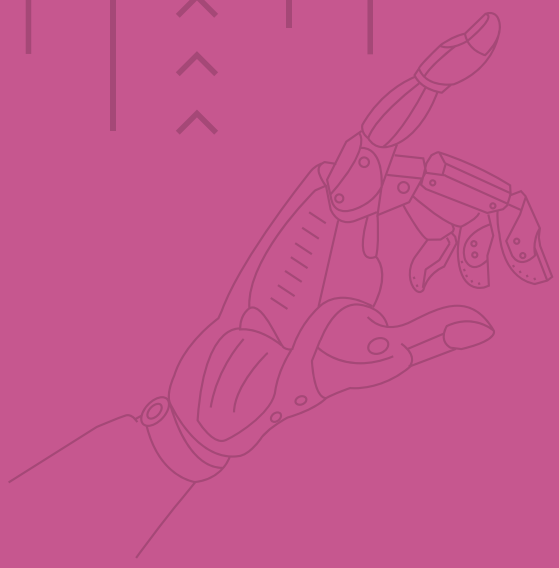
Even further, open dialogue between industry and education must be supported to create a feedback loop. If adequate communication is facilitated, then both stakeholders can have a better understanding of the need to adapt to be able to best serve one another. There can be a systematic process to accumulate, manage and implement feedback from industry in educational curricula. Engaging alumni who work in the manufacturing sector to meet with students and explain what skills they need in their companies or organisations is one way to bring industry and education closer together to understand what is truly relevant and needed. Further, this closer communication can help to reduce the lag time between a needed skill being identified and educational programmes to learn such a skill being implemented. This is also vital in understanding when a course may no longer be relevant. In a way, applying the concept of lean to skills and educational training can help to manage courses and educational programmes to best meet industry needs.

Additionally, we must take other actions to put relevant skills at the forefront of education. Encouraging integrated "real world experiences" through placeholders in educational curriculums can also provide more closely tailored relevance. Opportunities such as a guest lecturer, internship, or co-operational educational opportunity can provide some hands-on training to illustrate to learners what is practically needed of them and what a task truly entails. We also must ensure that teachers or instructors are also kept up to date and understand new technology so they can properly and accurately facilitate learning of students.

The global manufacturing community also has the power to shape what is relevant and how educational processes can be improved through this mechanism. By taking actions such as teaching relevant skills at a younger age and teaching skills that support sustainable industrial development, leaders can shape how industry will function in the future. While it was noted previously in the skills chapter and in recommendation five that every skill will have an expiration date, it is important to continuously evaluate skills and understand relevant skills in order to meet industry needs and work towards providing sufficient skills for the future of manufacturing.

09

Elevate the Value of Vocational Technical Education and Training Pathways



Promote vocational technical education to complement formal education

Encourage cooperation between vocational technical training and formal education providers

Increase the quality of vocational technical training related jobs

The overarching focus of dialogue in manufacturing today centres around digital technology and Industry 4.0. However, when you look at the core of manufacturing it is primarily concerned with one thing above everything else: making things. Manufacturing has a physical component that will never be replaced. This is why educational tools such as learning factories are highly important. As a result, skilled technical workers will always be needed and as such we must work to elevate the value of technical educational pathways that are more vocational than academic in nature. If we are able to engage and support more workers in manufacturing, then multiple pathways for education must be opened including those that are vocational.

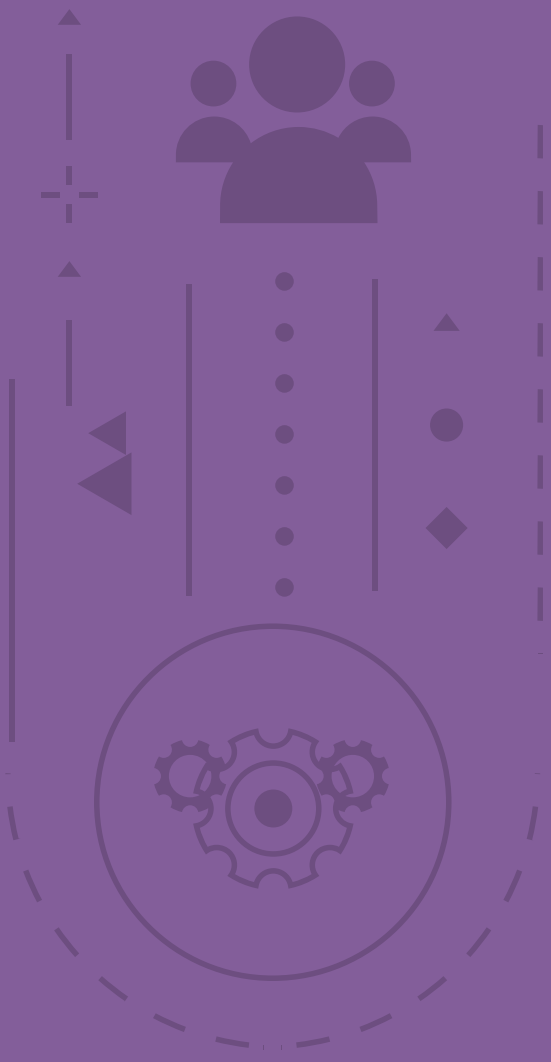
Technical expertise needs to be perceived as on par with theoretical expertise in order to encourage more people to view this as an equally desirable career path. Equally, technical education must be as well respected as higher education in order to make both educational tracks appealing. As a community, the manufacturing world needs to illustrate that there are many technical job opportunities and they have equal respect. By providing more technical and vocational pathways that don't require more formal secondary education, many more people can look to manufacturing as an exciting and interesting career path that does not automatically require a traditional educational path.

When promoting vocational technical training for manufacturing both digital technology and practical technical training need to be integral to the process. Making sure students in these pathways have quality teachers and instructors can ensure that students will be prepared with the aforementioned relevant skills and will be equipped to succeed in the current manufacturing workplace. Technical education can also help to guarantee quality and understanding of knowledge in a standardised route rather than just learning on-the-job.

Not only will technical education help to provide workers that are apt to fill important positions but it can also help to lower the barrier of separation between technical and higher education. By having more crossover and information between various educational providers more standardisation and understanding of relevant skills can be achieved. Vocational technical training has improved to be very effective with having the correct skills and as such those who have completed these programmes should be regarded with a high perception of quality and knowledge. We should invest in these educational programmes accordingly and work to provide assurance that those pursuing vocational technical training will have good, quality jobs that allow for upward mobility.

10

Foster Collaboration to Address Skills Development Needs



Set aside competition to cooperate on industry-wide skills initiatives

Share knowledge and best practices on workforce education

Harness the potential of industry and trade associations to promote skills development

Based off of the WMF's research and interviews of experts around the world and given the focus of this report, it is without doubt that skills development for manufacturing is one of the most pressing issues facing our community. As a result, it is necessary to note that we must foster collaboration to address skills development needs if the skills gap is to be solved.

Fostering collaboration between all manufacturing stakeholders increases the speed of knowledge sharing in that it shared peer to peer instead of going through formal and more involved methods. The benefits of knowledge sharing regarding skills effect both the giver and the receiver. There is a benefit beyond giving out seemingly "free knowledge." Being a leader and sharing information regarding best practices pertaining to skills can set an organisation apart as being a strong force within their field. Working as an industry and throughout company borders helps to strengthen the entire industry therefore promoting an overall stronger manufacturing sector while associating your name with a positive reputation and innovation.

Industry has an easier time trusting industry rather than getting advice or know-how from a third party. Particularly this is true of SMEs who, unlike larger multinational organisations, struggle more overall to find resources to address their needs. Parties can collaborate in order to tackle the skills gap even if they are competitors since this is an overarching problem that has been affecting the manufacturing community as a whole.

Further, there is a role to play from industry organisations in order to facilitate this collaboration. They can play an integral role in connecting companies and stakeholder with similar issues and facilitating dialogue to help find common solutions for all. Additionally, we must harness skills assessments within certain areas to gain a broader understanding of trends and what is needed. Collaboration can help to expedite the process of solving the skills gap issue that persists throughout the globe.

Finally, it is important to consider who is part of the conversation regarding the collaboration to address skill and development needs. In the past, it may have been sufficient to only have industry leaders in the conversation. However, as worker needs become more cross-sectional, it will be important to have leaders from outside of the manufacturing industry in addition to relevant academics and government agencies. Working together will be an integral part of addressing relevant development needs.

Conclusion

The 2019 *WMF Report: Skills for the Future of Manufacturing* provided an extensive discussion of the skills gap phenomenon in manufacturing, bringing to light its complexity and implications for society.

Our report highlighted that skills needed by the manufacturing workforce is fast evolving. The digitisation of manufacturing means that tasks will increasingly be automated and the required skills will shift from those that are manual and repetitive to those which are human-centric. In addition, the adoption of advanced technologies would only lead to optimal outcomes if workers have the necessary skills to work alongside them. It is therefore imperative to see the value of workers amid technological evolution and accept the need for continuous upgrading of workforce skills.

It is evident that tackling this challenge requires initiative and effort from everyone. Workers should understand the value of training and take the initiative to improve their skills when necessary. Companies should consider workforce training and development as a topmost priority. Educators and training providers would need to ensure that the correct skills are being thought. Governments should formulate policies that promote skills development. Each actor has its role. The *2019 WMF Report*, through its recommendations aims to help stakeholders take actionable steps to promote education and training, contributing to the creation of a skilled and productive society.

While eradicating skills shortages in manufacturing seems like a daunting task, it is important to understand that small steps also count. Facing the skills gap issue requires a change of mindset and a great amount of determination from all manufacturing stakeholders. The sooner the manufacturing community realises the importance of issue and stakeholders come and work together to face this industry-wide challenge, the better it is equipped to face the skills challenge. There is no better time to act but now!

WMF OPEN CALL FOR INITIATIVES ON SKILLS FOR THE FUTURE OF MANUFACTURING

The WMF launched an open call for skills initiative proposals and programmes in early 2019 to be featured in this years' report. The open call was promoted throughout the manufacturing community and urged organisations and individuals to share the experiences and successes of programmes that deal with skill development for the future of manufacturing.

While we aim to provide comprehensive insight and analysis it is also important to showcase and highlight practical, real-world examples of those who are making great strides in the area of manufacturing. Given the focus of the 2019 report, we received a large number of submissions on programmes devoted to promoting and enhancing skills for the future of manufacturing. This initiative proved to be successful in locating and recognising programmes and organisations throughout the world that are working to actively reduce the skills gap.

Each submission was reviewed by the WMF Report Editorial Board and selected based on community impact, ingeneuity and knowledge contribution to global manufacturing. We are pleased to share the winners of the open call in the following section. We hope that readers are able to learn from these initiatives and utilise the knowledge and motivation displayed in each to help spur progress forward.

e.DO Experience: Innovative Learning Through Robotics

Nicoletta Beretta
Business Development, e.DO Experience and Comau ACADEMY

Interest in robotics has increased dramatically in the last few years. Nevertheless, most schools lack both the resources and the autonomy to define their own robotics curriculum and must work with a national curriculum. It has been proven that robotics enhances the potential of learners and as a result new ways have to be found to integrate it into school curricula. On the other hand, universities have greater freedom to adopt innovative technologies in their programmes, therefore robotics has more opportunities in universities and polytechnics.

In consideration of the above, Comau Academy - in collaboration with the Comau Robotics Business Unit - has developed e.DO Experience. It provides innovative educational contents by the use of flexible platform and interactive open-source robots, designed to stimulate creativity and participation inside and outside the classroom. Furthermore, it delivers hands-on experiences to encourage cooperation and inclusion among students, for example overcoming gender differences and other forms of disparity.

Moreover, the e.DO Experience gives support to all teachers and trainers in applying new methodologies while delivering skills in key-areas such as STEM subjects, robotics, entrepreneurship skills and manufacturing. It also raises the awareness of the digital transformation in manufacturing and positively affects the industrial landscape, by attracting and developing tomorrow's manufacturing talent. In brief, e.DO Experience provides unconventional and engaging learning and teaching journeys and develops the ability to link disciplinary activities to the real world of manufacturing. Due to constantly increasing capabilities of lightweight robotic systems paired with falling prices, there is a rising demand for skilled people in manufacturing, who are able to collaborate with and operate robots. Furthermore, new entrepreneurs need to be equipped with skills related to technology and robotics in manufacturing and Industry 4.0 solutions, in order to develop new startups and think outside the existing manufacturing box.

However, educators in general and universities in particular have a key-role to teach the relevant skill sets. By disseminating learning materials (packaged as didApps for the Learning Lab and Training Packages for the Learning Centres, but also e-learning activities for the Robotics License) for schools and universities, e.DO Experience actively engages learners, teachers, professors and trainers.

The methodology that Comau Academy employs in this project considers robotic technologies not as simple tools, but rather as potential vehicles of new ways of thinking about teaching, learning and education in general. e.DO Experience encourages students to actively participate in the learning process. Students are also invited to work by activating problem solving techniques, team work, critical thinking, creativity implementing research and learning strategies that encourage growth and educational development, seeking solutions to real-world problems based on a technological framework that involves the curiosity and motivation of students. e.DO Experience teachers have at their disposal a wide range of materials (i.e. videos, exercises, questionnaires, tests) that can be used in classroom sessions with students or can serve as inspiration for activities they carry out on STEM topics. Teachers are also accompanied step by step in the development of the lessons through the Teaching Guides that lead them through a unique methodological approach.

To date e.DO Experience has achieved the following results:

- 500 Top Executives involved in different Academy learning paths using e.DO Experience (i.e. Executive Master in Manufacturing Automation and Digital Transformation -EMMA -, Human and technology with and for Hult Ashridge
- 5,500 Students engaged in e.Do Learning Centre Combo (Turin) activities in the scholar years 2017-2018 (Oct-June) and 2018-2019 (Oct-June)
- 1,600 Students involved in e.Do Learning Centre Fondazione Dalmine (Bergamo) from 2019 January to July 2019
- 7,500 students involved in Robotics License programme from September 2017 to June 2019.

"Just-In-Time" The Revolutionary New Way to Learn through Augmented Reality: Volvo Group

David Immerman
Business Analyst, PTC

Jon Lang
Lead Principal Business Analyst, PTC

The manufacturing industry is forecasted to soon have 2.4 million vacant positions, which could impact economic US output by $2.5 trillion over the next decade.

While this worker shortage issue continues to mount, the method by which workers learn hasn't changed. Education and training programmes today deliver all the information an employee "might" need to know and hope they can both retain that information and apply it in the right situation. This burdensome just-in-case training model creates challenges for knowledge retention and limits skills development, while being a costly endeavour for manufacturers (US training annual expenditures in 2018 reached a staggering $88 billion).

Currently training budgets are largely allocated to blended learning methods, yet these out-of-context systems contribute to poor knowledge retention statistics with high error rates and low productivity as the resulting business impact. Only twelve percent of workers apply skills from training to their jobs and the estimated total loss from ineffective training to a business is $13.5 million per one thousand employees.

What's been shown to be the most effective training delivery method in industrial environments is on-the-floor pairing/shadowing – where trainees observe and interact with experts performing the actual job. This just-in-time training form capitalises on human nature, transferring knowledge through a multi-sensory mix of auditory, visual, tactile, and kinaesthetic learning methods within a contextualised work environment. However, this hands-on expert training is subject to costly challenges and bottlenecks for scheduling, interrupting operators and trainer availability.

Manufacturers are turning to PTC's augmented reality solutions to solve this just-in-time training paradigm and deliver on-demand relevant digital information in-context to front-line workers, improving knowledge retention, skills development, and operational efficiencies. BAE Systems is training new employees' thirty to forty percent more efficiently than traditional methods through virtual work instructions, GSI (an AGCO brand) recognised a sixty percent reduction in installation time of its new grain systems, and Global Foundries has reduced training time for employees in the classroom and factory by fifty percent through capturing expertise and workflows of its experienced workforce with AR.

The Volvo Group is similarly facing skills development challenges on its engine quality control lines. With PTC's augmented reality, the OEM can significantly reduce training time of its new quality operators from five weeks to less than two weeks. Using a Vuforia augmented reality experience, operators can quickly recall the most up-to-date configurations in 3D to ease the cognitive burden of sorting through stacks of paper. The results are gains in productivity, quality control, and overall process efficiency. Expediting the onboarding of key personnel enables Volvo to be more flexible and agile in response to shifting market and customer demands.

Through the implementation of AR in strategic situations, Volvo anticipates savings of thousands of euros per station per year, creating competitive recruitment advantages, and enabling the OEM to get even closer to their zero Part Per Million (PPM) quality goal.

The less trainees are succumbed to traditional just-in-case training programmes and information is instead delivered through "just-in-time" methods to a worker in-situ, the greater the acquired knowledge is retained and seamlessly acted upon in real-world environments. The approximately 2.7 billion global deskless workers can benefit now more than ever from information delivery on-demand and in-context to their work environment just-in-time rather than just-in-case. Augmented reality will increasingly be this just-in-time tool for the next-generation of training in industrial environments, and inevitably the future platform for learning.

Addressing the Need for Skills in Additive Manufacturing: The Metals Project

Filip Geerts
Director General, CECIMO

The EU machine tool industry is a key enabling sector supplying highly customised, innovative and quality products to industries such as automotive, aerospace, energy or medical devices. The sector is composed of approximately 1,500 companies, over eighty percent of which are SMEs, and 150,000 workers.

The competitiveness of the sector is based on the knowledge, skills and competences gained through Vocational Education and Training (VET) and work-based learning, which are needed to design, produce, operate and maintain machine tools. Emerging technologies such as Additive Manufacturing provide new opportunities and challenges for the sector. To leverage these opportunities, workers and companies need to have the right skills; however, in the last decade, the EU machine tool sector has been challenged by the shortage of skilled workers.

The METALS - MachinE Tool ALliance for Skills - project, which was co-funded by the Erasmus+ Programme of the EU, aimed to increase the competitiveness of the EU machine tool industry and to boost the employability of its workforce. The first step of the project was the development of the EU machine tool industry skills panorama offering an overview of current and future occupations and skills needed in the sector until 2025. The skills panorama identified Additive Manufacturing (AM) as a key area for training due to the potential impact of this technology on the sector.

The AM workforce will be characterised by a hybrid skills pool. Conventional competences in subtractive manufacturing will be coupled with new skills specific to Additive Manufacturing. These new competences will be concentrated in stages such as design, STL (Stereolithography) conversion and file manipulation, post-processing, testing and maintenance. Moreover, greater soft skills in communication and presentation will be part of this skills set.

In order to support VET learners and graduates in the acquisition of those skills, a new curriculum at EQF (European Qualifications framework) level five was developed including twenty-seven learning units, formal learning outcomes and self and peer-assessment tools. The learning units cover both technical and soft skills. This material is available for free thanks to the METALS e-learning platform, which gives access to new learning materials to the sector. The e-learning platform went through a piloting phase involving VET learners and employees of European machine tool companies or companies using Additive Manufacturing. The positive outcome of the piloting phase confirmed the project has developed training materials providing useful background knowledge in the field of AM, not only for companies already interacting with this technology, but also for students willing to become future employees in those companies.

Another important outcome of the project has been a Position Paper addressed to European and national policy makers to raise awareness about the importance of AM skills in the European advanced manufacturing sector and the need to support their development. The outcomes of the project were supported by more than thirty stakeholders through the signature of a Memorandum of Understanding. The unique cooperation of industry, education providers and local/regional authorities through the project has benefited different groups. VET learners and workers involved in the piloting phase improved their entrepreneurship skills, employability and adaptability to changes in needed skills. The project helped VET providers in partner countries (Belgium, Germany, Italy, Spain) to understand the skill needs of industry and to design a curriculum ad hoc to provide learners with necessary skills. Looking at the machine tool sector and its companies, the project had a real impact by improving the sector skills intelligence, the ability to shape VET policies and training programmes which will lead to increased competitiveness through skilled workforce.

GTI International Master Programme for Automotive Workforce Transition to Future Zero Defect Manufacturing (ZDM) Working Environments: Innovalia "Automotive Engineering in Quality and Metrology" Case Study

Alicia Gonzalez
Director of Innovalia Academy, Automotive Intelligence Center (AIC) Unit, Innovalia

Francisco Alvarez
Corporate Learning and Development Director, Gestamp

Amaia Elorriaga
Coordinator - Talent Attraction & International Programmes, Gestamp Technology Institute (GTI)

Digital transformation spending by businesses worldwide is expected to hit 1.7 trillion dollars in 2019, while seventy percent of employees have not yet mastered the digital skills they need for their current jobs today and/or their future career development. Current workforce holds immense manufacturing domain and process knowledge, while young generations, particularly vulnerable to unemployment in the south of Europe, have developed enormous digital talent. It is in the hand of European industry to unlock the business workforce potential towards new productivity-enhancing roles. On the other hand, the automotive sector being one of the most demanding in terms of quality, continuously calls for more cost-effective, efficient, flexible zero defect manufacturing strategies for high quality products. Precisely, for these reasons, GTI, in collaboration with Innovalia, set an international learning programme for current workforce upskilling and young graduate digital talent attraction to master digital engineering and manufacturing platforms and ensure a competitive transitioning towards future zero defect manufacturing shop floor operations and connected factory digital processes.

The programme is unique from the very same design of its international dimension, which hosts local and international students from more than twenty countries all over the globe and which turns the GTI at the vanguard Automotive Intelligence Centre (AIC) in Boroa (Basque Country, Spain) an international reference in highly specialised knowledge and talent development inside the automotive sector.

The programme is driven by principles of excellence, collaboration, specialisation, openness and career transitioning. In fact, the programme centralises training excellence in new Gestamp digital technologies at a global scale; training the workforce not only for the future but more importantly leveraging for them a digital future through active development of new skills and competences. The Innovative Vocational Education Skills programme is the first of its kind to meet the highest standards of the Automotive sector; being fully ready for the European Certification and Qualification Association (ECQA) skill framework under the DRIVES Automotive Skills Alliance supported by the European Automotive Skills Council.

The "Automotive Engineering in Quality and Metrology" programme is a pioneer in making available in a holistic, integrated and cooperative manner over 1600 m2 of lecturing theatres and highly qualified training areas provided by GTI pilot lines and Innovalia Zero Defect Manufacturing (ZDM) Digital Innovation Hub (DIH) teaching factories. Exploiting such unique worldwide training facilities, the "Automotive Engineering in Quality and Metrology" programme puts in practice a "learning by doing" methodology providing in the first place a solid scientific foundational background on metrology. This foundational programme is followed by the theoretical-practical knowledge and skills development for quality system tools, data analytics and cutting-edge industrial metrology digital platforms applied to automatic measurement, reverse engineering and data analytics and statistical process control reporting, with real automotive parts. From a global analytical and critical engineering perspective to approach problems in manufacturing, the students develop knowledge in core resources and abilities according to recognised standards such as ISO-TS 16949 and other tools and techniques like Lean Six Sigma applied to the Industry 4.0, Cyber Physical Production Systems (CPPS) and Industrial Internet of Things (IIoT) manufacturing processes.

According to the "learning by doing" methodology, during six months, the students complete the upskilling training by further developing and applying the skills and competences gained in a real working environment at any of the Gestamp's factories and R&D centres worldwide.

In December 2018, over 4,000 students had enrolled in training programmes at GTI. The GTI & Innovalia Academy partnership is already running for three years. Ninety-six percent of the students finishing the programme were able to find a job inside the automotive sector with students stating an eithy-seven percent satisfaction with the programme. Not less important is the endorsement received by the Basque Government organisation for employment, Lanbide, which supports the programme for transitioning of unemployed qualified people towards digital jobs in automotive. The programme has also been recognised in 2016 with the "Award to the Best Skill Training initiative" in Spain.

ManuFirstSC: Accelerating South Carolina's Workforce

Elisabeth Kovacs
Deputy Director-Workforce Development, SC Department of Commerce

The ManuFirstSC initiative was developed to support South Carolina's manufacturing companies by introducing manufacturing to all South Carolinians and creating an innovative pathway to a career regardless of one's current education, experience or position in life. It expands the pool of viable candidates for manufacturers in South Carolina and provides a realistic way for anyone to change their trajectory in life, while remaining employed. The drive for a holistic approach stems from South Carolina's emergence as an advanced manufacturing leader.

South Carolina has established itself as a centre for twenty-first century advanced manufacturing, announcing $31.4 billion in investment and 89,000 jobs since 2011. The Charleston region has been the beneficiary of transformative investment by Volvo Car USA and Mercedes-Benz Vans, with both companies announcing more than 5,700 jobs from 2015 to the end of 2017. Growing from a few hundred automotive workers to a hub of automotive manufacturing in such a short period placed an exceptional demand on the local workforce.

Enter the ManuFirstSC initiative: a public-private initiative between Volvo Cars, the South Carolina Department of Commerce, Trident Technical College, readySC and Berkeley County. This initiative's sixty-two-hour curriculum was crafted from the nationally-recognised one hundred forty-hour Manufacturing Skill Standards Council (MSSC) certificate. The ManuFirstSC certificate's unique strength originates from Volvo accepting it in lieu of one year of manufacturing work experience, effectively qualifying any individual with a certificate as meeting the minimum requirements to apply for further training with the readySC workforce-training programme. Shortly after the announcement of the ManuFirstSC certification with Volvo Cars, Mercedes-Benz Vans agreed to accept the certificate in lieu of one year of manufacturing experience as well.

A grassroots approach was necessary to educate citizens on the certification and communicate Volvo Cars' ambition of hiring local Berkeley County residents. South Carolina partners engaged surrounding churches and community centres, specifically targeting rural and urban areas not known for supplying a manufacturing workforce. Community events were hosted to educate attendees on the benefits of a career in manufacturing, to present a path for every individual to earn the ManuFirstSC certificate and to connect attendees with state partners to begin the process of registering for educational resources. This community event model attracted more than 2,200 attendees across six events in the region.

Implementing this certificate programme required the local technical college offer courses both morning and evening, with an initial eight-hour Saturday class, allowing students to balance personal responsibilities and coursework. This flexible class schedule, county scholarships that defray residents' cost, and one month of class time were key components to attract adults to the ManuFirstSC initiative. Addressing the workforce demands in the region required a different approach to workforce development. The typical United States workforce development programme is designed to target specific groups and unique populations; alternatively, ManuFirstSC is available to everyone. Instead of only looking to upskill workers, the ManuFirstSC initiative was built to reduce barriers to entry, such as time, cost and experience, for all participants.

The success of the ManuFirstSC initiative can be measured by a number of metrics. Through the beginning of 2019, there are eighty-six companies across South Carolina accepting the certificate in lieu of one year of manufacturing experience; and almost one thousand South Carolina citizens have earned the ManuFirstSC certification and are qualified to apply for a career in manufacturing, expanding the local labour supply. Former bus drivers, bartenders and security guards now staff manufacturing floors, helping Volvo Cars and Mercedes-Benz Vans meet the hiring quotas necessary for production demands. ManuFirstSC will have to evolve to meet long-term manufacturing workforce demands but for the short-term, the ManuFirstSC initiative has been a success.

digITALIA: Development of Dual Vocational Training and Upskilling Pilot Models on Mechatronics and Industrial IoT within the Manufacturing Industry in Italy

Katrin Helber
Director of Dual.Concept S.r.l., German-Italian Chamber of Commerce, Milan

Valentina Rigoli
Project Manager, Dual.Concept S.r.l., German-Italian Chamber of Commerce, Milan

Due to the global importance of Italy's economy as the second largest industrial nation in Europe and within the framework of the bilateral cooperation between Germany and Italy in the field of Vocational Education and Training (VET) and labour market policy, the German-Italian Chamber of Commerce (AHK Italien) launched the two-year project digITALIA in November 2018, which is co-financed by the German Federal Ministry of Education and Research (BMBF). The project focuses on the skills development in the manufacturing industry and aims both to bridge the skills gap and to tackle the skills mismatch within Italian manufacturing companies by creating new competency profiles that cover not only technical know-how, but combine it with interdisciplinary and soft skills required by the Industry 4.0 paradigm.

Little knowledge about training opportunities and professions in the technical fields as well as the lack of appeal of STEM-study programmes have contributed to the above-mentioned skill issues in Italy as well as in the international arena and will lead to competitive disadvantages in the long term. Based on this urgency, at the beginning of the project the AHK Italien performed a unique needs analysis on 120 Italian companies in order to identify the specific skill demands of the manufacturing industry in the 4.0 era and to be able to determine the project target. The results and their discussion during the project kick-off international conference with high-ranking representatives from business, politics and industry have shown that most of the companies do not feel well prepared to face the challenges of Industry 4.0 and believe that the priority should be the promotion of vocational training and upskilling nationwide. Furthermore, companies active in Industry 4.0 declared that they increasingly require employees with specific soft skills, such as problem solving, creative thinking and client-oriented approach which are currently difficult to find in the labour market, causing a clear need for further education and training.

Following these conclusions, the AHK Italien as a member of the Association of German Chambers of Industry and Commerce – the central body for vocational education as well as certification in Germany and the coordinator of the network of foreign chambers worldwide – has started to develop prototypes of both vocational training courses for young talent as well as upskilling and reskilling courses for professionals in the key sectors of Industry 4.0, with a focus on mechatronics and Industrial IoT. Hence, thanks to a close dialogue between industry and educational institutions such as higher professional schools (Istituti Tecnici Superiori – ITS), a new qualification landscape based on the German dual VET system was established within digITALIA – a landscape which is perfectly aligned with the needs of Italy's industry and economic structure. Course participants thereby acquire both hard and soft skills via a practice-oriented approach and across all business units. Moreover, in the near future, the AHK Italien will launch a brand new online platform giving institutions, companies and strategic stakeholders the opportunity to promote their educational offer by publishing interactive courses and demand-oriented training projects. The platform will also function as a meeting point, a virtual place connecting the world of training with the world of business.

The piloting of the first upskilling modules will start in October 2019 in cooperation with the Bosch Group. Dual vocational training courses on "Mechatronics IoT" in cooperation with ITS are planned to be simultaneously launched in several Italian regions by the end of 2019. Overall, the professional qualifications issued at the end of the courses represent a lower yet valuable practical addition to university degrees in the Italian qualification landscape and will create a national qualitative standard of dual vocational education in Italy.
In the final phases of the project, transferability to other professional profiles and countries will also be examined. Therefore, in addition to the development of a demand-oriented qualification offer for Italy, digITALIA pursues the goal of providing useful insights and recommendations for action with respect to other international training concepts synchronised by the industry, in order to successfully promote education and skills development and thus help to establish societal well-being.

NPR-Hub: Transforming Higher Education Institutions in Tunisia into Hubs Dedicated to the Next Production Revolution (NPR)

Wyssal Abbassi
Associate Professor of Marketing and Management, National Engineering School of Tunis (ENIT)

The next production revolution (NPR) is occurring because of a confluence of digital technologies, new materials, and new processes. As these technologies and processes transform production, they will have far-reaching consequences for productivity, employment, skills, trade, well-being and the environment (OECD, 2017). Manufacturers and business in developed and emerging markets alike need to adapt to this rapid change if they are not to be left behind by their competitors.

Tunisia is one of the African countries that has understood early enough that the digital transformation and the next industrial revolution offers exciting opportunities for the country to make its great leap into the future. However, major reforms and efforts are needed at the level of infrastructure, education, training and scientific research to provide Tunisian industrialists with the human skills capable of appropriating the technologies accompanying this revolution.

To this end, the NPR-Hub project aims to develop a closer connection between universities and industries and reinforce the role of Tunisian universities to promote the transition toward the Next Production Revolution and adapting to the evolving needs of the labour market in Tunisia. It is an integrated approach involving education, research, vocational training and innovation labs.

More specifically, the NPR-hub will serve three objectives: the first objective is to develop practical modules and curricula oriented towards NPR. This is to produce students with 4.0 (even 5.0) competencies for the labour market. The second objective is to adopt a more collaborative, patentable research with a strong national and social impact. Finally, the third objective of the Hub is to set up a training and innovation platforms for students, professionals and local businesses.

As a pilot project, we have chosen the National School of Engineers of Tunis (ENIT), which has a favourable infrastructure for launching such a project. The NPR-hub of ENIT encompasses four components:

1. Education: the school is in the procedure of revising its current curriculum to integrate courses related to NPR (e.g. Artificial Intelligence, IoT, Big Data, Industry 4.0, Smart grids), with experiential learning. ENIT also wants to promote entrepreneurial culture among students and researchers and provide them with support for business creation.

2. Research: ENIT, has research structures that are already working on topics connected to NPR such as ICTs, renewable energies, Industry 4.0, robotics, etc. However, it is necessary to value the results of these projects through technology transfer and patenting.

3. Training: The Career and Certification of Competencies Centre (4C-ENIT) will take care of this component. The centre targets students, teaching staff and professionals and aims to: a) better professional integration and continuous adaptability to the national and international job market and b) promote entrepreneurial culture and support for business creation. Moreover, 4C-ENIT hosts a co-working space, which will promote networking with the internal and external environment at the school.

4. Innovation Platform: This platform will bring together the digital manufacturing laboratory (FabLab ENIT) and an "Industry 4.0" laboratory, which is currently under construction. The platform will be used, both for educational and research purposes. It will also serve as a training and support space for startups and local businesses.

To develop the four components of the NPR-Hub, we have put a place a strategy that relies both on internal resources (e.g. school infrastructure, staff, research units and departments) and external resources (e.g. participation in national and European programmes) of the school, and by collaborating with private, academic and institutional partners.

In addition to strategic partnerships, the sustainability of this project can be ensured by the financial contribution of the local businesses that will use the services of the Hub.

Smart Manufacturing for a Connected World: No SME Left Behind from Digital Transformation

Irene Sterian
President & CEO, Refined Manufacturing Acceleration Process (ReMAP)

Smart everything, connected products and the factory of the future, are some of the most exciting developments in the manufacturing industry in decades. New technologies, including AI, big data, automation, additive manufacturing, the internet of things (IoT), and 5G networks are collectively driving our industries towards a Fourth Industrial Revolution, where smart, connected, automated, and data-driven is the key to productivity. Industry 4.0 is a term coined in Germany that refers to cyber-physical systems communicating and cooperating through the Internet of Things with each other and humans in real-time along the value chain.

Digital technologies can be a game-changer for manufacturing. However, the adoption of Industry 4.0 in Canada is low compared to the rest of the world. As international competition increases, Canada will need to adapt to the new digital economy. In 2017, the Canadian economy totalled 1.18M employer businesses. Of these, ninety-seven percent were small businesses contributing to forty one point nine percent of the total value of exported goods. Large multinational organisations have the size, global presence and funds to undertake digital manufacturing initiatives. Digitisation can be overwhelming for SME as it requires great effort to overcome significant barriers to entry. Given the importance of small businesses in Canada, they cannot be left behind.

Understanding the benefits for the average factory, calculating ROI, scaling complex, capital-intensive manufacturing processes, retooling the workforce and prioritising where to focus first, are just some of the challenges of Industry 4.0. In response to this gap, ReMAP developed a Smart Manufacturing framework that enables SMEs (10-100 employees) across the country to discover Industry 4.0 and what it means for them. The ReMAP Smart Manufacturing framework directly aligns to two of the *10 Key Recommendations for the Future of Manufacturing* identified by the World Manufacturing Forum, 1) Cultivating a positive perception of manufacturing and 2) Assisting SMEs with their digital transformation.

The Smart Manufacturing for a Connected World framework, provides interested SMEs with the knowledge and basic tools to design a roadmap of both the manufacturing process as well as the products they build. Focusing on how to link product design and development with manufacturing process and automation; the Industry 4.0 assessment is mapped to Technology (TRL) and Manufacturing (MRL) Readiness Levels. SMEs not only look at Smart Connected Products and Smart Manufacturing Processes, but they investigate Smart Business Models too – selling a hardware, software and AI solution enables exponential growth.

With over seven hundred registrants from coast-to-coast to date; ReMAP has delivered a hands-on workshop in eight cities across Canada. In these four-hour sessions, participants are provided with an overview of digital manufacturing with a scalable approach to the adoption of Industry 4.0. We provide real-life examples of new technologies they can incorporate into their operations with as little as one hundred CAD to as much as one-hundred-thousand plus CAD. Industry experts (i.e. SMEs in agriculture, automotive, industrial) are invited to the sessions to share best practices and how they got started. Understanding how other SMEs from their own community have tackled Industry 4.0 motivates participants to respond with an action plan.

In the second half of the workshop, peer groups engage with facilitators, educators, students and industry advisors to discuss issues, assess Industry 4.0 readiness and brainstorm company-specific solutions. “The brainstorming session at our table was phenomenal,” said Carrie Wilkes, VP, CWBTech. Participants craft a unique action plan with one to two priorities to kick-off their digital transformation. They receive expert coaching, gain new skills and learn how to leverage available funding and/or collaborations with new partners. SMEs leave the session with a tangible action plan to teach other stakeholders in their organisation to accelerate global competitiveness and efficiency in productivity, operating costs and quality. To view more testimonials, go to: NRC-IRAP, Innovative Automation, Footage Tools, Fibos, Georgian College, iGen Technologies and Invest Barrie.

Smart Ecosystem for Innovation, Technology and Knowledge Growth in Mozambique

Lourino Chemane
CEO, Mozambique Research and Education Network

Fernando Lichucha
Dean of Faculty of Economics, Eduardo Mondlane University

Lucia Ginger
Lecturer, University of St. Thomas of Mozambique

Claudio Buque
Energy Specialist, Energy and Extractive Industries Global Practices, World Bank

The Next Production Revolution developments represent challenges to less developed countries like Mozambique, in particular on the skilled workforce necessary to address the complexities related to the application of Industry 4.0 technologies, given their weak infrastructure and limited technological knowledge. Appropriate education and innovation systems are critical factors for the achievement of Sustainable Development Goals in less developed countries so that they can be able to address challenges and risks of social exclusion, mainly of the youth, the majority of the population, resulting in high levels of unemployment and social tensions. The Government of Mozambique is promoting social and economic inclusion, mainly in training the youth and the population in general to participate in the Next Production Revolution (NPR). It also acknowledges the role of technology, in particular digital technologies, as facilitators of innovation and transformation of teaching and learning processes.

The current education system in Mozambique needs to include relevant content of the NPR. The graduates lack the necessary skills to be employed in NPR based industries. The Smart Ecosystem for Innovation, Technology and Knowledge Growth in Mozambique Project aims to contribute in training the youth in relevant skills based on NPR content.

This project is innovative and unique as it differs from the traditional methods of knowledge transmission and technology transfer. A web-based learning approach including the development and delivery of digital educational content based on MOOCs (Massive Open Online Courses), will use the existing Internet infrastructure, the MoRENet (Mozambique Research and Education Network), and extend it to places never served before such as industry, communities, schools, health centres providing e-Services with content based on the Fourth Industrial Revolution. The project aims to build a partnership of stakeholders engaged in contributing in skills developments of the youth and communities in four provinces of Mozambique namely, Cabo Delgado, Tete, Inhambane, and Maputo, to enable them to become relevant actors of the Fourth Industrial Revolution.

The examples of organisations not yet connected through MoRENet are secondary schools, health centres, agribusiness centres, and industrial research labs or departments. This project will contribute in bringing these organisations to the ecosystem to build a collaborative and knowledge transmission environment focused on skills required by the Fourth Industrial Revolution.

Some activities of this project have started and some entities joined as technological partners opening education content available in their MOCCs like Polimi (POK), FCCN (NAU), Liquid Telecom and other industry corporations. 750 participants from Mozambique have already registered and attended courses available in MOOCs, workshops and short training courses and gained knowledge and skills that are important for their professional and academic carriers. Universidade Eduardo Mondlane, Universidade São Tomás de Moçambique, and Universidade Rovuma also joined the project and ready to contribute with experts for content development and in organising workshops focused on the challenges of the Fourth Industrial Revolution. The Research and Technology Transfer Center of Mozambique (CITT) also accepted to join and to use the CMCs as platforms for the organisation of thematic workshops for the training and engagement with the community in the areas defined as priority in this project (health, industry, education, and agribusiness). Tmcel and Movitel, telecommunications operators in Mozambique, have also accepted to join the project and to design special packages with focus on discounts to allow the achievement of significant cost reduction in Internet and other e-Services.

The main beneficiaries of the initiative are the secondary schools and universities students and teachers, local manufacturing companies, and the members of the community working in industry, health facilities, and agribusiness.

Development of the First European/International Qualification System for Additive Manufacturing Personnel

Eurico Assunção
Deputy Director, European Welding Federation (EWF)

2019 Wohlers Report indicates that AM market continues to rise, with more new companies using AM, more investment made, and a higher number of new and innovative products designed for AM being released to the market, a trend that is predicted to evolve in the upcoming years. Technology in AM is evolving at a much faster pace than the development of knowledge and skills that allow using it. This increasing growth in AM technology requires the definition of new professional profiles, skills and knowledge for personnel working in this sector. However, due to a fragmented training offer, which does not cover all levels of education, there is a lack of responses to those requirements and to AM labour market's needs for skilled professionals.

In the face of this reality, EWF recently launched the first International/European Professional Qualification System in Additive Manufacturing, in line with the ManuFUTURE Vision 2030 Strategy. This is a unique initiative of high relevance for the labour market, creating new qualification levels, from Operators to Engineers. It is based on knowledge and skills assessment and a Quality Assurance System that ensures the recognition of the same qualification in all countries sharing the system. This initiative also reduces the hurdle of skills recognition and assures the reliability of the awarded diploma at International and European levels as it is recognised and accepted by industry, training institutions and certification bodies.

The creation and implementation of the AM Qualification System relies on EWF's expertise in managing an International/European Training System for qualification and certification of welding and joining personnel for the past twenty-seven years, and on the work, currently being developed in the scope of three European Funded projects in the field of AM, in which EWF is actively involved together with the respective partners from 8 EU countries but with the support of organisations from across the world.

In collaboration with SAM, CLLAIM and ADMIRE partners and with the support of relevant AM organisations, EWF has conducted market searches and surveys, to collect information on market needs for future workers and professionals already involved in the AM sector. Validation workshops with experts from the Industry and Education were also organised. This holistic approach, that encourages a close collaboration with major AM organisations to collect inputs for the establishment of the AM Qualification System, ensures Professional Profiles' quality and transparency.
This synergy among projects and Industry is essential for the development of this initiative, which will encompass the following outcomes:

- A Network of International/European Training Centres and Universities using the same European/International AM Qualifications;
- Training guidelines for AM Qualifications, according to Industry requirements;
- An AM Observatory to centralise the identification, assessment and validation for AM current and future skills at regional, national and European levels. It provides an updated mapping and monitoring of the AM industry technological trends, skills shortages and mismatches, policies and figures for the AM Qualification System;
- An online Qualifications' catalogue to continuously update and enlarge the AM Qualification System, integrating all the developed sectoral qualifications;
- A European Network to incentivise future cooperation and mobility in the field of education and work, as well as promoting the project results as a best practice to other sectors;
- Industry and Education Councils that will be able to identify and validate skills needs, implement AM training courses and approve training guidelines;
- European Qualifications Framework (EQF) levels, boosting recognition and transfer of credits by applying European Credit System for Vocational Education and Training (ECVET) methodology and tools;
- Enhance VET and Universities' trainers' skills and competences in AM.

Empowering Workers to be Co-designers of their Lifelong Upskilling Programmes in the Factory

Kieran Delaney
Senior Research Fellow, Cork Institute of Technology

Jacqueline Kehoe
Senior Researcher, Cork Institute of Technology

Barbara O'Gorman
Human Resources Director, Boston Scientific Ltd

Ronan Emmett
Learning & Talent Acquisition Manager, Boston Scientific Ltd

The FIT4FoF project is developing novel educational and training solutions for advanced manufacturing, placing the worker at the centre of the co-design process for the first time. This is building upon the educational paradigm of Communities of Practice through which FIT4FoF is working to create new engagement models for analysing skills needs and capacities that will enable the more effective use of these new educational approaches.

Europe faces a considerable challenge in addressing the future skills needs for the emerging opportunities in manufacturing. The skills required in the sector are changing greatly. The prevalence of digital technologies is leading to more automation, increasingly making manual and routine tasks redundant. At a human level, this characterises new technologies as a potential threat to the workforce, which is given weight by existing gaps in digital skills. The skills of the existing workforce are not always compatible with emerging technologies, ninety percent of future jobs will require digital skills and fourty-four percent of Europe's citizens lack basic digital skills. This skills gap is widening in the face of implementation of new automation solutions towards the Factory of the Future (FoF) and many companies, particularly SMEs, are struggling to hire workers with the right skillsets or internally upskill people.

The increased globalisation in manufacturing also introduces requirements in terms of teamwork, intercultural and language capabilities, the need to deal with shorter production cycles, and changes in demographics requiring workers to stay active for longer. Looking at these challenges from the perspective of the worker, one can be confronted with increasingly complex and disrupting effects from new technologies; current training and educational solutions that are silo'ed and largely dissociated from work activities; growing gaps that make it increasingly challenging to adapt and work proactively as well as contribute to innovations in the work place; an absence of mechanisms to engage and address this.

FIT4FoF is an H2020 Project seeking to address this by undertaking a series in initiatives to reduce identified skills gaps in manufacturing, promote upskilling of the current workforce and increase the innovation performance in the sector. The project is acting on this by identifying new skills requirements and job profiles in the discrete manufacturing sector. To help workers adapt to the changing and new skills requirements that increased digitisation and automation will introduce into advanced manufacturing, FIT4FoF is developing a unique yet transferable education and training framework. This is designed to create a paradigm shift that empowers the existing workforce (both women and men) to be co-designers of their life-long training and education solutions for future skills in the factory.

An example of this is the GROW Programme, a "bottom-up" initiative by Boston Scientific in Cork, Ireland. This was created to respond to the rapidly emerging skills gap that they were facing. Boston Scientific, with Cork Institute of Technology and other educators, developed a two-strand initiative for undergraduate students and for upskilling their workers in the workplace. In the first strand, they run an educational programme, aligned with undergraduate course work, and which operates as a form of apprenticeship; students complete a placement on the product lines and attend instructional learning sessions, building a deeper skillset. In the second strand, they run an adapted version of the training for product developers in their own workforce that is very successful and has resulted in improve performance and promotion for many of the participants. Workers and Students attend sessions together, facilitating collaborative learning; both strands feature strong mentoring programmes, which is seen to be a key part of the process.

Described as an "educational revolution" this programme is now being developed by other companies in the region, fostered through a government supported regional skills forum. FIT4FoF is leveraging innovative programmes like this, in combination with new educational approaches developed from communities of practice research, to deliver the necessary new training techniques for European manufacturing.

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2019 KEY RECOMMENDATIONS
BY THE WORLD MANUFACTURING FORUM

1. CREATE A MANUFACTURING MARKET WITH A LIFE-LONG LEARNING MIND-SET
2. INCREASE INVESTMENT IN WORKFORCE EDUCATION TO REACH THE FULL POTENTIAL OF NEW TECHNOLOGIES
3. ENACT POLICIES TO PROMOTE MANUFACTURING WORKFORCE EDUCATION AND TRAINING
4. EXCITE PEOPLE TO PURSUE CAREERS IN MANUFACTURING
5. DEVELOP NEW PROFILES WITH TECHNICAL EXPERTISE COMPLEMENTED BY GENERALIST KNOW-HOW
6. USE DIGITAL TECHNOLOGIES TO INNOVATE DELIVERY OF EDUCATION AND TRAINING
7. SUPPORT SOCIAL MOBILITY THROUGH MANUFACTURING
8. ENSURE THAT RELEVANT SKILLS ARE BEING TAUGHT
9. ELEVATE THE VALUE OF VOCATIONAL TECHNICAL EDUCATION AND TRAINING PATHWAYS
10. FOSTER COLLABORATION TO ADDRESS SKILLS DEVELOPMENT NEEDS

World Manufacturing Forum
WMF

World Manufacturing Foundation
Global Headquarters:
Via Pantano, 9 - 20122 Milano, Italy
Via Lambruschini, 4/b - 20156 Milano, Italy

www.worldmanufacturingforum.org