

Positioning Paper

Next Generation Skills

Enabling today's and tomorrow's
workforce to benefit from automation

published by
International
Federation of Robotics
Frankfurt, Germany

November 2020

INTRODUCTION

Over the last 30 - 40 years, rapid advances in technology have profoundly altered supply and demand for manufactured goods. The internet means that businesses and consumers are able to access a global marketplace for products of choice. Buyers increasingly expect products to be tailored to their specific requirements, resulting in ever-smaller batch sizes that are a challenge for manufacturers to produce cost-efficiently. Globalization, enabled by digitalization and liberalization of trade and labor policies, means that manufacturers can distribute production throughout the globe. At the same time, advances in automation technologies enable manufacturers to respond cost-effectively to the demand for smaller production runs and the need to adapt production quickly to changing global customer demand.

Robots are a central component of automation strategies in a wide range of manufacturing sectors. Robot adoption continues to rise steadily¹ and new robot technologies, combined with developments in machine vision and mobility, are expanding the range of tasks robots can perform. Industrial robots are increasingly integrated into automated processes, interfacing directly with other machines. Many robots are no longer separate, caged machines, but work alongside manufacturing employees, supporting them in unergonomic and monotonous tasks. Mobile robots increasingly carry out tedious fetching-and-carrying work in manufacturing and in a range of service sectors.

Skills impact of automation

The rise of automation is changing the skills manufacturers need at all levels of the workforce. Technology advances in robotics and automation call for new technical skills. Task automation shifts the focus of production workers from carrying out processes manually, to managing multiple processes, while engineers and production managers interface with a wider range of different systems. This increases the focus on 'soft' skills, such as decision-making, flexibility and collaboration.

Automation offers significant benefits to manufacturing workers – a safer, more varied work environment, the opportunity to learn new skills and move to higher-paid work, and the promise of working in a sector at the forefront of technology development. Yet IFR members, and many of their customers, report a gap between the skills manufacturers seek and those available on the market. They fear the gap will only widen over the next 10 years unless coordinated action is taken by policy makers, education institutes and manufacturers to develop flexible, tightly integrated skills development and training programs that closely match evolving market demand. While experts and institutions agree with these requirements, identifying and assessing future skills gaps in automation is hard to do in practice. The IFR has spoken with members and their customers in an effort to develop an overview of missing skills, future requirements and best practice in closing the current and future skills gaps specifically related to robot adoption. This positioning paper aims to provide a roadmap to help robot manufacturers, their customers, education institutes and policy makers ensure that the socioeconomic benefits of robots can be fully realized.

Addressing the skills gap over the next decade

We look at the technologies driving current and future robot adoption, then turn to the increasingly important role of robots in automation strategies and the benefits for companies and employees. We focus on how four traditional roles in manufacturing – operator, technician, production manager and engineer – will evolve over the next 10 years, and which new roles will be created as a result of automation and robot adoption. We assess the skills gap now, and in relation to the changes we have identified for the next 10 years. We provide an overview of best practice in responding to the current skills gap and preparing the workforce for the future of manufacturing. Finally, we recommend actions that different stakeholder groups, including future workers, must take to ensure that companies and their employees can reap the substantial benefits of the rise of automation.

¹ IFR World Robot Report, Industrial Robots 2020

EXECUTIVE SUMMARY

- **Manufacturers are turning to advanced automation and flexible manufacturing in order to cost-effectively respond for demand for smaller, customized production runs.** Robots play an increasingly important role in automation strategies: From 2013 to 2019 robot installations increased by 11% on average per year.
- **Automation will not replace employees but is shifting skills requirements to higher-skilled, better-paid jobs.** Manufacturing employees will spend more time in the future on technical versus largely repetitive physical tasks, moving from task execution to the oversight and management of a range of tasks and processes. They will work in multidisciplinary teams combining employees with knowledge spanning a range of technologies and processes, and domain experts.
- **Advances in robotics will significantly change manufacturing jobs and skills profiles over the next 10 years.** IFR members predict that over 50% of manufacturing operators will be working with robots in 10 years' time. Robots will assist workers in tedious, unergonomic work such as feeding machines, lifting and holding heavy parts and performing repetitive tasks that require high degrees of precision such as applying glue or polishing surfaces. Many operators will learn to program and supervise robots. Advances in robot interfaces mean many applications can be programmed intuitively and quickly by manufacturing operators with no programming skills.
- **Automation and increasing robot adoption is creating new, interesting roles in manufacturing:** Examples include: The Smart Factory Manager, responsible for the smooth-running of the entire automated supply chain; The Solution Planner, tasked with developing plans to address customer issues; The Production Technology Engineer, who integrates, reconfigures, monitors and maintains the resources of an entire production line and; The Robot Teaming Coordinator' (RTC) – an employee who designs business processes that integrate robotics into production and distribution operations and trains humans and robots to work together collaboratively. Examples of new deep domain expert roles include the Robot Debugger and the Vision System Technician
- **Manufacturers will place higher value on human skills such as critical thinking, problem-solving, and people management.** For many manufacturers, a shift in corporate culture, led from the top, will be required to enable an environment where agile teams of employees working locally and remotely have the autonomy to identify and resolve issues collaboratively, as well as develop and try out new solutions to optimize production efficiency
- **Manufacturers today struggle to hire workers. A shortage of qualified workers at all skills levels is forecast to continue unless action is taken:** New job growth in manufacturing will center around high-skilled technical tasks. However, the retirement of baby boomers (born between 1944 and 1964) will create a shortfall of existing low-to-mid skilled workers in manufacturing. Just under 10 million plant, machine operator and assembler positions are forecast to remain vacant in Europe between 2016 and 2030, with a shortage of 450,000 welders in the US by 2022
- **Action is required by a range of stakeholders: Policy makers** must promote automation and technology adoption as a driver of national and regional competitiveness: **Manufacturers, education institutes and government** must promote attractive career paths in manufacturing for young people AND older workers as well as develop lifelong learning programs for employees. Programs for reskilling existing, older workers are vital: **Manufacturers and education institutes** must collaborate to adapt curricula to evolving demand for technical skills: **Manufacturers** must focus more on re-skilling existing employees and hiring for potential rather than skills. Robot manufacturers must continue to simplify programming interfaces to ensure that robotics becomes accessible to lower-skilled employees: **Employees** must be involved in planning work processes involving robots.

THE RISE OF THE ROBOT: TECHNOLOGY DEVELOPMENTS DRIVING ROBOT ADOPTION

Robot adoption has steadily increased over the last decade. The number of installed industrial robots more than doubled between 2009 and 2019, reaching over 4 million industrial robots at work around the globe in 2018. From 2013 to 2019, annual installations increased by 11% on average per year². Robots have for decades been a standard feature in automotive manufacturing, carrying out dangerous and unergonomic tasks such as welding, metal cutting and assembly of large parts such as car chassis and doors. However, robot adoption has diversified substantially over the last 10 years to other industry sectors. The electronics sector is now vying with automotive for first place in the share of annual sales of industrial robots. Other sectors that have experienced rapid increases in robot adoption include food and beverage production and pharmaceuticals / cosmetics. China has an extremely diverse manufacturing industry with over 100 different sectors. Many of these sectors, such as wood processing and furniture manufacturing, have only just begun to adopt robots, leaving significant potential in the world's largest robot market.

Industry diversification has been driven by two trends. One is the falling price of robot systems - driven by lower component prices, and by rapid developments in ease of installation and programming which drive down the overall cost of installation. The second trend is new technology developments that are enabling manufacturers in different sectors to automate tasks that robots were previously not able to perform cost-effectively. Three technology areas stand out - gripping, vision, and mobility.



Figure 1: 3-finger robot gripper. Image credit OnRobot

Robot grippers have advanced substantially over recent years, enabling handling of small, delicate and irregular objects. Electronics assembly, for example, requires very rapid, precise placement of miniature objects that are often fragile, while food packaging requires the ability for robot grippers to deal with irregular shapes and materials that flex. Advances in vision technologies have enabled a range of new applications, from identifying and extracting parts from unsorted bins to performing quality inspections. Finally, many robot arms can now be installed on mobile bases that can move around factories, fetching and carrying parts and feeding machines. In the past, automated guided vehicles in factories and warehouses followed set routes, but thanks to vision and mapping technologies, mobile robots are able to re-plan their routes if they encounter an obstacle.

In addition to these advances, a new breed of collaborative industrial robots, designed to work alongside employees in factories and warehouses, have expanded the range of tasks robots can perform. These robots act as assistants, performing parts of production processes that are

heavy or tedious such as tending machines, fetching and carrying parts and materials and performing tasks such as stacking, parts assembly and product finishing. Collaborative industrial robots are typically made of lightweight materials enabling them to be easily moved around factories and with rounded edges to reduce the force of any unintended impact. Sensors on the robot's axes enable the

² IFR World Robotics 2020- Industrial Robots

Next Generation Skills

robot to 'sense' if a worker is too close for safety, slowing or stopping entirely depending on the distance and resuming work automatically once the worker moves away.

ROBOTS AND THE FUTURE OF MANUFACTURING

Manufacturers have, over the last few decades, focused on finding ways to enable cost-efficient production of smaller, customized production runs. Larger manufacturers – such as automotive manufacturers – achieve this by mass producing parts used across all product lines and then running smaller production lines for customized parts and processing. Smaller manufacturers may operate multiple low-volume production lines and / or switch lines frequently. In either case, manufacturers are focused on shortening the product life cycle – from design to shipment, as well as optimizing the supply and utilization of resources.

More recently, manufacturers are turning to advanced automation and flexible manufacturing to support the drive towards optimized customization. Robots have a role to play in both.

As we discuss in our paper [How Connected Robots are Transforming Manufacturing](#), manufacturers are turning to advanced automation to improve productivity, reduce costs and improve competitiveness. While automation refers to the performance of a task by a machine rather than a human, advanced automation refers to the control of one or multiple machines by another. In so-called 'Industry 4.0' advanced automation scenarios, the entire production process, from order entry in a manufacturer's enterprise resource planning system (ERP), to scheduling of delivery of finished goods, is automated, with each step of the process automatically triggering the next. Communication with and between machines generates data that can be aggregated and analyzed to improve production performance, reduce waste, monitor machine wear, and anticipate maintenance needs, saving costs in downtime that can run to over a million dollars per hour for large manufacturers.



Figure 2: Mobile robots feed machine workstations. Image credit Stäubli

Robots are a key tool in automating manufacturing tasks, and the technologies described above have vastly expanded the range of tasks robots can perform. In advanced automation scenarios, robots are digitally linked to other machines in the production process and can either direct other machines, or be directed, through the respective robot or machine controller.

The second trend is flexible manufacturing in which the traditional linear production process is divided into smaller, discrete production cells that perform one or more tasks across a range of production lines. Orders are divided as they are entered into ERP systems and distributed automatically between machines, with mobile robots executing scheduled delivery of materials and parts to the relevant workstation. (See a case study [here](#)). Advances in robot programming and interfaces, and peripherals such as grippers and machine vision support flexible manufacturing. Robots can be very quickly re-tasked. Programs can be adapted through intuitive user interfaces and robots fitted with tool change adaptors can automatically select the right tool for the new task.

What do these changes mean for manufacturing employees? Advanced automation, with its reliance on autonomous machines that can direct other machines, may suggest that manufacturing operators will become redundant. As we discuss in more detail below this is not the case. Rather, the majority of manufacturing employees at all levels will move from specialization and task execution to managing a range of tasks and processes. They will rely on information gathered from data generated by production machines to anticipate, identify and resolve problems, to develop new processes and optimize existing production lines. Many will programme robots through intuitive interfaces, or train artificial intelligence algorithms used in robotic applications. They will work with specialists in particular technologies from vision systems to artificial intelligence, depending on the manufacturer's needs.

THE IMPACT OF AUTOMATION ON SKILLS REQUIREMENTS IN MANUFACTURING

The changes described above are already impacting the skills required at various levels in manufacturing and logistics employees. These requirements will continue to evolve as existing robotic and other automation technologies are adopted at scale, and new technology advances are commercialized.

As we discuss in our paper [The Impact of Robots on Productivity, Employment and Jobs](#), a large body of literature establishes that automation does not destroy jobs. In fact, a number of studies point to the opposite – jobs have grown faster in occupations using automation and countries that invested more in robots have maintained jobs in manufacturing more than those that did not.

Instead, jobs at all levels are changing in ways that offer more job satisfaction and opportunities for skills acquisition for employees at all levels. Below, we take a look at how the four classic profiles of production operator, maintenance technician, engineer and production manager are impacted by the rise of robotics and automation and how these roles will change over the next 10 years.

PRODUCTION OPERATORS

Robots and other automation technologies and processes reduce the amount of time production workers spend on tedious, unergonomic work such as feeding machines, lifting and holding heavy parts and performing repetitive tasks that require high degrees of precision such as applying glue or welding. Operators have the opportunity to learn new, interesting skills related to managing these new technologies. IFR members believe that over 50% percent of welders, machinists and assemblers will be working with robots in 10 years' time. In the past, programming robots was complex and required engineering skills. While complex applications still require specialized knowledge, robots are increasingly easy to program and re-task for many applications. Many robot tasks can be assigned by production operators through intuitive interfaces or by demonstration (where the operator guides the robot arm through the task to be performed). Simple robotic tasks can be quickly programmed by operators with only a few hours of training. In many large companies, production workers already use robots as tools - for example lifting or holding parts in place so that the worker can perform a process. As robots become increasingly economically viable, IFR members expect significant uptake of robotic tools in small-to-medium sized manufacturers that have not yet invested in automation. A number of

Next Generation Skills

robot manufacturers are providing 'out-of-the-box' robotic tools that require a minimum of programming through demonstration.

Workers will be increasingly involved in training artificial intelligence algorithms used for robotic applications such as pick-and-place. The worker demonstrates to the robot which parts need to be picked or placed and then supervises the robot's activity until the artificial intelligence algorithm has been trained to correctly identify, pick or place the object. This also applies to robotic inspection systems, where the worker will train the robot's algorithm to distinguish between a product fault and something detected erroneously as a fault, caused, for example, by different lighting conditions.



Figure 3: Training a pick and place robot. Image credit KUKA

Workers will also be central to designing and adjusting processes to incorporate robots effectively as human assistants. Many companies have recognized that process design should be led by, or include, production operators as many have tacit knowledge of which parts of the process can be improved through robotic assistants, where human dexterity is required, and where bottlenecks are likely to occur. Workers will therefore increasingly combine manual skills with 'soft' skills such as creativity, decision-making and reasoning, to design and supervise production lines.

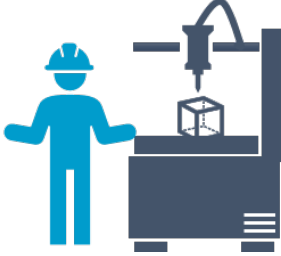



IFR members believe that, of the four profiles, the role of the production operator will change most over the next 10 years – with significant benefits for production workers. The extent of change will vary from company to company depending on the structure of production. In general, large, standardized production processes will be entirely or largely automated, with production workers overseeing the smooth-running of robots and other production machines. More complex tasks such as intricate, high-precision welds and the production of small, technically complex batch orders will largely be carried out manually by skilled production workers. Smaller but technically uncomplicated production runs are likely to be carried out increasingly by workers with robot assistants completing standard tasks such as fetching and carrying materials and loading machines. However, as experts point out³, it is a fallacy to think that human expertise can be replaced by automation. As one paper notes “Even in highly routine work even those engaged in machine and production-based work are often confronted with unpredictability, change, and complexity.”⁴ And another author comments⁵, “the more we depend on technology and push it to its limits, the more we need highly-skilled, well-trained, well-practiced people

³ See for example: On the combination of experience based skilled and robotics: Pfeiffer, Sabine (2016)

⁴ On the importance of vocational training and how wrong Frey/Osborne are: Pfeiffer, Sabine (2018)

⁵ Baxter, G.; Rooksby, J.; Wang, Y.; Khajeh-Hosseini, A. The Ironies of Automation ... Still going strong at 30? In: Proceedings of the 30th European Conference on Cognitive Ergonomics ECCE, Edinburgh, UK, 28–31 August 2012; pp. 65–71.

to make systems resilient, acting as the last line of defense against the failures that will inevitably occur”.

HOW THE FOUR MANUFACTURING ROLES WILL CHANGE OVER THE NEXT 10 YEARS	
	<p>Production operators will:</p> <ul style="list-style-type: none"> • Work with robots – IFR members estimate 50% will be working with robots in 10 years’ time. Tasks include: Programming of simple applications: Monitoring robot performance: Working collaboratively with a robot ‘assistant’ or robotic tool • Have the opportunity to learn new skills • Work across a range of production lines or cells
	<p>Technicians will:</p> <ul style="list-style-type: none"> • Rely on data generated by machines, and analytic tools to assess when machines need maintenance • Need broad information technology skills to interpret digital representations of physical machines and search databases • Start to take a proactive role in process optimization, exploring how processes could be altered to function more efficiently and avoid typical bottlenecks
	<p>Engineers will:</p> <ul style="list-style-type: none"> • Increasingly manage connected systems rather than discrete machines • Need expertise in electronics and software as well as traditional skills in mechanical engineering. • Require an understanding of the interfaces and communications protocols between back-end order systems and machine controllers, as well as Internet of Things communications protocols
	<p>Production managers will:</p> <ul style="list-style-type: none"> • Oversee a broader range of machines and processes than in the past • Need broad technology skills in related systems such as enterprise resource planning (ERP) • May in future work in production control rooms managing employees who monitor screens showing the flow of materials, production capacity, machine yield, alerts for machine malfunctions and output to warehouses for shipment. Will also perform complex optimization tasks across the entire production line

TECHNICIANS

As automation advances, more and more machines are digitally connected, transmitting data on their status against given parameters such as temperature and speed. Analysis of this data enables manufacturers to detect when machines are showing signs of wear and to predict the optimal point in time to perform maintenance – avoiding unforeseen and costly downtime. Digitization enables

Next Generation Skills

manufacturers to identify the specific parts that need changing – rather than technicians discovering this only when the machine has been dismantled. This means the required parts can be ordered in advance, reducing maintenance time.

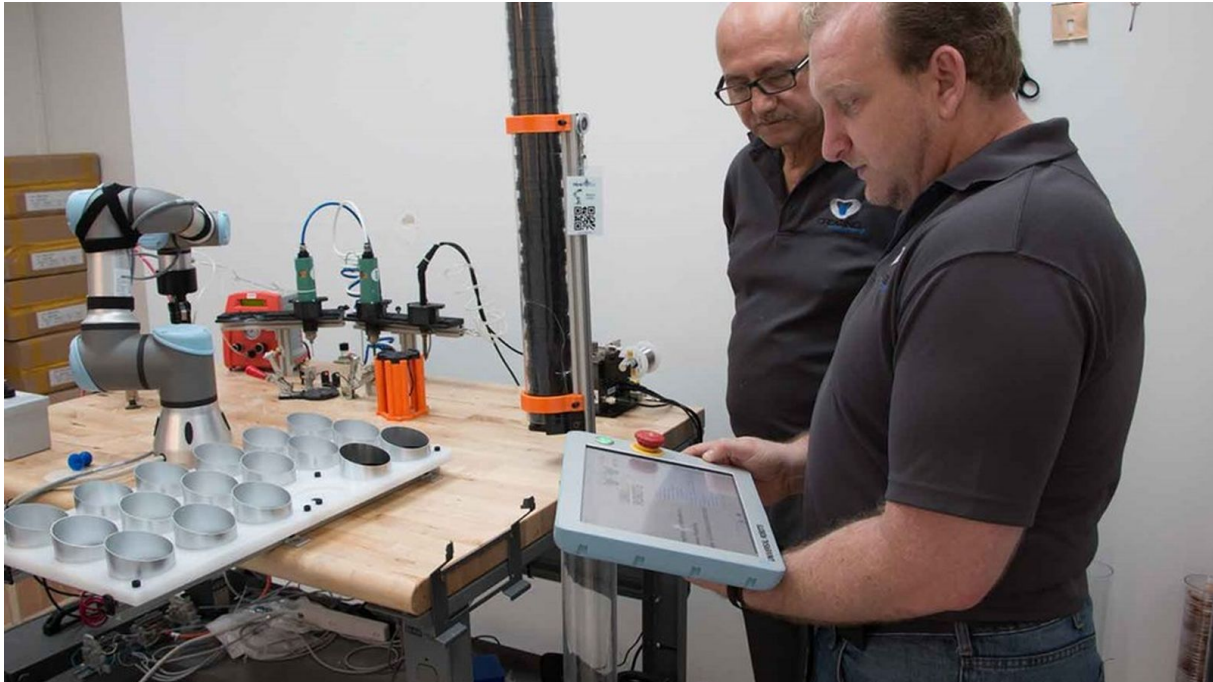


Figure 4: Technicians monitor robot progress at Creative Revolutions. Image credit Universal Robots

Digitization also means that technicians can capture expertise on problems and solutions that can be made available throughout the organization. For example, as we describe in our paper [‘How Connected Robots are Transforming Manufacturing’](#), robot manufacturer KUKA has connected all of the machines, including the 7 robots, in the production hall at its Augsburg manufacturing plant to the cloud. Production managers and technicians are able to monitor all of them through a smartphone-like interface. If error-messages appear, technicians have access to a wiki-type database providing almost half a million proposals for solutions. The technicians can also access data enabling them to retrace the whole process to look for anomalies.

In addition to expanding their range of technical skills in specific machines, technicians are therefore also increasingly acquiring broad information technology skills to interpret digital representations of physical machines and search databases.

ENGINEERS

Digitization is making its mark on the role of the engineer, in particular in the design and development phase. Engineers are already able to build new product models in computer-aided design and manufacturing systems that automatically generate lists of parts required. Simulations in digital twins enable engineers to model the impact of integration of the machine into the existing production setting, enabling them to see potential problem areas - for example the impact of vibration from one machine on the accuracy of others. 3D printing enables manufacturers to produce rapid prototypes from early designs and test these before embarking on costly production runs.



Figure 5: 3D CAD engineering. Image credit AutoDesk

CHANGES AFFECTING BOTH TECHNICIANS AND ENGINEERS

Over the next 10 years, technicians and engineers will increasingly manage connected systems rather than discrete machines. This will call for expertise in electronics and software as well as traditional skills in mechanical engineering. This is already evident in the relatively new job profiles of Mechatronic Engineer and Mechatronic Technician and System Engineer or Technician. However, it also applies to existing roles. For example, robot technicians, who program robots, increasingly require skills in interpreting computer-aided-design simulations, as well as vision system programming, data analysis, edge computing (the processing of data locally) and the configuration of devices and controllers that connect the robot to grippers and other end-effectors.

As they increasingly configure and manage bottlenecks in entire systems, technicians and engineers will require an understanding of the interfaces and communications protocols between back-end order systems and machine controllers, as well as Internet of Things communications protocols.

Technicians will continue to move from responding retroactively to problems to anticipating and preempting issues, using predictive analytic tools and technologies. This work may increasingly be carried out remotely, with alerts sent to technicians who can access required information online. This makes it much easier to build teams of technicians combining remote technicians with specific domain expertise and local technicians who have an understanding of the local plant's configuration. Technicians already frequently play a proactive role in process optimization. In the future, they will be equipped with increasingly sophisticated data and analytics tools to enable them to model how processes could be altered to function more efficiently and avoid typical bottlenecks.

The roles of technician and engineer are also likely to become more fluid – for example an emerging role of Engineering Technologist calls for higher skills than typically required for a technician but does not require an engineering degree.

PRODUCTION MANAGERS

The trends of digitization and the dis-aggregation of the traditional linear production line described above are also impacting the skills required by production managers. In general, production managers are increasingly required to oversee a broader range of machines and processes than in the past. They analyse digital representations, and data, to gain an overview of production status, and to

Next Generation Skills

identify potential bottlenecks. As manufacturers increasingly automate the full supply chain – from order entry to delivery – production managers are also acquiring broader technology skills in related systems such as enterprise resource planning (ERP).



Figure 6: The modern control room. Image credit ABB

In the future, we may see the emergence of production control rooms with production management employees monitoring screens that show the flow of materials, production capacity, machine yield, alerts for machine malfunctions and output to warehouses for shipment. Command centre staff will identify immediate or potential issues and alert the relevant production staff to resolve them.

TRENDS AFFECTING ALL FOUR JOB PROFILES

In general, the roles of all four profiles will become increasingly multidisciplinary. For example, production operators will work with a wider range of machines, and will likely be able to carry out performance measurement tasks, while production managers will require IT skills to interpret production data from a wide range of production systems. As production lines are increasingly automated, employees at all levels in manufacturing will need basic knowledge of a wide range of technologies such as collaborative robots, sensor technologies, pneumatic devices and vision systems. These technologies will become increasingly intuitive to set-up and use but employees will spend far more time applying technical knowledge than in the past. Consultancy McKinsey predicts that by 2030, manufacturing workers will spend almost 60% more of their time using technical skills and around 40% less using physical and manual skills.⁶

The degree to which employees will be required to be technology generalists rather than specialists will vary by company size and focus. Smaller companies may need more generalists than larger companies, for example. There will also be a need for specialists in specific domains – such as artificial intelligence or vision systems - who work in teams with technology generalists.

The four job profiles will increasingly work in multidisciplinary teams - that may also involve process technologists and IT experts - to design, build and operate new production lines and resolve problems. These teams will pool expertise in order to bridge classic IT systems, new automation technology, and 'legacy' machine controllers that form the foundation of advanced automation platforms. For example, within the automotive sector, production operations teams need to manage multiple production lines, covering a range of different functions. In addition to traditional laser welding, they may also supervise complex welding techniques for new, lighter materials that require significant expertise from operators. Operations teams also perform a range of analytical tasks. For example, they manage the processing and interpreting of welding monitoring data for traceability, interpret artificial intelligence applications that assess welding quality and geometry control and analyze performance data for predictive maintenance.

As a result of these changes, the roles of all four of the profiles outlined above – and others within the production process – will shift from physically executing tasks to managing automated tasks and

⁶ Skill Shift: Automation and The Future of the Workforce, McKinsey Global Institute 2018

processes, most often within a team of experts with different skills. As a result, ‘soft skills’ such as critical thinking, communications, problem-solving and creative thinking – applied to redesigning and optimizing production processes – will be increasingly important. Teams are likely to work in a mix of physical and remote constellations.



Figure 8: Multidisciplinary collaboration. Image credit Universal Robots

Getting the best out of teams that may assemble for short periods and collaborate remotely is likely to require a fundamental shift in the organization’s corporate culture which can only be led from the top. Many IFR members predict flatter and more inclusive organizational hierarchies. If an emphasis is put on creative thinking and problem-solving, employees need to be encouraged and given space to develop and trial new solutions and fail without recrimination.

AUTOMATION CREATES NEW JOB PROFILES

Automation is altering other functions within the organization as well as creating new job profiles. Information security experts, for example, will need to understand the type of data shared by machines and assess potential security implications if this data is stored in the cloud. In robotics, equipment manufacturers will increasingly move to selling integrated solutions versus robot components or discrete technologies.

New job profiles fall into two categories – deep technology domain experts and multidisciplinary roles that cross the traditional lines between the four roles we have discussed above.

Next Generation Skills

NEW JOB PROFILES THROUGH AUTOMATION		
MULTIDISCIPLINARY ROLES	Smart Factory Manager	<ul style="list-style-type: none"> Broad profile spanning production operations and quality control, as well as product design and engineering and IT and cyber security Uses predictive maintenance analytics to identify machines that are operating outside of established parameters and directs preventive maintenance teams to address issues
	Solution Planner	<ul style="list-style-type: none"> Spans engineering, technician and production planner roles Tasked with developing plans to address customer issues
	Process / production technologist	<ul style="list-style-type: none"> Supports the running of a highly automated automated factory High degree of multi-disciplinary flexibility and knowledge of multiple automation systems Germany has developed a vocational study program for this new professional profile ⁷
	Production Technology Engineer	<ul style="list-style-type: none"> Integrates, reconfigures, monitors and maintains the resources of an entire production line
	Robot Teaming Coordinator ⁸	<ul style="list-style-type: none"> Designs business processes that integrate robotics into production and distribution operations Trains humans and robots to work together collaboratively Monitors robot performance and provides feedback to programmers to optimize performance
	Automation technology trainer	<ul style="list-style-type: none"> Versed in multiple automation technologies Develops and runs training programs working with external education institutes and equipment manufacturers
DEEP DOMAIN EXPERTS	Vision System Technician	<ul style="list-style-type: none"> Responsible for supervising and adjusting (robot) vision systems
	Robot Debugger	<ul style="list-style-type: none"> Responsible for resolving software issues in multiple robots
	AI optimization expert	<ul style="list-style-type: none"> Develops algorithms for production optimization and predictive maintenance

⁷ Industrie 4.0 – Qualification 2025, conducted on behalf of the VDMA by the Department of Sociology of the University of Hohenheim

⁸ The future of work in manufacturing, Deloitte 2018

THE MANUFACTURING SKILLS GAP – PRESENT AND FUTURE

As noted earlier, a large body of literature establishes that automation does not destroy jobs – and can in fact create new jobs in manufacturing, logistics and related service industries. In fact, most manufacturers are currently unable to find needed skills. IFR members are concerned that this situation will worsen unless more is done to provide and promote attractive careers in manufacturing for young people and ensure ongoing skills training for existing employees.

In the US, nearly 80% of manufacturers are struggling to fill over 400,000 open positions⁹ and one third were forced to turn down new business in 2019 due to a skills shortage, according to the National Association of Manufacturers¹⁰. It's also taking longer to hire manufacturing workers of all skills levels¹¹.



Figure 7: Robot training in Thailand. Image credit:ABB

In Asia, the leading manufacturing economies of Korea and Japan have both instituted foreign visa programs to address the skills gap. Japan introduced its foreign visa program in 2019. Thirteen percent of the visas issued by the end of the year were for industrial machinery manufacturing workers. In Korea, one in ten employers with five or more employees rely on filling some vacancies with foreign workers and jobs at SME manufacturers are particularly hard to fill. 35% of job shortages in small companies are in manufacturing¹² and 10% of jobs in SME manufacturers are taken by immigrant workers¹³.

It's not just new technology and automation skills that are in short supply. As the 'baby boomer' generation (born between 1954 and 1964), retires, there will be an acute shortage of 'classic' manufacturing skills such as welding, machine operators and assembly workers. For example, Cedefop, the European Centre for the Development of Vocational Training, predicts a shortage of 29 million technicians and associated professionals and just under 10 million plant, machine operator and assembler positions in Europe between 2016 and 2030¹⁴. Cedefop forecasts that 91% of new hires in Europe to 2030 will replace retiring workers¹⁵, meaning manufacturers will have to replace traditional skills at the same time as introducing new skills required to manage and reap the benefits of automation technology. Meanwhile, the American Welding Society predicts a shortage of 450,000 skilled welders in the US by 2022. As we discuss below, the indications are that manufacturers must

⁹ US Department of Labour Job Openings and Labor Turnover – January 2020

¹⁰ NAM Manufacturers' Outlook Survey Third Quarter 2019

¹¹ 2018 Deloitte and The Manufacturing Institute skills gap and future of work study

¹² [Korea Herald](#) Sept 18 2019 accessed 09.04.20

¹³ Recruiting Immigrant Workers: Korea 2019, OECD

¹⁴ Cedefop, Eurofound (2018). Skills forecast: trends and challenges to 2030

¹⁵ Cedefop Briefing note – 9130, 'Less brawn, more brain'

Next Generation Skills

work to up-skill their existing experienced workforce to close this gap, rather than automatically hiring to acquire new skills.

Over the next 10 years, as advanced automation becomes more widespread within large companies, and as small-to-medium-sized manufacturers turn to automation to enable them to remain competitive, new, high-skilled and well-paid jobs will open up to people interested in working at the forefront of technology. Cedefop predicts that 80% of new jobs (across all sectors) in Europe to 2030 will be in high-skilled positions¹⁶. By 2030, 2.3 million additional workers with technological skills will be required in manufacturing in the US and Western Europe according to McKinsey¹⁷.

CLOSING THE SKILLS GAP

The governments of major manufacturing economies have broadly recognized that national and regional competitiveness in manufacturing depends on the ability to provide an enabling environment for automation, including broadband infrastructure, policy incentives and, crucially, the right educational programs. However, the extent to which these measures are being implemented varies greatly. Governments must realize that unless they actively support automation, national manufacturing sectors may be left behind.

Initiatives to Close the Skills Gap

Initiatives undertaken by governments and educational institutes to close the skills gap include:

Dual study / work programmes

Germany has a long tradition of matching skills training to demand, both through higher education, and through apprentice trainee schemes that do not require a higher education qualification. The 'Duales Studium' (parallel study) system enables students to complete a higher education qualification while working for a company. Seventy-five percent of Duales Studium students are employed on full (non-fixed-term) contracts following their studies, versus 50% of students in other higher education programmes.

Switzerland uses a similar model.

South **Korea** – where a greater percentage of young people complete higher education than in any other OECD country – has introduced a 'Meister' vocational training programme aimed at addressing a skills demand gap which, according to the World Economic Forum, led to 42% of Koreans being overqualified for their jobs in 2014.

Lifelong learning programmes and incentives

Governments in a number of countries have developed programmes and incentives to ensure that employees can continuously update their skills to match demand. The government of **Singapore**, for example, offers \$370 subsidies to all Singaporeans aged 25 and over to study in hundreds of career-oriented courses. Singapore's national university also adapted to offer more worker-friendly educational opportunities, including part-time degrees, modular certificate courses, executive education, and free classes for alumni.

Denmark, which has a long tradition of continuing education, runs an 'Arbejdsmarkedssuddannelser' programme of short courses focused on providing both low-skilled and skilled workers with the skills and qualifications they need. In **Sweden**, job security councils, jointly managed by the private sector and unions, retrain workers who need to upgrade their skills as a result of automation. Some US states have made community colleges free for residents in order to encourage ongoing skills training.

Some of these programmes and incentives focus specifically on retraining workers whose roles could be affected by automation. The **UK** government, for example, has launched a 'Get Help to Retrain' scheme aimed at helping adults identify and address skills gaps and job opportunities.

¹⁶ Cedefop Briefing note – 9130, 'Less brawn, more brain'

¹⁷ Skill Shift: Automation and The Future of the Workforce, McKinsey Global Institute 2018

Initiatives to Close the Skills Gap

In **Germany**, the German Academic Association for Production Technology, a consortium of leading German professors of production technology, has developed 15 1-2 day courses aimed at enabling workers in SMEs to upgrade their skills.

Public-private partnerships focus on matching skills training to demand

A number of public-private partnerships focus on ensuring that educational curricula are matched to local and regional employer demand. In the **US**, **Advanced Robotics for Manufacturing (ARM)** a national, member-based consortium aimed at accelerating growth in US-based manufacturing (and a member of Manufacturing USA, a network of institutes with a specialized technology focus) is developing a public website providing a comprehensive list of education providers and endorsed programs and institutions providing the skills needed for robotics jobs, as identified by over 200 ARM members and other experts. ARM is also developing a roadmap of competencies required for common job profiles within robotics. ARM is building a central, national database of validated training facilities and a range of training and certification programs, from apprenticeship training to advanced manufacturing, programs. ARM has defined a three-level career pathway in robotics with the aim of standardising skills requirements to enable manufacturers to more easily communicate opportunities and find qualified staff. A set of technical competencies and soft skills has been developed for each of the positions of Robotics Technician, Robotics Specialist and Robotics Integrator. As manufacturers create new jobs, they identify which of the three profiles their job requirement best matches, and then select the relevant competencies and essential soft skills for their position within the competency set for that profile.

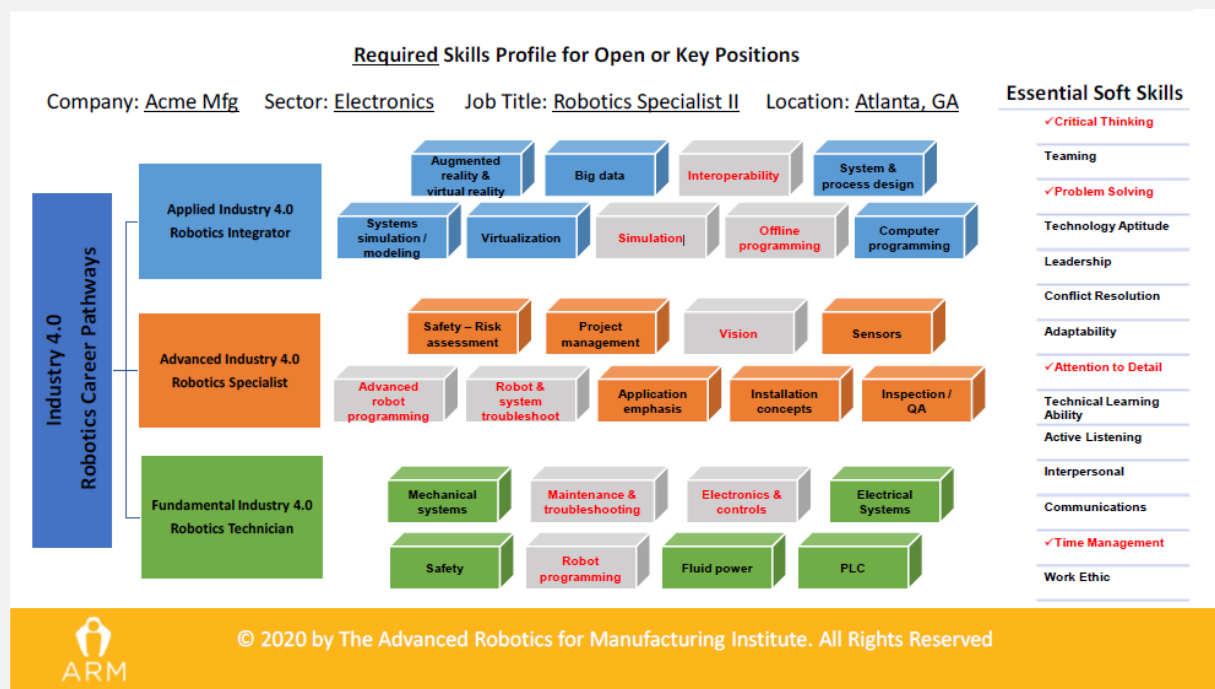


Figure 8: Example of the ARM competency framework, Source: ARM

Also in the **US**, the Markle Foundation has teamed with the states of Colorado and Indiana, educational institutions such as Purdue University, state-wide employers such as Microsoft, LinkedIn and Walmart, and local small-and mid-sized businesses to match curricula to skills demand from employers.

A number of Industry 4.0 Competence Centres established in **Italy** focus on technology and skills transfer to manufacturers. For example, MADE, headed by Politecnico di Milano, collaborates with 39 technology companies and other Italian universities to provide manufacturing companies in Italy with services including training. **Germany's** Fraunhofer Institute has partnered with technology companies to develop a Future Work Lab aimed at helping companies and employees experience and prepare for future automation scenarios. The Future Work Lab offers standardised and bespoke training courses in the new technologies demonstrated.

Next Generation Skills

Initiatives to Close the Skills Gap

The US has a number of public-private partnerships to identify and publicize current and future skills demand. Ascend, a scheme created by businesses, foundations and universities in central Indiana that aims to generate better data to find gaps in the state's workforce, train workers in skills industry needs and help match those workers to companies with openings. Another effort, Skillful, is a collaboration between organizations such as the Markle Foundation, LinkedIn and the state of Colorado that's also crunching data to ensure training programs are better aligned to industrial needs. Finally, the Haas eKentucky Advanced Manufacturing Institute (eKAMI) provides immersive programs with a particular focus on thousands of unemployed Kentucky miners. eKAMI focuses on building the skilled workforce needed to attract skilled, high-paying next-generation manufacturing jobs – such as computer numerical control (CNC) machinists, as well as machine building and tool maintenance technicians - to the region.

Many educational institutes have recognized the need to forge close links with manufacturers in order to anticipate and respond to skills requirements from industry. A number of countries have adopted 'dual study' systems that combine practical training within a company with formal education. Germany has been a leader in this regard. About 80% of German manufacturers collaborate with vocational schools and training institutes and 90% believe that dual study systems will become even more important going forward¹⁸. Korea and Switzerland have also successfully followed the German model. In the US, despite some promising examples, less than one third of manufacturers in the US partner with education /training institutes¹⁹. Automation technologies are advancing rapidly, and manufacturers and education institutes must regularly re-assess skills and training requirements. This information is often missing, and schemes focused on rigorous data collection, such as Ascend in the US (see inset box), are important to ensure supply matches demand.

Governments are also recognizing the need to provide lifelong training for workers in all sectors. This applies particularly to low-skilled workers, who account for 20% of the working population in OECD countries, yet are three times less likely to undertake training than high-skilled workers²⁰. Countries such as Singapore, Denmark and Sweden show best practice (see inset box) and trade unions have an important role to play in providing access to lifelong skills training.

Attracting young people into manufacturing is an issue in many manufacturing economies. US manufacturers, for example, cite the negative image of manufacturing as the second most important driver of skills shortages²¹. Manufacturers, industry associations and education institutes are working to address this. However, more must be done by companies, governments and educational institutes to promote attractive, technology-driven career paths for young people to incentivize them to choose a career in manufacturing.

Manufacturers recognize the need for action to close the current skills gap and ensure the right skills are in place as they ramp up automation. In the US, for example, 53% of US manufacturers are redesigning work around automation and 40% are creating robot programming roles²². Half of German manufacturers believe that robotics will be an important component of vocational training by 2025²³.

¹⁸ Industrie 4.0 – Qualification 2025, conducted on behalf of the VDMA by the Department of Sociology of the University of Hohenheim

¹⁹ [2018 Deloitte and The Manufacturing Institute skills gap and future of work study](#)

²⁰ OECD (2019), Getting Skills Right: Engaging low-skilled adults in learning, (www.oecd.org/employment/emp/engaging-low-skilled-adults-2019.pdf).

²¹ [2018 Deloitte and The Manufacturing Institute skills gap and future of work study](#)

²² Deloitte, 2018 Global Human Capital Trends, March 28, 2018

²³ Industrie 4.0 – Qualification 2025, conducted on behalf of the VDMA by the Department of Sociology of the University of Hohenheim

Initiatives to Attract Young People into Careers in Science and Manufacturing

In **Germany**, the Nachwuchsstiftung Maschinenbau runs interactive stands at industry trade fairs aimed at school students, while the German Mechanical Engineering Industry Association, VDMA, runs a 'talent machine' program with multiple initiatives aimed at attracting youth into careers in engineering and manufacturing, such as a program to train apprentices to market careers in engineering in schools. Mechatronics company ITQ runs a 'Smart Green Island Makeathon' in which teams from different academic disciplines create and develop technological prototypes as well as innovative solutions



Figure 9: First Robotics female teams are hosted by 3M. Image credit 3M

focused on automation, robotics, green energy and smart homes.

Science and technology company **3M** runs a global program to attract young people into careers in science through partnerships with schools, universities, and community organizations. **US** not-for-profit organization FIRST, which aims to inspire young people's interest and participation in science and technology, runs annual robotics competitions for high school students.

The **UK's** Manufacturing Institute runs a series of Make It challenges - a one-day, competitive manufacturing activity for schoolchildren aged 13 and 14 sponsored by different manufacturers throughout the UK.

However, manufacturers are not yet doing enough to upskill their current workforce and promote automation as a route to more satisfying work for experienced older workers. A recent survey found that only about one-third of companies globally are looking at reskilling existing employees versus hiring in order to fill skills gaps. Yet 70% of those organizations that have invested in reskilling say the business impact from the programs has been greater than or equal to the investment in them²⁴. IFR members agree that, for robot manufacturers, upskilling existing workers is critical. One IFR member that invests over twice as much in upskilling existing employees than in new hires commented that 'we see the benefit in a happier and healthier workplace culture, and a high retention rate'. New hires are likely to be employees with existing expertise and skills in new technologies. It is important that manufacturers build teams combining employees that bring deep expertise in the company's existing processes and legacy technologies, with newer employees who can apply new technologies to improve or re-design those processes. The extent to which organizations are able to build a culture where existing and new employees work in teams in which each can learn from the other and provide different perspectives on resolving issues and designing improvements can become a source of competitive advantage.

As we have noted, job profiles at all levels in manufacturing and logistics focus increasingly on the need for the flexibility and willingness to acquire skills across multiple automation systems, as well as work effectively in teams. It will be increasingly important to hire for these personality traits rather than the specific technical expertise offered by candidates. This also opens up a pool of existing employees with these attributes who are interested in moving to a new role.

Reskilling programs can take a variety of forms: paid leave for workers to attend training programs provided by third party providers and educational institutes; participation in training programs provided by equipment manufacturers, as well as on the job training. Large companies are naturally better

²⁴ Beyond hiring: How companies are reskilling to address talent gaps, McKinsey, January 2020

Next Generation Skills

placed to develop and fund apprenticeship schemes for employees, but educational institutes can support SMEs by pooling requirements from local companies and developing curricula that can service multiple employers. Vocational training provider RAMTEC (Robotics and Advanced Manufacturing Training) in Ohio, US, does this, working with a number of large and smaller manufacturers in the state to develop certification credentials for students that are recognized by manufacturers state-wide.



Figure 10: Production worker and robot. Image credit ABB

It is important that existing workers understand that using automation technologies no longer requires a bachelor's degree. Many robot applications can be programmed and managed by employees after only a few hours of training, while modern production management and maintenance systems have highly intuitive interfaces deployable on familiar consumer devices such as tablets and smartphones. Vocational training programs for relevant manufacturing roles should include basic robotics training that can then be expanded on-the-job and refreshed as robotics technology develops.

It is vital that manufacturers include employees in developing automated production strategies. Experienced operators and technicians bring a wealth of knowledge on tasks that can be automated, and those that are best carried out by humans. Involving workers in automation planning helps employees see automation as a tool to make them more effective rather than as competition for their competencies.

A CALL TO ACTION: WHAT STAKEHOLDERS CAN DO TO CLOSE THE SKILLS GAP

WHAT STAKEHOLDERS CAN DO TO CLOSE THE SKILLS GAP	
PARENTS	<ul style="list-style-type: none"> ▪ Encourage children - and in particular girls – to explore their abilities in STEM subjects and investigate options for a career in manufacturing
YOUNG PEOPLE	<ul style="list-style-type: none"> ▪ Take an interest in STEM subjects and investigate career options building off these subjects ▪ Look into vocational education supported by manufacturers that can provide an entry into skilled positions in manufacturing
MANUFACTURERS	<ul style="list-style-type: none"> ▪ Promote the advantages of a manufacturing career at the forefront of technology development to young people through job trade fairs, PR and social media campaigns and other recruitment drives ▪ Collaborate with education institutes to adapt curricula to evolving demand for technical skills ▪ Look at and promote employee development as a competitive differentiator ▪ Encourage employees to take advantage of lifelong training programs – and develop these programs internally, collaborating with education institutes
MANUFACTURING EMPLOYEES	<ul style="list-style-type: none"> ▪ Actively seek out opportunities to learn new technologies and skills and, where possible, develop skills across a range of technologies and expertise in the interfaces between them ▪ Investigate training and certification options from multiple sources including equipment manufacturers, education institutes and government programs
EDUCATION INSTITUTES	<ul style="list-style-type: none"> ▪ Promote the advantages of a manufacturing career at the forefront of technology development to young people ▪ Build robotics programming into vocational training for relevant manufacturing job profiles ▪ Collaborate with manufacturers to adapt curricula to evolving demand for technical skills ▪ Ensure that mechanical and electronic engineering training programs include a focus on building ‘soft skills’, particularly critical thinking, analysis and problem solving ▪ Collaborate with government and manufacturers to develop lifelong training programs for manufacturing employees, particularly low-skilled workers
TRADE UNIONS	<ul style="list-style-type: none"> ▪ Work with manufacturers and educational institutes to develop and provide access to lifelong training schemes for workers. ▪ Promote the benefits of automation for older, experienced workers
GOVERNMENT	<ul style="list-style-type: none"> ▪ Develop programs and incentives to ensure lifelong learning ▪ Provide incentives for manufacturers to collaborate with education institutes to develop training programs that incorporate cutting-edge technologies ▪ Incentivize and support skills training for low-skilled workers

CONCLUSION

Automation is profoundly altering the face of manufacturing, creating promising new opportunities for employees at all skills levels. Job profiles are changing rapidly, both within and outside of the traditional roles of production operator, technician, engineer and production manager. While new positions with deep domain expertise in specific technologies will be created, most manufacturing employees will become technology generalists, overseeing a range of technologies, machines and processes. They are supported in their work by data-driven analytic and decision-making tools spanning the whole supply chain.

It's an exciting future, for both new and existing workers, but a future whose potential will not be realized unless urgent action is taken to address an existing and future skills gap. As we have explored in this paper, it's not just employees with new technical skills who are missing. The retirement of skilled baby boomer manufacturing workers will create massive holes in the resourcing of core manufacturing processes such as welding and machining.

Fixing the skills gap will take a concerted, and collaborative effort on the part of policy makers, government, education institutes, manufacturers, and employees themselves. Lifelong learning is critical to ensure existing workers can continuously re- and up-skill to take advantage of new technologies. Manufacturers and education institutes have work to do to promote careers in manufacturing to young people as an opportunity to work at the forefront of technology.

Manufacturing is the backbone of many economies and has an important role in generating jobs in related service industries. Even countries that have shrunk their manufacturing sectors in favor of service sectors need a strong core of expertise in manufacturing to drive growth. Fixing the skills gap is an urgent and immediate priority for governments, educators, and manufacturers alike.