EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

Report on Most Relevant Trends for Advanced Manufacturing

02

Learning dialogues

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TABLE OF CONTENTS

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Acronyms and Abbreviations

AR	Augmented Reality
AM	Advanced Manufacturing
AMS	Advanced Manufacturing System
AFM	Spanish Association of Machine Tool Manufacturers
AI	Artificial Intelligence
BDA	Bid Data Analytics
CPS	Cyber-physical-system
CPSS	Cyber physical social systems
CPPS	Cyber physical production systems
DHBW	Duale Hochschule Baden Württemberg BD
EACEA	Education, Audiovisual and Culture Executive Agency
EXAM 4.0	Excellent Advanced Manufacturing 4.0
HVET	Higher Vocational Education and Training
I4.0	Industry 4.0
IaaS	Infrastructure as Service
IoT	Internet of Things
IIoT	Industrial Internet of Things
KET	Key enabling technologies
M2M	Machine-to-machine
OMR	Optical Mark Recognition
PaaS	Platform as a Service
RFID	Radio Frequency Identification
RP	Rapid Prototyping
SaaS	Software as a Service
SCM	Supply Chain Management
SME	Small-Medium-Enterprise
VET	Vocational Education and Training
VR	Virtual Reality
WP	Work Package
XaaS	Everything as a Service

Table of figures

ABSTRACT

Technology is advancing rapidly and the pace of change is increasing. Consequently, an increasing number of activities will have the potential to be performed by machines rather than by humans. Historically, technological progress has not significantly increased unemployment in the long run, but it remains to be seen whether this time will be the same (David H., 2015). What is certain is that technology will cause large labour displacements, especially in high-routine occupation categories. Institutions, companies, and employees will need to increase their focus on education and training to be able to keep up with the increasing pace of change.

INTRODUCTION

When components communicate independently with the production system and, if necessary, initiate repairs themselves or reorder material, when people, machines, and industrial processes are intelligently networked, then we speak of Industry 4.0. After the steam engine, assembly line, and digitization, we are now facing the fourth industrial revolution with intelligent factories

In the factory of Industry 4.0, intelligent machines independently coordinate production processes; service robots support people in assembly, automated guided transport vehicles take care of logistics and material flow independently. Networking does not only take place within "intelligent factories", but across company and industry boundaries - between different actors in the economy: From medium-sized logistics companies to specialized technical service providers to creative start-ups.

The use of digital technologies in the industry will result in a multitude of new production processes, business models, and products. For example, a production line no longer has to be restricted to one product. Mass-customization will have an impact on the design and product portfolio, supply chain management, and operations. This will change the requirements for industrial production or advanced manufacturing. New manufacturing concepts and IT-technologies will make it possible to flexibly adapt processing stations to a changing product mix. The research in the following chapters will describe the Industry 4.0 ecosystem, future trends and key enabling technologies, and how to manage the transformation in the world-of-work and institutions. A quantitative analysis is used to illustrate the latest trends in Spain, Germany, Netherlands, and Sweden.

2 Industry 4.0 Ecosystem: Governance, Strategy, Leadership, People Integration and Change

Advancing Industry 4.0 requires strong cooperation between ecosystem players, suppliers, operators of factories, plants, and warehouses.

The success of Digital Transformation is highly dependent on clear top-down governance. The right governance model provides appropriate levels of coordination and sharing for digital initiatives, in line with the company's structure, culture, and strategic priorities.

No matter the particularities, companies have to assess their vision of the industrial future and then decide how to move forward: pursuing existing strategies with reinforced vigor or developing new strategic approaches to successfully emerge from the fourth industrial revolution. Even more than the design of a digitally enhanced solution portfolio, the fourth industrial revolution will force manufacturers to rethink how to create this value, i.e. rethink the back-end of their business models. Company leaders should decide on which fundamental drivers to base their business on in the future.

Should it be:

- an innovation-driven one, based on a strong partner network and Smart Innovation processes, whilst outsourcing major physical production processes?
- an extremely agile production focusing on customized products in batch sizes of one, enabled by Smart Factories?
- an efficiency-driven one, with low prices and market-beating lead times, made possible by a Smart Supply Chain?
- a service-based one, transforming the manufactured product to serve only as of the source for valuable data and the door-opener to a wealth of Smart Services around it which form the actual value proposition?

Company leaders thus have to focus on identifying additional skill sets needed for their particular vision of a future, digitized manufacturing business. Next, they have to develop existing or hire new employees to fulfill these requirements. In terms of people development, the focus should lie on enabling learning all along the career path, with flexible working models and blended learning methods. The fostering of a 'digital mindset' is a crucial aspect.

A major component of successful leadership in Industry 4.0 will be the ability to create a learning organization: the value over time of fact-based knowledge is becoming smaller and smaller in a sector driven by digital innovation. In this context, the attitude and capability to continuously learn will be vital. Company culture should be open and ready to share knowledge. The challenges that I4.0 poses require continuous innovation and learning, which is dependent on people's capabilities. Industry 4.0 requires a labour force with high skill levels. This includes developing and establishing training and workshops for the employees, with the focus on new core tasks such as how to manage and control digitized systems. Therefore training and continuous professional development of employees are of major importance to succeed in the early stages of the transition towards digitalization (Kagermann et al., 2013).

Beyond skills, individuals are embedded in a social context, which requires the ability to communicate, cooperate, and establish social connections and structures with other individuals and groups. The full digital integration and automation of whole manufacturing processes in the vertical and horizontal dimensions imply that workers will be responsible for a broader process scope and will need the ability to understand relations between processes, the information flows, and to cooperate ad-hoc in finding appropriate solutions for particular problems (Erol et al., 2016).

3 Industry 4.0: Technologies, Outcomes, and the Future of Manufacturing

The automation potential of work varies across industries because different industries have different job constellations and similar jobs in different industries might comprise different sets of tasks. Also, there are significant differences among countries regarding the job constellation of their industries.

Though it is technically feasible to substitute human labour with machines in many jobs and job tasks, several other factors are affecting the pace and extent of automation, such as commercial availability, cost of implementation, economic benefits, labour market dynamics, and social, legal, and ethical acceptance. The first and most obvious economic benefit from the implementation of automation technologies is the reduction of labour costs, resulting from the substitution of human labour. It is unlikely that many jobs will be substituted completely, but it is likely that fewer employees will be necessary to achieve the same output due to increased productivity. Another important benefit for **market-oriented production companies** is - especially among the new opportunities Industry 4.0 provides through networking and real-time mapping of production in the future - the quick reaction to customer requirements and changing demands. Dealing with increasingly short-cycle and fluctuating markets is a key factor for the competitiveness of companies. **Volatility, adaptability, and flexibility** are the prerequisites to be successful. This applies in the area of production, for the plants, machines, and tools and along the entire value chains, but especially for the production work, i.e. for the employees. It has to be organized in a targeted and systematic way in the future.

The head of R&D Basic Technology, Klaus Bauer at TRUMPF, a machine tool manufacturer in Germany, describes the future scenario as: "*Industry 4.0 does not address exclusively mass production, but above all the flexibility of the production. The intelligent factory of the future is highly flexible, highly productive, and resource-efficient. This will lead to individualization and a lot size 1 at the economic conditions of a mass manufacturer reality.*" (Dieter Spath (Hrsg.), Oliver Ganschar, Stefan Gerlach).

Through the aim of the Industry 4.0 basic concept – the process automation with highly flexible networking of the digital data world with physical manufacturing processes, will fundamentally change forms of process control and the entire organization of factory processes. This results in extensive restructuring measures, which are not just affecting functions and job-profiles within, such as manufacturing, distribution, research, and development, leading to process-oriented structures and a focus on I4.0-process-specific job profiles.

The merging of production and logistics with information and communication technology will lead to new **interdisciplinary job profiles** and will also create new professions soon. The boundaries between the previously separate domains of computer science, electronics, mechanical engineering, and plant construction are being dissolved in the course of digitization.

IT is seen as a central business enabler. New capabilities will be needed in many functions, not only in IT-related domains. Manufacturing and R&D departments more than ever have to develop a system's engineering approach and skillset, i.e. thinking in product functions and flexible manufacturing processes instead of technical features. The software will become an integral part of manufactured products, so manufacturers have to establish the corresponding skills. As an example, today's machine operators will have to become analysts of production-related data, able to derive meaningful insights into process quality from a bulk of information.

Digitized, advanced manufacturing processes will also bring about big challenges for many manufacturers in terms of employee competences and skills. In Industry 4.0 there is a focus to create a learning organization: the value over time of fact-based knowledge is becoming smaller and smaller in a sector driven by digital innovation. In this context, the attitude and capability to continuously learn will be vital.

INDUSTRY 4.0 - APPLICATION TRENDS

Smart Solutions, Smart Innovation, Smart Supply Chains, and the Smart Factory are the fields in which manufacturers will realize enormous potentials by digitizing their business. While Smart Solutions and Innovations primarily leverage company growth, Smart Supply Chains and Factories mainly drive efficiency.

Smart Solutions

In smart manufacturing, solutions learn and interpret patterns and related outcomes, which will improve fault predictions, security, and productivity over time.

Smart Products: Smart products integrated into modern production flows can self-process, store data, communicate, and interact within the industrial ecosystem. Today smart products don't only provide their identity, but also describe their status and lifecycle history. They are capable of computing algorithms and machine learning, which makes them adept at processing further steps, including the production stages resulting in the finished product and also upcoming maintenance operations.

Smart Products are:

- equipped with sensor technology giving access to condition information regarding the product and its environment
- equipped with computing power that enables autonomous decision-making and self-learning processes based on defined algorithms
- equipped with a M2M communication device that enables interaction and data exchange with other cyber-physical systems
- equipped with control technology that enables autonomous product adaption based on internal or external commands

Smart Services: A Smart Service is a digital service that reacts to collected and analyzed data based on networked, intelligent technical systems and platforms. In contrast to the technology of Industry 4.0 which can exist in just one specific sector, Smart Services require cross-functional areas. These areas provide services that respond to analyzed data of other areas. Manufacturers or third-party service operators can make reliable predictions at which point in the future a production system will require maintenance, based on real-time data about the wear and tear of the system (predictive maintenance).

Smart Services will:

- open up exciting paths to business growth
- allow higher added value, enhance customer experience and intensify the customer relationship
- improve the efficiency of service delivery
- optimize the lifecycle value for associated *Smart Products.*

The mass of data (Big Data) that is collected by Smart Products must be analysed in real-time with information extracting methods and intelligent algorithms to generate new knowledge. The real-time data collection here is very important, otherwise, the reality is not shown and customer needs cannot be satisfied. This new knowledge is called Smart Data. A very relevant and important source in analysing the information in the cloud respectively the cloud-computing.

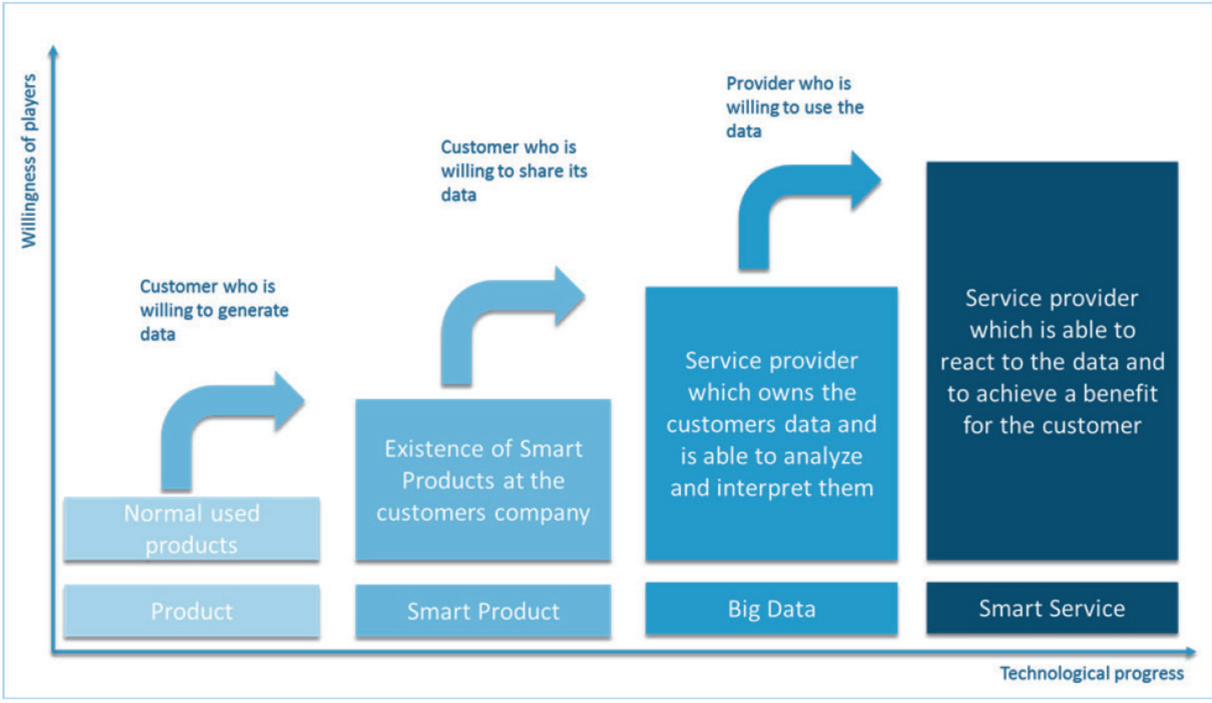


Figure 1: Requirements for Smart Service

Overall, manufacturers will need to leverage innovative combinations of *Smart Services* and *Smart Products* to increase the scope of their value creation activities.

Smart Innovations

The digitalisation of industry will not only transform value-creation processes but also give rise to new business models and innovations. Smart, digital production processes present great opportunities for businesses – particularly for SMEs. New impulses come from a multitude of sources outside the own organization, and they have to be proactively integrated into an open innovation process. However, in an interconnected Industry 4.0, ideas are much more valuable if they are embedded in an equally innovative periphery of devices or related solutions. **Extended Innovation** embraces the creation and distribution of ideas across organizational borders, whereas **Connected Lifecycle Innovation** leverages product lifecycle data as a source for innovation.

Extended Innovation requires opening up innovation processes in manufacturing companies to external partners and customers. Communication and connectivity allow for cross-company innovation activities. Extended Innovation is a two-way exchange, with information flowing into and out of the company. While outside stimuli are actively brought into the company, it acts as a hub for then feeding them into the partner network to broadly support innovation and idea generation. Collaboration in the innovation process with both customers and partners will reduce the time-to-market and drive innovation speed towards a constant flow. Finally, innovations will become more sustainable by sharing information throughout the manufacturer's ecosystem.

Connected Lifecycle Innovation differs from 'ordinary' product lifecycle management in its holistic approach: product-related information is coupled with other relevant data, such as machine parameters or customer order data. It is then analyzed, processed, and put to use for generating innovation, enabling data-driven R&D decision-making and business process innovation throughout the entire organization, such as in sales processes. Like Extended Innovation, Connected Lifecycle Innovation will lead to an increase in innovation frequency. It will reduce the time-to-market, implying growth potential as well as improved efficiency in operations, with decreased R&D cost.

Smart Supply-Chains

Smart Supply Chains are highly integrated and automated, enabled by the use of digital technologies and cyber-physical systems. IoT takes supply chain communications to another level: the possibility of human-to-things communication and autonomous coordination among 'things' while being stored in a facility or being transported between different supply chain entities. These new capabilities offer tremendous opportunities to deal more effectively with SCM challenges. IoT provides new levels of supply chain visibility, agility, and adaptability to cope with various SCM challenges (Ellis S. et al., 2015).

Agile Collaboration Networks describes the shift in horizontal integration towards a flexibly defined extended enterprise, enabling manufacturers to focus on core competences yet allowing them to offer customized products in any market.

Connected Supply Chains are formed through the vertical supply network by recreating supply flows on a virtual level, allowing the seamless integration and automation of physical processes and providing companies with dramatically increased transparency.

Christopher defines structural flexibility as the ability of the supply chain to adapt to fundamental changes in the business environment. However, flexibility and resilience come at an additional cost in the form of additional resources such as buffer inventory and extra capacity, and higher coordination costs (Christopher Martin, 2016). To balance the required level of resilience and flexibility and the cost of achieving it, firms need to have high visibility of the whole supply chain, the necessary velocity to respond quickly to changes, and effective collaboration with suppliers and customers. Christopher summarised the principles that can guide supply chain managers into what he calls the ‘4Rs’: responsiveness, reliability, resilience, and relationships (Christopher Martin, 2016).

Smart Factory

In the age of Industry 4.0, factories consist of many smart units: machines coordinate manufacturing processes without any human interaction, service robots and people work side by side in the assembly shop, driverless transport vehicles run logistics tasks on their own.

The literature has proposed many definitions of the term "smart factory". We select a comprehensive definition by Radziwon, who defined the smart factory as "*a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. This special solution could, on one hand, be related to automation, understood as a combination of software, hardware, and/or mechanics, which should lead to optimization of manufacturing resulting in reduction of unnecessary labour and waste of resource. On the other hand, it could be seen in a perspective of collaboration between different industrial and nonindustrial partners, where the smartness comes from forming a dynamic organization" (Radziwon et al., 2014).*

The design principles of a smart factory help designers build new smart factories or upgrade existing traditional factories to be smart (Hermann et al., 2016). These principles are illustrated as follows:

Modularity: This refers to the design of system components. Modularity can be defined as the capability of system components to be separated and combined easily and quickly. System components are loosely coupled and can be reconfigured on a plug-and-play principle. The smart factory should possess high modularity, allowing the rapid integration of modules that can be supplied by multiple vendors. Modularity enables the real-time capability to allow the system to respond to changing customer requirements and to overcome internal system malfunctions.

Interoperability: This refers to both the ability to share technical information within system components, including products, and to the ability to share business information between manufacturing enterprises and customers. CPS enables connection over the IoT and the IoS. Standardized mechanical, electrical, and communication information is essential to enhancing interoperability.

Decentralization: System elements (modules, material handling, products, etc.) will make decisions on their own, unsubordinated to a control unit. Embedded computers enable autonomous CPS to interact with their environment via sensors and actuators. Such interaction will adapt processes to each order, enabling low-cost, custom-tailored products.

Virtualization: This refers to both creating an artificial factory environment with CPS similar to the actual environment and being able to monitor and simulate physical processes. Information transparency in CPS and the aggregation of sensor data enable the creation of such an environment. A virtual system is used to monitor and control its physical aspect, which sends data to update its virtual model in real-time. A virtual system enables the implementation of designs, creating digital prototypes that are very similar to the real ones. The design can be checked, modified, and tested before its order into the physical system. In addition, a virtual system is helpful for other issues such as training the workforce, guiding the workforce while performing manual processes, diagnosing, and predicting faults, and guiding maintenance tasks to fix malfunctions. Virtual reality and augmented reality combination with mobile devices provide customers more insight into the detailed design of their products and allow them to track the manufacturing process.

Service orientation: This refers to the idea that manufacturing industries will shift from selling products to selling products and services. Manufacturing industries are becoming service providers as their products have reached competitive equality.

Real-time capability (responsiveness): This refers to the ability of the system to respond to changes on time, such as changes in customer requirements or the status of the internal production system (e.g., malfunctions and resource failures). To respond to customer requirements, the information should be accessed and analyzed in real-time. The system will investigate the possibility of meeting requirements using existing resources through reconfiguration or cooperation with other factories via CPS. Achieving the holistic view of operations throughout the Smart Factory, however, depends on the integration of relevant data from a multitude of different sources. The leverage of data in operations will provide competitive advantages by increasing process efficiency and end-product quality. Costs can be significantly reduced through more targeted quality assurance processes. Over time, internal benchmarks can be established and best practices derived from data. Besides, the reliability of productive assets and their long-term utilization is maximized.

> In a traditional dedicated manufacturing line, the workforce has a specific and repetitive task, and high-level skill is not required. In a flexible manufacturing system, machines and robots replace the workforce where a high automation level would be appropriate. The smart factory system introduces a new concept of the role of the workforce in the production system. Workers should be highly skilled not only to cope up with renewable products and processes but also to have the supervision and problem-solving skills to autonomously address failures. Smart factory workers integrate with the system, can access the product and process information, and have sufficient programming and mechatronics skills to fix software and technical problems. Most of the innovative ideas to improve the processes and products come from the worker, where s/he is the top expert on the system.

INDUSTRY 4.0 FUNCTIONAL AREAS AND CORE PROCESSES

This chapter identifies the trends and change management in the five functional areas of Industry 4.0.

An "I4.0 functional area" summarizes the applications in the company related to Advanced Manufacturing management processes (Zhong et al., 2017). They can be understood as cross-functions or I4.0 core processes within corporate divisions and are valid such as production, logistics, and maintenance functions.

The five "I4.0 functional area" are:

- *Data acquisition and processing*
- *Assistance systems*
- *Networking and integration*
- *Decentralization and Service orientation*
- *Self-organization and autonomy*

Data acquisition and processing form the basis for Industry 4.0. The functional area includes the collection and evaluation of data on processes, quality, products, means of production, employees as well as their environment. Central for Industry 4.0 is the IT-based data acquisition of a customer, product, production, and usage data. In the functional area of data acquisition and processing, the key focus is on discontinuous data evaluations, e.g. the consideration of the overall plant effectiveness down to big data analysis. The goal is a constant process or quality improvement.

Key elements:

- *Sensor technology / RFID / barcode*
- *Data analysis / big data analysis*
- *Documentation and data management*
- *Simulation (product, production, plants, etc.)*
- *Data security*

Assistance systems aim to make it as easy and quick as possible for the employee, anytime, anywhere to provide the information required on the shop floor. In the functional area of assistance systems all technologies are summarized, to support and enable the employees in the execution of their work and get them concentrated on their core tasks. These are in particular technologies for the provision of information such as visualization systems, mobile devices, tablets, and data glasses or tools that perform calculations or provide support in the human-machine interaction.

Key elements:

- *Visualization, augmented reality*
- *Mobile devices*
- *Human-machine interaction*
- *3D printing / scan*
- *Simulation (product, production etc.)*

The **networking and integration** between areas or departments within a company (vertical integration) but also between different companies (horizontal integration) is a central element of the Industry 4.0 vision. The goal of digital networking is to improve collaboration, coordination, and transparency across the divisions as well as along the delivery and value chain. The functional area includes cross-departmental cooperation within the company and cross-company cooperation in value creation networks. It includes the approaches of cloud computing and the internet of things.

Key elements:

- *Vertical and horizontal integration*
- *Flexible networking of systems, processes, and products*
- *Internet of Things*
- *Cloud computing*

Decentralization & service orientation is the key driver for changing I4.0 business models. The Industry 4.0 revolution results from the change from central control to decentralized process responsibility and from product orientation to customer/service orientation. The functional area decentralization and service orientation, therefore, include the modularization of products and processes, decentralized control, and the change to a service orientation. A key technology to express this is XaaS (Everything as a Service). Decentralization enables clear coordination and makes complexity manageable as the control task no longer has to be done in one place only.

Key elements:

- *Apps, web service, XaaS*
- *New business models*
- *Service orchestration*
- *Decentralized control*
- *Versatility*

In the **self-organization and autonomy** functional area, the vision of Industry 4.0 – that the intelligent ‘system’ controls its own production – becomes reality. Technologies and processes are combined, which carry out an automatic data evaluation, and based on the results the systems react independently. Such control loops can be used, for example, for self-configuration and self-optimization of systems up to complete self-organization. The ability to self-organize and control is an important characteristic of cyber-physical systems, that communicate with each other in addition to the collection, evaluation, and storage of data and having an own identity and interact with their surroundings. Examples of such autonomous systems are intelligent, flexible driverless transport systems (AGVs) solutions in intralogistics or intelligent containers, triggering automatic reordering.

Key elements:

- *Control loops / self-organization*
- *Self-configuration / optimization*
- *Cyber-physical systems*
- *Process monitoring*

HUMAN-MACHINE INTERACTION

The debate on Industry 4.0 is mostly summarized with three development scenarios for human-machine interaction (Ahrens & Spöttl, 2018).

Tool scenario: This scenario describes the development of expert systems with tool character for qualified specialists, e.g. an assistance system for detailed production planning, which enables specialists in the production area to perform tasks with special requirements based on experience.

Automation scenario: It focuses on the advance of intelligent, self-regulating technologies in plants and machines, production and logistics (more decisions are delegated to intelligent, highly automated systems, concrete process steps become opaque in the manufacturing area, functional and informational distance occurs, intervention in the event of human interference is getting more and more difficult).

Hybrid scenario: People and machines work together, creating new forms of interaction and cooperation that lead to new demands on specialists.

In addition to typical manufacturing, maintenance, etc., specialists in industrial production are increasingly performing production organization tasks (Frenz et al., 2015).

ALTERNATIVE DIRECTIONS OF HUMAN DEVELOPMENTS IN I4.0

When differentiating the digitization concepts, a central role is the division of tasks between humans and machines. Are the machines the extended arm of the humans or the humans the extended arms of the machines?

Future Scenario I: Substitution of Labour and Tasks

The substitution is one digitization concept, replacing main areas of activity with highly tasksmated processes. The potential of substituting labour is often focused on the individual tasks that constitute jobs, rather than jobs in their entirety. The reason for this is that jobs include several different types of tasks, which all have a different relation to the current capabilities of I4.0 technologies. Consequently, some types of tasks can be automated while others cannot.

To determine the job substitution potential of digitization conceptualized work as a series of tasks rather than complete jobs (David H., 2003). Specifically, the model distinguishes routine tasks from non-routine tasks and manual from cognitive tasks. This classification results in a 2x2 matrix, which is displayed in Figure 2. Routine tasks are defined as tasks that follow explicit rules, which can be exhaustively specified and, hence, translated into code. For non-routine tasks, these rules are not understood sufficiently well, which makes them much harder to codify. As a corollary of this definition, routine tasks are automatically classified as tasks that are easily substituted by technology while non-routine tasks are not.

Manual tasks are physical activities that require motor skills and mobility whereas cognitive task relates to mental processes.

	Cognitive	Manual
Routine	Explicit rules Mental processes	Explicit rules Motor skills
Non-routine	Rules difficult to codify Mental processes	Rules difficult to codify Motor skills

Figure 2: Four Categories of Job Tasks (David H., 2003)

ROUTINE MANUAL TASKS

The routine manual task category includes physical activities that require systematic repetition of a consistent procedure, i.e., structured physical tasks that take place in predictable environments.

These tasks are easily translatable into computer programs and the technology to perform them is at an advanced level, especially for gross motor skills, where machines have been outperforming humans for a long time. More recently, advances in sensory perception and manual dexterity have made it possible for robots to be assigned to tasks that require higher precision, e.g. assembling customized orders, manufacturing electronic components. With their increased dexterity and mobility, robots are increasingly able to take on complex routine manual tasks in the advanced manufacturing and service industry. Many routine manual tasks can and most likely will be performed by robots in the future and the share of repetitive, rule-based activities in jobs will decrease. With advances in sensors and increasing robot dexterity, more high-precision tasks will become candidates for substitution, such as manufacturing tasks in the electronics sector. As robots become safer, they will likely take up more positions next to their human co-workers.

NON-ROUTINE MANUAL TASKS

Non-routine manual tasks are non-structured physical tasks that take place in unpredictable environments, often involving situational adaptability and in-person interaction. They require capabilities like sensory perception, fine and gross motor skills, social and emotional capabilities, natural language processing, navigation, and mobility. The majority of these capabilities have not yet reached human-level performance and the incorporation of flexibility remains a considerable challenge (David H., 2015).

Recent advances in sensory perception and physical capabilities as well as machine learning have enabled machines to take over an increasing number of manual non-routine tasks. Improvements in sensor technology and manual dexterity allow robots to perform high-precision, non-standardized tasks. A well-known new application of machines for non-routine manual tasks is the autonomous vehicle. Autonomous driving was deemed impossible not so long ago as it requires activities such as parking, switching lanes, and adapting to traffic lights, other vehicles, and pedestrians. Autonomous mobility has also entered the warehousing industry (David H., 2015). Here, enabled by environmental control, many warehouses, such as Amazon's warehouses, have become largely automatic. Nonetheless, most non-routine manual tasks remain out of reach for machines for now and the near future.

ROUTINE COGNITIVE TASKS

Routine cognitive tasks include all mental (non-physical) tasks that repeat a certain procedure in a predictable environment. To a large extent, this relates to the different aspects of processing structured information, such as data collection, organization, and storage (David H., 2003).

The required capabilities for these tasks are retrieving information, recognizing known patterns, optimizing and planning, logical reasoning/ problem solving, and natural language processing. The automation of cognitive tasks started with the introduction of the computer (David H., 2003), which enabled the digitization and automatic processing of information. Subsequently, many processes, including administrative tasks, bookkeeping, invoicing, optimizing resource needs, and numerous others, have already been automated (Acemoglu D., 2011).

Today, technological advances and the current focus on digitalization have brought the automation of routine cognitive tasks to an unprecedented scope and pace. Many companies have embarked on so-called "digital transformations", which refer to the simplification, standardization, and digitalization of an entire organization. At the front-end, this means that large parts of customer interaction interfaces will be automated. As companies progress on their digital transformations, more data and processes will be digitized and therefore likely automated. Moreover, further automation of customer service activities will depend on the machines' capability to interact with customers and thus depends on advances in natural language processing and emotional capabilities.

NON-ROUTINE COGNITIVE TASKS

Non-routine cognitive tasks are mental (non-physical/abstract) tasks that do not follow a structured procedure and/or take place in unpredictable environments (David H., 2003). These types of tasks require several cognitive capabilities, including creativity, logical reasoning, generating novel patterns, and coordination with multiple agents. In addition, natural language processing and social and emotional capabilities are often of high importance (Acemoglu D., 2011); (David H., 2015). These types of tasks include activities that relate to interfacing with stakeholders, applying expertise, and managing and developing others. Especially tasks that require creativity, problem-solving, and complex communication (a confluence of natural language processing and social and emotional capabilities) have a very low substitution potential (David H., 2003).

Future Scenario II: Technical Assistance

The provision of technical assistance is another future scenario of Industry 4.0 and this includes '*..aggregating and visualizing information comprehensively..*' for people to understand and make informed decisions and assist with problem-solving; and second, the ability to assist humans by performing tasks that are unpleasant, too exhausting, or unsafe for humans to undertake.

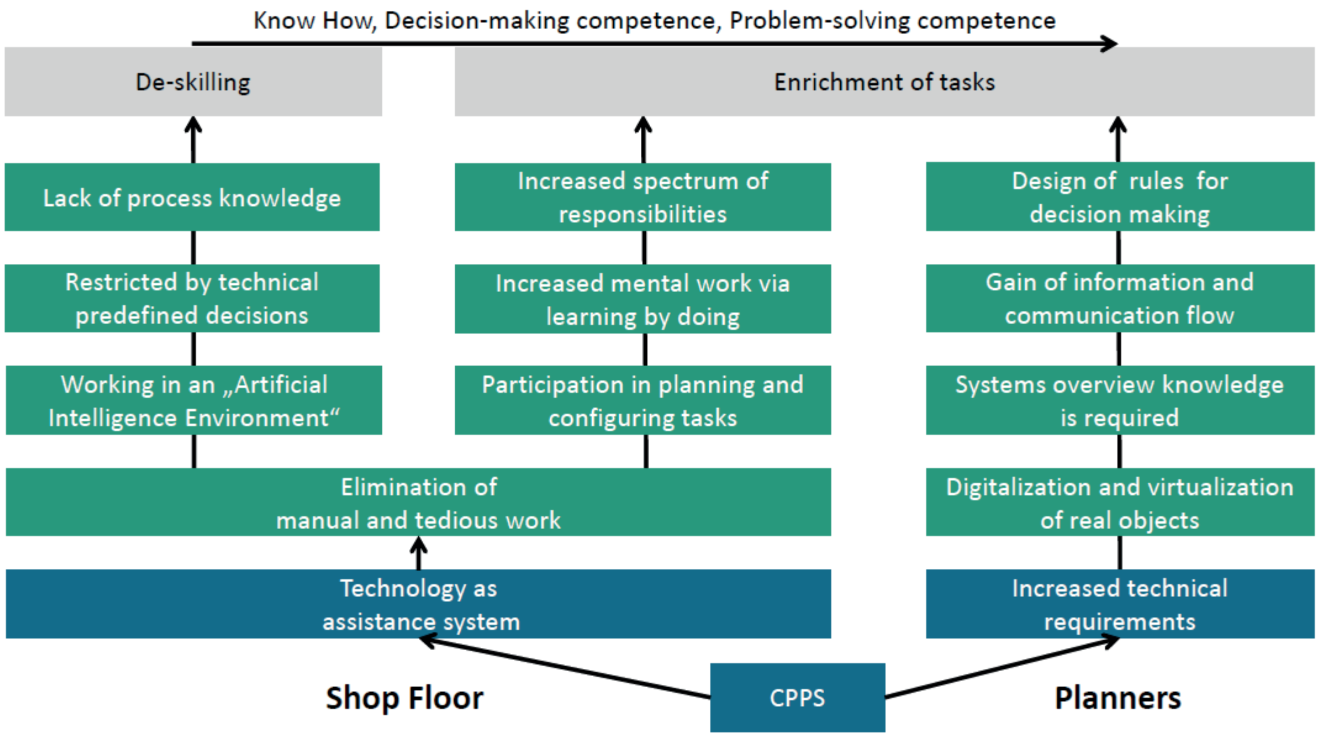


Figure 3: Change of qualification requirements (Ranz & Jäger, 2014) ESB Business School, Reutlingen, 2019)

Considering the change described in the previous chapter, the human being will remain in a dominant role, because it is not expected that the human factor with its characteristics and capabilities will be substituted entirely by autonomously acting technology in the foreseeable future. Mechanical intelligence, for instance, is limited to the selection of predefined options, while human creativity, flexibility, the ability to learn and to improve are required to design and configure systems, processes, and products. Humans have the expertise and experience to analyze, assess and solve - even in exceptional situations.

For many production environments, there is hardly any automation without intensive employee involvement.

Humans will remain an integral and indispensable part of the production world in the future because they are the most flexible and intelligent part of todays and future factories. With industry: 4.0 people and technology are moving closer together (Kärcher, 2015).

This hybrid-scenario will drive the development of new forms of interaction, cooperation, and control of tasks and lead to new demands for the shop-floor specialists. The type of qualification and competences and quality of the requirements is ultimately determined by the key I4.0 processes and work for the organization.

The amount of purely manual tasks for shop floor workers will decrease. Cyber-physical systems enable process data to be recorded and visualized in order to provide people with an insight into the complexity of the system. The potential of the hybrid scenario is recognized and predicts that the technological innovations will make employees less used as machine operators (Ahrens & Spöttl, 2018; Kagermann et al., 2013).

The role of shop floor workers will change from a manually executing to a proactive preconceiving worker with increased responsibility. Due to the growing degree of digitalization and interconnectedness, also the tasks and responsibilities for planning and design personnel will continuously expand and become more complex. The work in versatile ad-hoc networks with advanced ICT-tools and assistance systems will lead to increased requirements regarding the knowledge, capability, and capacity of the respective employees. The on-going pervasion of IT and the emergence of systems with unprecedented complexity specifically require significantly improved capabilities in analysis, abstraction, problem-solving, and decision making from future labour.

The future role of the ‘employee I4.0’ in these scenarios is, the role of the senior-expert, decision-maker, and also coordinator to find the right balance between efficiency and flexibility for the design of the work processes.

In the hybrid scenario, humans and machines will work cooperatively. The strengths of human beings and technological applications will be used complementarily in the production process. The range of tasks of the future factory worker, by contrast, will change and largely consist of the specification, monitoring, and safeguarding of production strategies in the cyber-physical production system (Gorecky D., Schmitt M., Loskyll M., 2014).

Summary: The World-of-work Future Scenarios in I4.0

Industry 4.0 places high value on networking in production by using modern internet technologies. The objective is to facilitate communication between the operating equipment, products, and its components to guarantee efficient and customer-specific production processes. Automation and products of batch size 1 will no longer be mutually exclusive. The potential for networking and customer-specific production resides in innovative business models covering the entire product life cycle – from conception to disposal.

Smart Solutions, Smart Innovation, Smart Supply Chains, and the Smart Factory are the fields in which manufacturers will realize enormous potentials by digitizing their business. While Smart Solutions and Innovations primarily leverage company growth, Smart Supply Chains and Factories mainly drive efficiency.

MATURITY MODEL

The introduction of Industry 4.0 involves significantly upgrading a manufacturing company's digital competencies and capabilities and entails changes across large parts of the organisation. The strategy necessitates a step-by-step approach to the company's development.

A company must implement only those technologies that are valuable for addressing specific pain points and improving operations and processes. Yet evaluating the benefits of individual Industry 4.0 technologies in a particular context and deciding which to implement first can be challenging. The common approach is to use a traditional business case to quantify the potential return on investment and determine the time frame for achieving a positive return. Business cases are effective for evaluating both the direct and indirect benefits of many Industry 4.0 technologies, including advanced robots, augmented reality, and cloud computing. For some technologies, such as horizontal and vertical system integration, a qualitative assessment is also required to fully understand the value, because it is harder to quantify the benefits that improved collaboration will ultimately yield.

The change should be planned and implemented in such a way as to ensure that positive impacts on profitability – i.e. growth and efficiency – occur at various stages throughout the transformation. According to Schumacher maturity models are positioned as tools for comparing the current level of an organization or process to the desired level in terms of maturity by conceptualizing and measuring (Schumacher Andreas et al., 2016).

MANAGING THE DIGITAL TRANSFORMATION OF COMPANIES

Companies that transform their businesses and operations regarding Industry 4.0 principles face complex processes and high budgets due to dependent technologies. The transformation affects process inputs and outputs and it requires a broad perspective on the company's strategy, organization, operations, and products. Digital transformation of companies' businesses and operations is driven by investments in information and telecommunication technologies and new machinery. Besides, the need for the integration in current technologies, new machines, and automated work processes restrain horizontal and vertical integration along the value chain (Erol et al., 2016). However, it is not enough to address the developments associated with the fourth industrial revolution from just a technological perspective – companies also need to transform their organisation and culture.

The acatech Industry 4.0 Maturity Index provides companies with guidance for carrying out this transformation. It comprises a six-stage maturity model in which the attainment of each development stage delivers additional benefits. It helps companies to determine which stage they are currently at in their transformation into a learning, agile company. It assesses them from a technological, organisational, and cultural perspective, focusing on the business processes of manufacturing companies. It requires the formulation of a digital roadmap for all the relevant areas with a step-by-step approach to achieving the benefits that reduce the investment and implementation risks for the company. The roadmap helps companies to understand the importance of developing a common digital strategy for the whole business. This approach is illustrated in Figure 9. It should be planned and implemented in such a way as to ensure that positive impacts on profitability – i.e. growth and efficiency – occur at various stages throughout the transformation (Schuh, 2017).

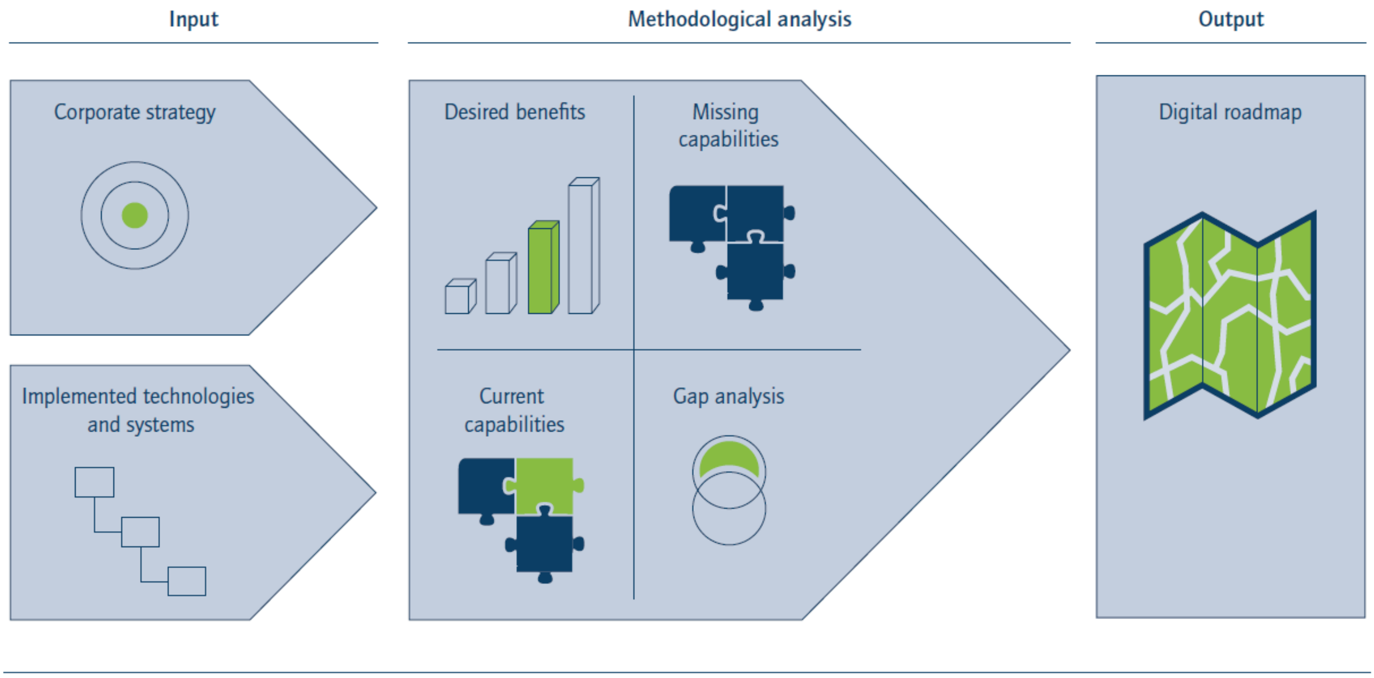


Figure 4 : Methodology for introducing Industry 4.0 (source: Acatech study, Schuh 2017)

The companies' transformation path comprises six development stages. Each stage builds on the previous one and describes the capabilities required to attain it and the resulting benefits to the company (see Figure 5). The transformation process is a continuous journey of many successive steps that are taken incrementally and may not be perfectly synchronised across businesses, plants, lines, and cells. It is up to each company to decide which development stage represents the best balance between costs and benefits for its particular circumstances and should therefore be adopted as the target state for the end of the planned transformation process.

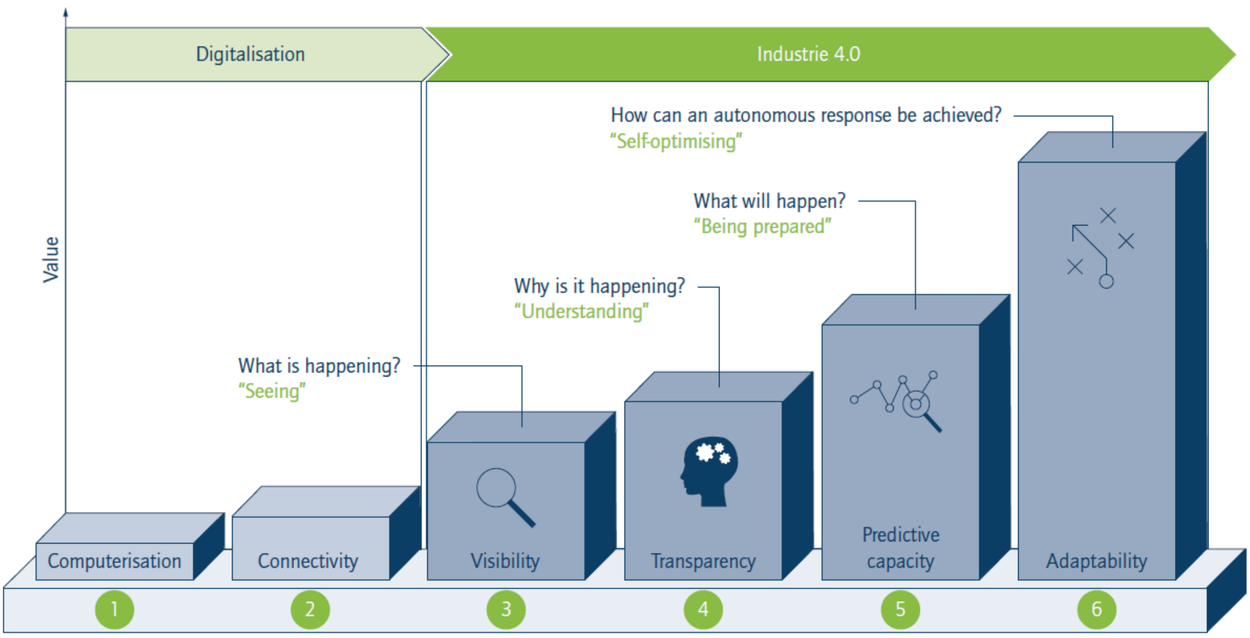


Figure 5: Stages in the Industry 4.0 development path (source: FIR e. V. at RWTH Aachen University)

5 The Institutions' Future Scenario

The institution's task will not only be to develop or further develop the education and training profiles for I4.0 in cooperation with the world of work involved, but also to promote the establishment of new forms of learning in HVET/VET institutions and companies.

An example of an Advanced Manufacturing lab is the Festo Didactic cyber-physical factory, which offers technical training and qualification to large vendors, universities, and schools. The cyber-physical systems of Festo Didactic encompass the new developments of networked production in Industry 4.0 and offer a modular Smart Factory system for teaching and research purposes.

One way to make the various qualifications transparent, understandable and comparable is to **describe them in terms of learning outcomes**.

It is widely understood at the institutional and world of work level, that the overall competence for mastering digital/ advanced manufacturing cannot be summarized in one person or one training profile. Digitization and Advanced Manufacturing require increased collaboration in mixed teams. The development and establishment of team-related competences and skills are a major challenge for training and education. To this end, new forms of education, training, and further training are to be developed that enable accompanying training of specialists at all levels. Institutional learning in seminars will be complemented by situational and experimental learning in labs and during apprenticeships. Continuing education and training are to be established in an everyday part of the work in an entrepreneurial context and established through appropriate offers for all ages and training levels.

6 Survey Results and Summary of National Expert Interviews

SURVEY METHOD

The pursued objectives of the study are to identify statues of representative companies in the countries of the project partners regarding digital transformation as well as to validate the two frameworks "EXAM 4.0 technology framework" and "EXAM 4.0 competence model".

The methodology used firstly was creating a universal questionnaire, which was applied by every partner country to contrast and compare results of the different EU regions and countries. The questionnaire was distributed to attendees as support before carrying out expert interviews with the concerned participants.

The expert interviews have taken place online between June and August 2020. The majority of participants represented large companies and SMEs. Four institutions did also participate in expert interviews (DHBW, Chamber of Industry and Commerce Eastern Wuerttemberg, Association of German Chambers of Industry and Commerce, Chamber of Handicrafts Ulm).

The results of this study do not represent quantitative but rather qualitative research. However, the selected companies are sufficiently representative to obtain and represent relevant information to be included in WP2 of EXAM 4.0.

The study examines two aspects of the impacts of Industry 4.0. These two aspects refer to technology impacts and competences. Furthermore, the questionnaire and interviews are divided into two parts, first part focusing on the current status and situation of companies concerning technological developments, qualifications, and current demands of employees. The second part of the study explores future technological trends, changed demands due to Industry 4.0, and how to prepare and reskill employees for the AM.

SUMMARY OF NATIONAL REPORT - SWEDEN

Regarding the national report of Sweden, the participating companies were notably agreeing to the different questions in the interview. The answers are variating in some areas because the companies work in different business units. Some representatives seemed to be more aware than others of their company's stage of development regarding I4.0 as well as what strategy their organisation is using to implement I4.0 technologies. The majority of participating companies did already execute and implement initial projects. Some companies do have a specific strategy for digitalisation. These are in most cases larger enterprises. For example, a few companies present a holistic approach concerning the development of new products, growth opportunities, and identifying key areas of effective investments. Concerning required competences in the future and new labour models, the interviewed companies pursue an ad-hoc strategy. In ten years' time, the majority of representatives forecast their companies to develop towards automation as support.

In terms of technology many companies used different I4.0 technology enablers, for example, all companies indicated the use of mobile devices in this survey. Further technologies often used by participants imply robotics, sensors, cloud computing, and safety & security. Asked about future technological trends, the representatives expect IoT to increase in importance. As a result, many companies do plan to introduce IoT as well as Big Data and further mobile devices in the future.

Besides, the interviewed companies did not determine the importance of different competences for different professions and future skills needed. The methodological, functional, social, and personal competences were considered almost equally important by most companies. However, the results display individual competences which were rated most important of every typology. These competences imply technical expertise, creativity, innovation, and cooperation & teamwork.

The results in this survey show that Sweden requires a change of the education strategy regarding I4.0. This is because graduates do not present all skills and competences that are required to work independently according to the companies. The companies were however unaware of which education strategy should be used instead.

SUMMARY OF NATIONAL REPORT – BASQUE COUNTRY (SPAIN)

In the case of Basque focus groups, 19 representatives of regional companies partook the questionnaire and expert interviews. The digital transformation in most cases is driven by a comprehensive and holistic strategy that runs through the organization. However, the level of implementation of I4.0 does vary for all the interviewed companies. Three profiles of companies are identified concerning the level of implementation: machine tool sector, technology providers, and component production-driven SMEs. Those profiles show characteristics throughout the interviews. For example, companies referring to the industry of technology providers tend to show the highest degree of maturity. Companies in the machine tool sector are incorporating different solutions and technology enablers into their products. As a result, the level of testing and validation of I4.0 solutions is much higher among those companies. Finally, component manufacturing SMEs are implementing I4.0 technologies at an early stage, testing different solutions and starting (and in some cases implementing) the first digitization projects.

Furthermore, it could be detected that all of the I4.0 technology facilitators included in the study are being used by Basque companies to varying degrees. As a first conclusion in this context, it is relevant to comment that none are ruled out. According to the results of the study, technology enablers referring to mobile & tablets and information exchange channels are often implemented and used by companies who have evaluated them. A similar observation could be made regarding additive manufacturing to a lower extent. The potential of M2M communications and robotics to a lower extent is also widely evaluated although it is not as broadly implemented so far.

It should be noted that most of the participating companies see their organizations in a high degree of digitalization in a period of ten years. Only 16% of the companies foresee digitalization as support.

Concerning possible risks that I4.0 may evoke, a recurrent concern among respondents is security, data security, and connected machines and processes.

Concerning competences, it is difficult to generalize the answers obtained, because they are often linked to specific jobs and tasks. The participating representatives emphasized the importance of functional competences and underline the importance of transversal competences in the context of digitalization. The interviews dealt with methodological, functional, social, and personal competences and the participating companies considered all the competences proposed as important or very important with few exceptions, for example, emergency management.

SUMMARY OF NATIONAL REPORT - GERMANY

With Regard to Germany, the results of the study with 20 companies contribute to insights of current status and future trends of German companies concerning technology, competences, and demands. The digital transformation in most cases is driven by a comprehensive and holistic strategy that goes across the organization. However, it can be observed that especially large companies did already implement several technology enablers and applications. In the questionnaire, SMEs could not indicate and explain as many executed projects referring to I4.0 technologies as larger companies. This observation could be explained by greater financial and human resources in large companies and their possible uses of I4.0 technologies.

SUMMARY OF NATIONAL REPORT - NETHERLANDS

In the case of the Dutch research group, nine representatives of local companies filled in the questionnaire and six interviewees participated in focus group interviews. The results of the study provide insights into the current status and future trends of Dutch companies concerning technology, competences, and demands. Larger companies generally have adopted more structured strategies company-wide. Also, the smaller companies have experimented with a range of technology enablers and applications, more often than not a combination of those. The implementation shows various stages of maturity.

Certainly, there are technologies used by the majority of participating companies such as mobile, additive manufacturing, and robotics. However, all companies plan to introduce more technology enablers to stay competitive and to be able to react to customer and market demands. Therefore, it comes as no surprise that interviewed companies indicated the strongest impact of I4.0 regarding IT.

Concerning future requirements, current employees and graduates entering the companies will constantly need to upgrade their competences and skills. Their starting qualifications are generally sufficient to provide a basis for further development of functional competences. As the results demonstrate, companies will introduce more technology enablers and complex systems in I4.0 requiring employees to obtain technical expertise and complex problem-solving skills. Also modeling, future employees predominantly working in diverse and intercultural teams, lead to the increasing demand for competencies on an interpersonal exchange of information and an interdisciplinary working approach. Several interviewees have stressed the importance of balancing the personal skills that graduates usually acquire in initial education and the functional and technical expertise they still have to acquire in a working AM environment. The training institutions are insufficiently able to fill the gap between the demands of the labour market and the number and quality of the graduates entering the labour market.

There is a great challenge for (H)VET to cater for this gap and to train future employees for the rapid changes in the working environment both technically and as far as interpersonal skills are concerned. The Dutch government and the educational institutes are thinking about concepts of life-long development. This will require huge investments by companies, the government, and workers themselves. For traditional VET institutions, this also requires forward-thinking and training their staff to combine traditional educational paths with modern concepts of life-long development of non-traditional student groups. It may also involve the addition of new types of qualifications instead of traditional diplomas and certificates.

CATEGORIES OF COMPETENCES FOR KEY ENABLING TECHNOLOGIES

The PwC EU Service identified six categories of competences for Key enabling technologies for high-tech professionals (KET) including the results of required skills in the AM institutes (PricewaterhouseCoopers EU Services EESV, 2016). The categories of competencies for KETs include competences regarding (see Figure 6)

- **Technical subjects**
- **Quality, risk and, safety**
- **Management and Entrepreneurship**
- **Communication**
- **Innovation**
- **Emotional intelligence**

Technical competencies are related to practical subjects based on scientific principles, for example, coding, computational thinking, mathematical modeling, and simulation. Due to the knowledge-intensive nature of Key Enabling Technologies, the latter competencies are described as the heaviest category regarding required knowledge and skills (PricewaterhouseCoopers EU Services EESV, 2016).

The second category concerning quality, risk, and safety implies competencies such as quality management, quality control analysis, emergency management, and response, industrial hygiene, and risk assessment. Employees working with KETs need to operate with a high level of accuracy because of highly expensive equipment. Therefore, employees working with KETs need to be able to concentrate over a long period and to keep attention to detail. They are also expected to follow stringent and specific quality and safety procedures (PricewaterhouseCoopers EU Services EESV, 2016).

Management and entrepreneurship present another category of competences for KETs, including market analysis, strategic developments for product demonstrations with significant risk, marketing, project management, and R&D management. Competencies of this category refer to the ability to acquire and manage large investments and to coordinate international teams (PricewaterhouseCoopers EU Services EESV, 2016).

Competencies referring to the category of communication relate to the interpersonal exchange of information, verbal as well as written communication, and virtual collaboration. In the study, PwC EU Service emphasizes the importance of diverse teams in KETs, therefore, competences related to communication are key competences required of employees working in an advanced manufacturing environment. Employees need to be able to work productively, drive engagement, integrate and establish as a member of virtual teams (PricewaterhouseCoopers EU Services EESV, 2020).

The fifth category of competences regarding innovation refers to the designing and creation of new things. This category implies competences such as integration skills, complex problem solving, creativity, and systems thinking. The competences of this category pertain to the ability to use and combine different disciplines into joint solutions to solve complex problems in an advanced manufacturing environment (PricewaterhouseCoopers EU Services EESV, 2020).

The last category of KETs competences, emotional intelligence, includes the ability to operate with own and other peoples' emotions and to use these to guide thinking and behaviours. Competences implied in the aforementioned category are leadership, cooperation, a multi-cultural orientation, stress tolerance, and self-control (PricewaterhouseCoopers EU Services EESV, 2020).

Moreover, the competences presented in the framework are distinguished between general and specific competences or rather KET-specific and multi-KETs competences. General or multi-KETs competences present a common core of competences and apply to the majority of high-tech employees regardless of their respective field or job profile. Specific competences, on the other hand, are unique to particular domains or job profiles. These competences imply for example highly specialised technical knowledge, skills required when working with specific equipment, and in-depth knowledge of non-technical subjects and topics that do not refer to all high-tech professionals. Furthermore, PwC EU Service adds that the differentiation between general or specific competences also depends on the occupational level (PricewaterhouseCoopers EU Services EESV, 2020). By identifying categories of competencies for KETs, PwC clustered and structured required competencies and skills for working in an advanced manufacturing environment.

TEACHING NEW SKILLS AND TEACHING SKILLS IN A NEW WAY

I4.0 Skills and Competencies

The skills evolution of qualified personnel and junior employees for current and future changes in the workplace will require employees who are 4.0 specialists and possess interdisciplinary skills, uniting classic mechatronics qualifications with sound IT knowledge and high levels of social competence. The transformation of the work environment will change the job profiles and therefore requires employees to be outfitted with a wide range of competencies. To successfully get through the transformation towards I4.0, a definition of the competencies for I4.0 is required. Based on the KET categories the EXAM 4.0 consortium developed an I4.0 competency framework.

Figure 6: Categories of Competences (Pricewaterhouse Coopers EU Services EESV, 2020)

As the basis of knowledge graduates must bring domain-related competencies as well as the ability to apply expertise and use technology. In this area, all graduates need to bring IT and I4.0 technology affinity and while working with engineers from different groups, graduates should understand the integration of heterogeneous modeling technologies, gain knowledge about mobile technologies and embedded systems and sensors, knowing network technology and M2M communication as well as possess knowledge of robotics and artificial intelligence. On the other hand, IT and IS graduates should both bring modeling and programming knowledge, knowledge about cloud computing and cloud architectures, in-memory DB knowledge, and statistics. For all I4.0 graduates, big data and data analysis and interpretation will be of big importance.

I4.0 graduates should know service orientation and product service offerings, business process, and change management. They should know about digital security, including data and networks. Economics knowledge and being able to extract business value, a focus on business strategy, always changing business models and entrepreneurship are important skills all graduate programmes should offer.

Communication is one of the key competencies required from graduates. By putting the communication competency in relation with other competencies like literacy and technical communication, intercultural competency, or presentation ability, social skills like collaboration, compromising, and negotiating combined with emotional intelligence will play a key role in I4.0. Since they also play an important aspect in teamwork, project management, and management ability, customer orientation, maintaining customer relationships, and creating business networks, they should be part of each I4.0 curriculum design.

Work and collaboration will become more complex, therefore I4.0 requires graduates to analyzing competencies like problem-solving, optimization, analytical skills, and cognitive abilities. To be able to coordinate these competencies, being able to manage complexity and abstraction ability are crucial. Graduates in I4.0 should bring leading and deciding competencies like decision making, taking responsibility, and leadership skills, which should be combined with a set of principles and values with competencies like respecting ethics, environmental awareness, and awareness for ergonomics.

Teaching Skills in Learning Factories

To develop expertise for using and working with the latest digital industry technologies within the framework of Industry 4.0, modern learning systems can be customized ensuring solutions that combine work with learning. They are equipped with innovative industrial technologies so that the knowledge required for digital production can be imparted practically, while simultaneously developing skills through hands-on trial and error. Initiatives such as Learning Factories have sought to develop experiences through the inclusion of industrial projects under the active learning approach on the curriculum of a variety of engineering programs. Preliminary studies have shown better performance in the development of skills and acquisition of knowledge than traditional approaches (Abele E., 2015).

Depending on the perspective, learning factories are:

- highly complex learning environments that allow a high-quality, self-contained competency development (teaching-learning perspective) or

- idealized replicas of industrial value chain sections in which informal, non-formal, and formal learning can take place (operational perspective) (Abele E., 2015).

Advanced Manufacturing learning factories in educational, production and service-oriented facilities have set up almost realistic learning and research environments. They rely on a truly industrial production facility that provides a direct approach to the product creation process. The learning factories are also based on a didactic concept focusing on experimental and problem-oriented learning.

The learning factories comprise physical and digital environments. The physical environment includes real system components like machining, assembly, logistics, and information flow and energy flow modules. Integrated planning, modeling, visualization, and simulation tools are parts of the digital environment. Both physical and digital environments should also be integrated. This offers new possibilities to transfer digitally created solutions to a real system for testing, evaluation, and demonstration. Furthermore, there should be automatic feedback from the real system components to the digital environment to plan adaptation and change.

The main goals of learning factories are either an effective competency development (if used for education and training), i.e. the development of the participants' ability (including motivational and emotional aspects) to master complex, unfamiliar situations or technological and/or organizational innovation (if used for research). Therefore, a didactic concept that specifies what and how should be learned by whom is an indisputable part of a learning factory. Learning in the learning factory can either take place in the planning, realization, and ramp-up phase (greenfield) but also in the improvement of existing processes and factory environments (brownfield).

For the classification of the different learning factory characteristics, the morphology designed by ABELE could be used so far. This theoretical classification based on predefined dimensions will be reduced and focused on essential characteristics, shown in Figure 7.

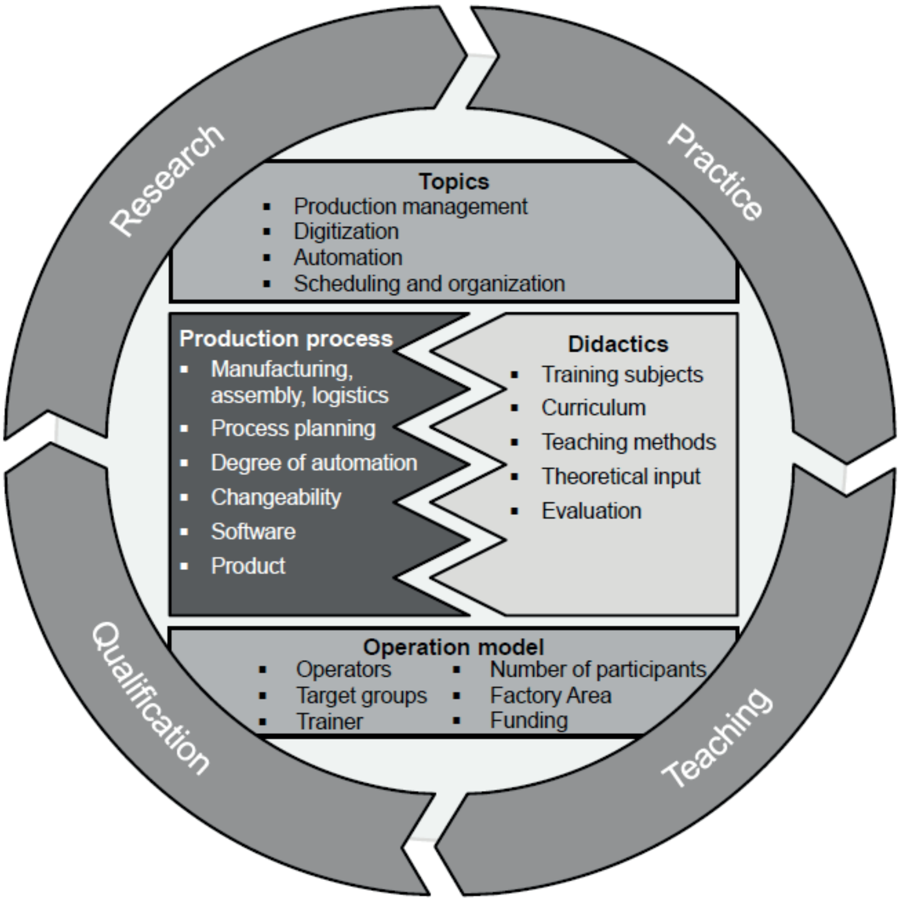


Figure 7: Learning factory characteristics (Abele E., 2015)

There is a broad range of learning factory configurations. Characterizing single facilities and comparing those with one another is greatly facilitated by description models. The major advantage of the description model as a tool for describing the complex system of a learning factory is the inclusion of all relevant features and characteristics and their potential attributes. Thus, a picture of learning factories both holistic and generic can be drawn while at the same time a particular learning factory can be classified, allowing a simplified illustration of the correlations between all existing options to conceptualize a learning factory and the specific design of the actual learning factory that is being described.

The CIRP CWG on learning factories as well as the consortia project Network of Innovative Learning Factories (NIL), which was funded by the German Federal Ministry of Education and Research through the German Academic Exchange Service (DAAD), simultaneously developed and validated a multidimensional description model. It can serve as an orientation in the design of a new learning factory as well as a classification tool for existing learning factories at the same time. For the description model presented here, more than 50 single features in seven dimensions were identified before elaborating the respective attributes for each. It fulfills three major purposes:

Providing orientation and guidelines in designing and establishing a new learning factory, serving as a tool for delineation of existing ones, and working toward a standardization of the learning factory concept.

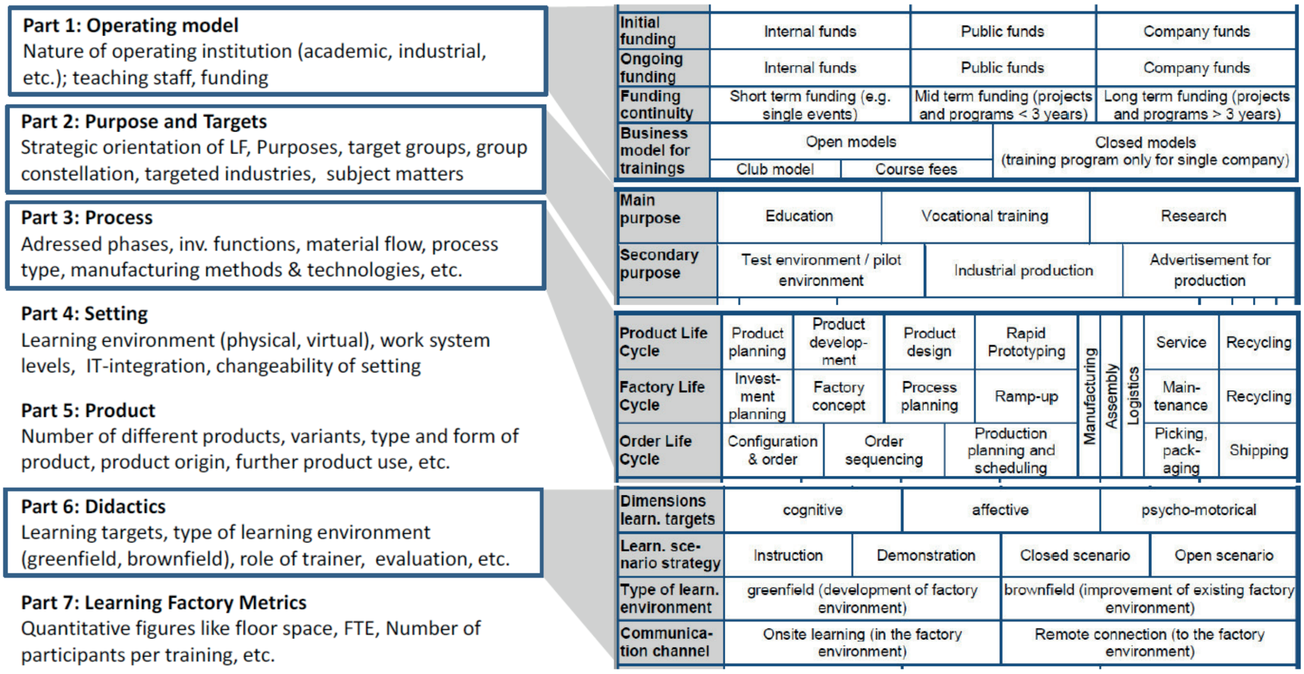


Figure 8: Components of Learning Factory (Abele E, Metternich J, Tisch M, Chryssolouris G, Sihn W, ElMaraghy H, Hummel V, Ranz F (2015) Learning Factories for Research, Education, and Training. 5th CIRP-sponsored Conference on Learning Factories, Procedia CIRP 32:1-6.

To overcome the limits of learning factories the following suggestions are considered helpful:

- Systematic approaches to design LFs of any kind.
- Virtual learning factories are less resource-consuming and allow the scalability and mobility of the LF approach.
- Concepts using ICT equipment to enable a location-independent operation

of the learning factory.

- Methods to measure competence-oriented learning success.
- A network of learning factories to overcome the problem of a limited scope of single facilities

There is a need for joining efforts among those who have established learning factories to develop teaching and hands-on learning modules and applications that can be shared among users to save development time and share development experiences and lessons. The Exam4.0 hub will address this need.

8 Conclusion

The research and initiatives were undertaken within aimed to contribute and identify future trends in Advanced Manufacturing and Industry4.0 in a wider sense. The report informs institutions' management, program developers on how to increase the quality and relevance of existing curricula, the work-based training in the labs, and to promote better cooperation between industry and education and training organisations. To align Advanced Manufacturing education and training with the needs of the New Industrial Age, a clear understanding of the industry trends is provided. It involved data collection and research, design of guidelines, testing and validation, taking into account industry and market needs and best practices, based on contributions from all key stakeholder groups. The research focussed on non-tertiary Vocational Education and Training and Professional Higher Education.

Industry 4.0 includes the transformation of work and production through autonomous and real-time systems that enable personalized, interconnected, and smart products as well as services. Companies are forced to adapt their know-how and organizational structures towards this change to be successful in the market. Among many challenges that arise for companies in this paradigm, one of the most important ones is the employee qualification with the necessary competencies for working successfully in the transformed work environment. It is crucial to prepare the workforce of tomorrow for the disruption that the technology and business world is undergoing. This educational challenge should be first addressed in higher-level education to prepare students as employees of tomorrow with the competencies for Industry 4.0.

The survey has shown that the fast-pacing change due to developments in technology is a concern for all stakeholder groups and implies an area requiring closer, stronger, more consistent, long-term collaboration. Effective methods of collaboration are found in dual education around joint participation of stakeholders in governance and consultation structures, joint knowledge transfer, and extensive surveying of stakeholders to inform decision-making at the institutions.

Today's innovation-driven economy depends on the creation of wholly new ideas, services, products, and solutions. To foster this kind of development, education systems will need to shift from a process-based to a problem-based approach to learning. Problem-based learning can be implemented by assigning students to collaborative projects in learning factories or labs to create solutions to real-world challenges. Through a project-based approach, students need to research the topic and understand the various viewpoints, ideate and design a solution, and then finally develop a prototype.

To transform pedagogical practices in higher education, to achieve a balance between social skills, science knowledge, and technical training, the following transformation objectives should be part of the I4.0 curriculum design:

- Implement new learning strategies for the practices of the curriculum of Advanced Manufacturing in the direction of active and experiential learning.

- Consider a transformation framework that integrates the latest industry global trends with academic content, physical infrastructure, and engineering practices.

Furthermore, Advanced Manufacturing education should develop and address the following aspects:

- Interdisciplinary educational programmes holistically teaching science, engineering, and business courses/modules also providing rapid/real-time innovation of the programmes, and modules in partnerships with industry.

- The adaptive learning environment and associated strategies of rapid adoption.

The industry developments have direct implications for the skill requirements. The survey helped to identify the competencies needed for Industry 4.0, which will lead to the development of the EXAM 4.0 technology and competency frameworks in WP2.A4. The main requirement for implementing Industry 4.0 is a wide range of competencies. Defining the competencies is the first step towards preparing the workforce of tomorrow for Industry 4.0. The further challenge consists in preparing students and the workforce in adapting these competencies through dedicated teaching concepts and curricula and the work-based training in the labs and for the latter there is a clear need to promote better policies, measures, and initiatives at all levels by fostering transparency, increasing awareness and sharing good practices.

9 Appendix

EXAM 4.0 SURVEY QUESTIONNAIRE

DEMOGRAHICS

1. **Which business unit do you work for?**
   - ☐ Sales and internal sales
   - ☐ IT
   - ☐ Production
   - ☐ Work preparation
   - ☐ Development/ Construction (R&D)
   - ☐ Supply Chain Management / Logistics
   - ☐ Administration (finance, human resources, and others)
   - ☐ Institutions, University
2. **What is your functional area?**
   - ☐ Higher management – Division manager / Plant manager
   - ☐ Middle management – Head of a department
   - ☐ Lower Management – shift supervisor, team manager/group manager, skilled labour (with management functions)
   - ☐ Employee (without management functions)
3. **What is the size of your enterprise?**
   - ☐ small enterprise
   - ☐ medium-sized enterprise
   - ☐ large enterprise

Size of enterprise	Number of employees	Sales/Year
Small enterprise	< 10	< 1 Mio. €
Medium-sized enterprise	10 ≤ 499	1 Mio. € ≤ 49 Mio. €
Large enterprise	≤ 500	≤ 50 Mio. €

4. **Which industry does your company belong to?**
   - ☐ Automotive
   - ☐ Machine tool
   - ☐ Electronics
   - ☐ Aeronautics
   - ☐ Services (e.g. logistics)
   - ☐ Others (PLEASE SPECIFY HERE): ______________________________

5. Please describe the digital transformation initiatives and priorities on which your company made progress towards Industry 4.0

Type of digital transformation	No formal strategy at this time (1)	Ad-hoc approach when needed (2)	A comprehensive and holistic strategy that goes across the organization (3)	Don't know
Protecting our organization from disruption	☐	☐	☐	☐
Developing new business models	☐	☐	☐	☐
Developing I4.0 IT architecture (e.g. Cloud, Big data, IoT)	☐	☐	☐	☐
Developing innovative/ differentiated products and services	☐	☐	☐	☐
Finding growth opportunities for existing products and services	☐	☐	☐	☐
Identifying key areas to make effective I4.0 investments	☐	☐	☐	☐
Investigating connected, integrated approaches in the value chain to implement I4.0 technologies	☐	☐	☐	☐
Understanding what skills will be needed	☐	☐	☐	☐
Training and developing the workforce for I4.0	☐	☐	☐	☐
Utilizing new labour models	☐	☐	☐	☐

Comments:

6. Regarding Industry 4.0 (I4.0), what kind of activities did your company already complete?

- ☐ Orientation phase
- ☐ Analysis of potential
- ☐ I4.0 strategy and the implementation road map (potentials and what to do)
- ☐ I4.0 strategy execution and implementation of initial projects
- ☐ Successfully accomplished projects
- ☐ No activity so far
- ☐ Others : ________________________________

Comments:

7. In case your company initiated I4.0 projects, please describe how the projects were managed.

- ☐ by inner working teams
- ☐ by company members who have been trained on I4.0 topics
- ☐ outside consulting firms guiding the implementation
- ☐ fully subcontracted
- ☐ Others: ____

Comments:

8. Which of the following Industry 4.0 technologies/applications did you evaluate and are familiar to you?

- ☐ Machine to Machine Communication
- ☐ Additive Manufacturing (3D-Printing, …)
- ☐ Safety & Security
- ☐ Cloud Computing
- ☐ Cyber-Physical Systems (CPS)
- ☐ Mobile (tablet, etc.)
- ☐ I did not deal with it yet
- ☐ Augmented reality / Virtual reality
- ☐ Big Data analytics
- ☐ IOT (Internet of Things)
- ☐ Smart Actuators/Sensors
- ☐ Identification (RFID, …)
- ☐ Robotics, autonomous systems

If there are other I4.0 technology enablers please comment HERE:

9. Which of the following technologies/applications do you already use in your company?

- ☐ Machine to Machine Communication
- ☐ Adaptive Manufacturing (3D-Printing, …)
- ☐ Safety & Security
- ☐ Cloud Computing
- ☐ Cyber-Physical Systems (CPS)
- ☐ Mobile (tablet, etc.)
- ☐ Augmented reality / Virtual reality
- ☐ Big Data analytics
- ☐ IOT (Internet of Things)
- ☐ Smart Actuators/sensors
- ☐ Identification (RFID, ..)
- ☐ Robotics, autonomous systems

If there are other I4.0 technology enablers please comment HERE:

10. Please describe projects and technology applications initiated by your organization related to I4.0

Example 1:

- Name of I4.0 technology:______________________________
- Description of projects:______________________________

Example 2:

- Name of I4.0 technology:______________________________
- Description of projects:______________________________

11. In case your company implemented I4.0 technologies, please rate the implications in the organization in the following categories.

Organizational implications	No impact (1)	(2)	(3)	(4)	High impact (5)	Don't know
Organizational structure	☐	☐	☐	☐	☐	☐
IT	☐	☐	☐	☐	☐	☐
Human resource management	☐	☐	☐	☐	☐	☐
Business processes	☐	☐	☐	☐	☐	☐
Supply Chain Management	☐	☐	☐	☐	☐	☐
Customer interaction	☐	☐	☐	☐	☐	☐
Comments:						

12. Please rate the following qualifications regarding the actual requirements of your department/unit.

Type of Qualification	Insufficiently qualified (1)	(2)	Sufficiently qualified (3)	(4)	Excellently qualified (5)	Don't know
Skilled labour (EQF4)	☐	☐	☐	☐	☐	☐
Professional (EQF 5)	☐	☐	☐	☐	☐	☐
Bachelor, Foreman, Technician (EQF 6)	☐	☐	☐	☐	☐	☐
Comments:						

13. For the following questions (Q–14/15) please specify the function you are most familiar and refer your answers to.

- ☐ Manufacturing / operations
- ☐ Supply chain/logistics
- ☐ Engineering /product design
- ☐ Service/maintenance
- ☐ IT
- ☐ No activity so far
- ☐ Other functions PLEASE SPECIFY HERE: ______________________________

Comments:

14. Please rate the following competencies with regard to the requirements of Industry 4.0 at your company and the function you are most familiar with.

Type of Qualification	Not sufficient (1)	(2)	Partly sufficient (3)	(4)	Highly sufficient (5)	Don't know
Functional competencies: • Specific abilities and professional skills to solve clear-defined tasks	☐	☐	☐	☐	☐	☐
Methodological competencies: • Qualify individuals to independently solve new and complex problems • Imply planning and decision- ability, ability to apply one's skills and knowledge as well as knowing how to acquire missing competencies	☐	☐	☐	☐	☐	☐
Social competencies also referred to as interpersonal competencies: • Imply behaviour, attitudes, and ability of communication and cooperation	☐	☐	☐	☐	☐	☐
Personal competencies: • Include professional relevant attitudes, values, and personal characteristics • Influence the ability of professional self-reflection	☐	☐	☐	☐	☐	☐

Comments:

15. To what extent do you agree with the qualification and competence level of the VET and HVET graduates regarding the I4.0 requirements?

Skills and competences level of graduates	Not sufficiently prepared (1)	Somehow prepared (2)	Sufficiently prepared (3)	Well prepared (4)	Excellently prepared (5)	Don't know
VET	☐	☐	☐	☐	☐	☐
University of Applied Science/HVET	☐	☐	☐	☐	☐	☐
Academic University	☐	☐	☐	☐	☐	☐

Comments:

FUTURE TRENDS

16. Where do you see the development of your company in the next ten years? (Please highlight in the axis shown below)

Low-cost Automation
Assistance systems monitor and guide production processes performed by low-skilled employees

Automation as a support
Assistance systems support highly qualified employees with special tasks

Maintained automation
extensive automation is supported and optimized by process engineers

Complete automation
Systems do control and monitor themselves autonomously

Comments:

17. Which of the following I4.0 technology enablers will be introduced in your company's production in upcoming years?

- ☐ Machine to Machine Communication
- ☐ Additive Manufacturing (3D-Printing, …)
- ☐ Safety & Security
- ☐ Cloud Computing
- ☐ Cyber-Physical Systems (CPS)
- ☐ Mobile (tablet etc.)
- ☐ Augmented reality / Virtual reality
- ☐ Big Data analytics
- ☐ IoT (Internet of Things)
- ☐ Smart Actuators / Sensors
- ☐ Robotics, autonomous systems
- ☐ Identification (RFID, …)
- ☐ Others (PLEASE SPECIFY HERE):________________________________

Comments:

18. Please describe projects and technology enablers that will be initiated by your organization related to I4.0

Example 1:

- Name of I4.0 technology:_________________________________
- Description of projects:___________________________________

Example 2:

- Name of I4.0 technology:_________________________________
- Description of projects:___________________________________

19. What is your opinion of the business impacts of Advanced Manufacturing (I4.0) in your company?

Impacts of I4.0	Quite the contrary (1)	(2)	(3)	(4)	Fully agree (5)
I4.0 evaluates existing practices and initiates the change processes necessary to enhance customer value and satisfaction	☐	☐	☐	☐	☐
I4.0 has a strong impact on processes and operations and will continuously improve our business unit performance	☐	☐	☐	☐	☐
I4.0 has a strong impact on the overall growth and efficiency of our company	☐	☐	☐	☐	☐
I4.0 has a strong impact on the quality of services of our company	☐	☐	☐	☐	☐

Comments:

20. How would you estimate the importance of the following I 4.0 technology enablers in your advanced manufacturing environment?

Industry 4.0 technology enabler	Less important (1)	(2)	(3)	(4)	Very important (5)
Machine to Machine Communication	☐	☐	☐	☐	☐
Additive Manufacturing (3D-Printing, …)	☐	☐	☐	☐	☐
Cloud Computing	☐	☐	☐	☐	☐
Safety & Security	☐	☐	☐	☐	☐
Cyber-Physical Systems (CPS)	☐	☐	☐	☐	☐
Mobile (tablet, etc.)	☐	☐	☐	☐	☐
Augmented reality / Virtual reality	☐	☐	☐	☐	☐
Big Data analytics	☐	☐	☐	☐	☐
IoT (Internet of Things)	☐	☐	☐	☐	☐
Smart Actuators/Sensors	☐	☐	☐	☐	☐
Robotics, autonomous systems	☐	☐	☐	☐	☐
Identifikation (RFID, …)	☐	☐	☐	☐	☐

If there are other I4.0 technology enablers please comment HERE:

21. How important are in your opinion the following conceptual principles in the teaching & learning of skills in an advanced manufacturing environment?

Categories of I4.0 competences	Less important (1)	(2)	(3)	(4)	Very important (5)
Competences related to **practical/techmodelingects** based on scientific principles (*e.g. programming, computational thinking, mathematical modeling and simulation, top-down fabrication techniques*)	☐	☐	☐	☐	☐
Competences related to **quality, risk & safety** aspects (*e.g. quality management, computer-aided quality assurance, quality control analysis*)	☐	☐	☐	☐	☐
Competences related to **management, administration**, IP, and finance (*e.g. strategic analysis, marketing, project management*)	☐	☐	☐	☐	☐
Competences related to **interpersonal communication** (*e.g. verbal communication, written communication, presentation skills, public communication, virtual collaboration*)	☐	☐	☐	☐	☐
Competences related to **design and creation of new things** (*e.g. integration skills, complex problem solving, creativity, systems thinking*)	☐	☐	☐	☐	☐
Competences and ability to operate with own and other **people's emotions**, and to use emotional information to guide thinking and behaviour (*e.g. leadership, cooperation, multi-cultural orientation, stress-tolerance, self-control*)	☐	☐	☐	☐	☐

Comments:

22. To what extent do you agree with the following statements regarding the future trends of qualifications for employees in I 4.0?

Change requirements/ Objectives	Do not agree (1)	(2)	(3)	(4)	Fully agree (5)	Don't know
In Industry 4.0 demands and change requirements concerning **soft skills** (e.g. interdisciplinary competencies) **will increase**	☐	☐	☐	☐	☐	☐
In Industry 4.0 demands and change requirements concerning **hard skills** (e.g. expertise) **will increase**	☐	☐	☐	☐	☐	☐

Comments:

23. How would you rate the importance of the following criteria of methodological competencies with regard to a future production environment of I 4.0?

Methodological competencies	Less important (1)	(2)	(3)	(4)	Very important (5)
Presentation skills	☐	☐	☐	☐	☐
Strategical thinking	☐	☐	☐	☐	☐
Linked/ collaborative thinking	☐	☐	☐	☐	☐
Expertise	☐	☐	☐	☐	☐
Transfer skills	☐	☐	☐	☐	☐
Analytical thinking	☐	☐	☐	☐	☐
Coordination skills	☐	☐	☐	☐	☐
Knowledge of EDV-software	☐	☐	☐	☐	☐
Creativity	☐	☐	☐	☐	☐
Customer-oriented approach	☐	☐	☐	☐	☐
Complex problem-solving	☐	☐	☐	☐	☐
Project management	☐	☐	☐	☐	☐

Comments:

24. How would you rate the importance of the following criteria of functional competencies with regard to a future production environment of I 4.0?

Functional competencies	Less important (1)	(2)	(3)	(4)	Very important (5)
Technical expertise	☐	☐	☐	☐	☐
Language skills	☐	☐	☐	☐	☐
Linked thinking	☐	☐	☐	☐	☐
IT knowledge	☐	☐	☐	☐	☐
Project management	☐	☐	☐	☐	☐
Quality management	☐	☐	☐	☐	☐
Emergency management	☐	☐	☐	☐	☐
Industrial hygiene	☐	☐	☐	☐	☐

Comments:

25. How would you rate the importance of the following criteria of social competencies with regard to a future production environment of I 4.0?

Social competencies	Less important (1)	(2)	(4)(3)	Very important (5)	
Empathy	☐	☐	☐	☐	☐
Cooperation/Teamwork	☐	☐	☐	☐	☐
Ability to deal with conflicts	☐	☐	☐	☐	☐
Ability to be critical	☐	☐	☐	☐	☐
Leadership	☐	☐	☐	☐	☐
Communication skills	☐	☐	☐	☐	☐
Intercultural competencies	☐	☐	☐	☐	☐
Stress tolerance	☐	☐	☐	☐	☐

Comments:

26. How would you rate the importance of the following criteria of personality competencies with regard to a future production environment of I 4.0?

Personality competencies	Less important (1)	(2)	(4)(3)	Very important (5)	
Structured working approach	☐	☐	☐	☐	☐
Systematical working approach	☐	☐	☐	☐	☐
Self-organization	☐	☐	☐	☐	☐
Decision-making skills	☐	☐	☐	☐	☐
Determination	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐
Creativity	☐	☐	☐	☐	☐
Innovation	☐	☐	☐	☐	☐
Responsibility	☐	☐	☐	☐	☐
Self-control	☐	☐	☐	☐	☐
Integration skills	☐	☐	☐	☐	☐

Comments:

27. Who do you think would be primarily responsible to teach the competencies listed below? (multiple references possible)

Primarily responsible party	Web 2.0 Mobile devices	CPS, IoT	Additive manufacturing	Advanced robotics	Big Data analysis
General schooling	☐	☐	☐	☐	☐
VET institutions	☐	☐	☐	☐	☐
Training on the job as part of apprenticeships	☐	☐	☐	☐	☐
Further training in companies	☐	☐	☐	☐	☐
HVET institutions	☐	☐	☐	☐	☐
Individual learning	☐	☐	☐	☐	☐
Company offers of e-Learning	☐	☐	☐	☐	☐
Inter-company offers of e-Learning	☐	☐	☐	☐	☐

Comments:

28. Who do you think would be primarily responsible to teach the competencies listed below? (multiple references possible)

Primarily responsible party	Knowledge of data safety and security	How to deal with a large amount of data	The ability of interdisciplinary and cross-functional cooperation	Ability to engage and integrate into innovation processes
General schooling	☐	☐	☐	☐
VET institutions	☐	☐	☐	☐
Training on the job as part of apprenticeships	☐	☐	☐	☐
Further training in companies	☐	☐	☐	☐
HVET institutions	☐	☐	☐	☐
Individual learning	☐	☐	☐	☐
Company offers of e-Learning	☐	☐	☐	☐
Inter-company offers of e-Learning	☐	☐	☐	☐

Comments:

29. Industry 4.0 causes changes concerning the requirements of employees. In which sectors does your company plan offers of upskilling or further education and training for existing employees to meet the demands of Industry 4.0.

- ☐ Further education concerning theoretical knowledge and expertise
- ☐ Social and personality competencies (communication, teamwork, collaboration, leadership, etc.)
- ☐ Practical training concerning recently introduced technologies/applications
- ☐ Others: ____

Comments:

30. The importance of the approach to lifelong learning is constantly increasing. Is there already a concept describing how to implement the approach of lifelong learning for employees at your company?

- ☐ No, not yet.
- ☐ Yes, the company suggests: ____

Comments:

31. In the course of Industry 4.0, which demands will change for existing employees?

Please comment HERE:

32. Which qualifications are essential for the transition and to be able to perform as an Industry 4.0 company?

Please comment HERE:

33. Where do you see the highest benefits and chances in Advanced Manufacturing (I4.0) in your company?

Please comment HERE:

34. What are the possible risks of Advanced Manufacturing (I4.0)?

Please comment HERE:

10 Detailed Country report – Sweden

This document compiles the results of two different methods that Curt Nicolin High School used to gather information regarding the digital transformation with a perspective on the Swedish industry. The first method is called "EXAM 4.0 focus group meeting's results" and it is a summary of interviews with representatives from 5 companies in Sweden. The interviews were based on a questionnaire that contained inquiries regarding industry 4.0 which the representatives answered from their company's perspective. The result from this survey will be used as a reference for Sweden's status regarding Industry 4.0.

ABBREVIATIONS

AM= Advanced Manufacturing

AR/VR= Augmented Reality/ Virtual Reality

EQF= European Qualification Framework

EXAM 4.0: Excellent Advanced Manufacturing 4.0

I4.0= Industry 4.0

IIoT= Industrial internet of thing

IoT= Internet of thing

M2M= Machine to machine

MES= Manufacturing Execution System

RFID= Radio frequency identification

CONTENTS

EXAM 4.0 FOCUS GROUP MEETING'S RESULTS

This single nation report was created within the WP2 Learning Dialogues of the project EXAM 4.0. The objective of this study is to distinguish Sweden's current status in industry 4.0, the digital transformation. It intends among other things to identify which specific industry 4.0 applications that are used by companies in Sweden. The final goal is to validate the EXAM 4.0 technological framework" and the "EXAM 4.0 competence framework" which will be used to create further results within the EXAM 4.0 initiative.

The method was used to gather information from all the countries within the consortium. The same questionnaire was used by all the participants in the EU-project EXAM 4.0.

5 companies participated in interviews and answered the questionnaire, this took place between June and August 2020. The companies that took part in the questionnaire were 3 large and 2 medium enterprises.

These few amounts of answers are unfortunately not enough to define the definitive current situations for companies and industry in Sweden regarding digital transformation.

Gathering information from Swedish industry companies was difficult due to several factors:

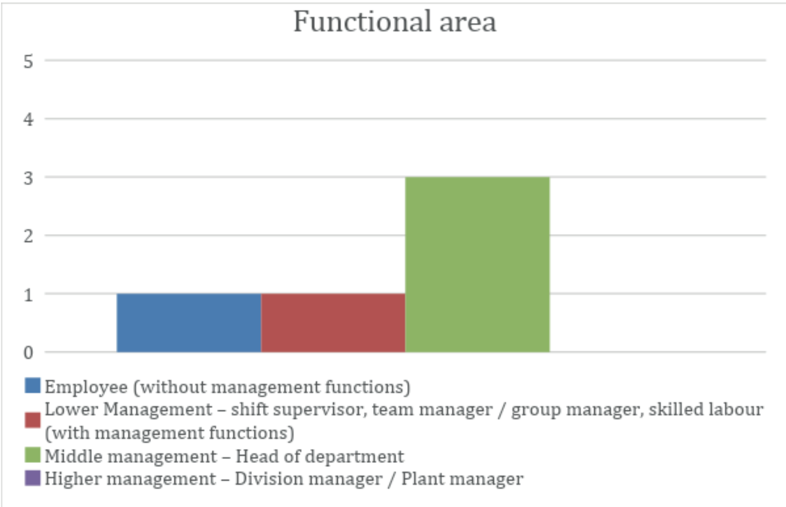
- Companies were not sufficiently aware of I4.0 to give complete and correct information in the questionnaire
- Companies had time pressure and did not have the time to answer the detailed questionnaire
- Companies did not find it beneficial to answer the questionnaire concerning its time-consuming structure
- Companies did not want to share their development model
- Representatives did not feel qualified to represent their company in this questionnaire
- The questionnaire was too complex

The representatives participating in the questionnaire are entirely appropriate to describe relevant facts and information that will be included in the WP2 of EXAM 4.0 and this information will be used as a reference for Sweden's industry 4.0 status.

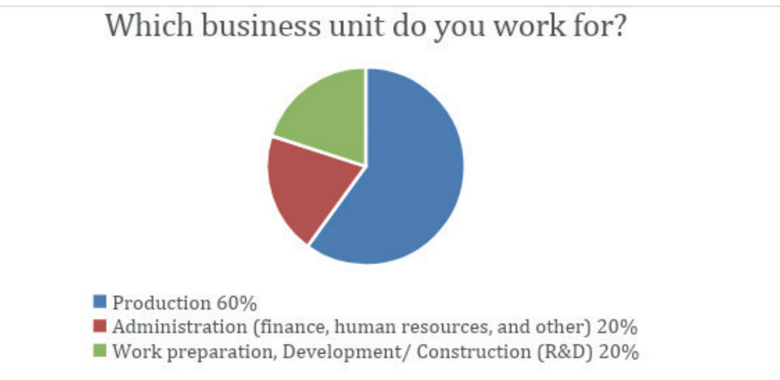
Two aspects of the impact of I4.0 regarding companies in Sweden are covered in this study. These two aspects are technological impacts and competencies.

DEMOGRAPHICS

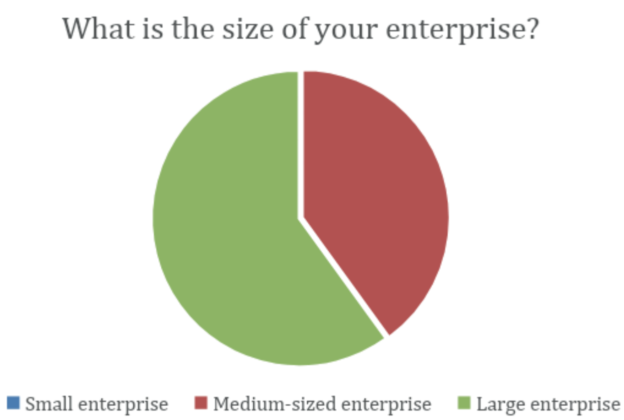
The 5 representatives from Sweden that participated in the interviews and answered the questionnaire were mainly middle management. The main theory wherefore the higher management did not participate in interviews and the questionnaire is that they were under time pressure or did feel like they had cases with higher priority to handle.



1. Graph Functional area of the representatives



2. Graph Business units



3. Graph Size of company

Most of the participating companies were large enterprises. The main business unit is produced. All production units participating in this survey were large enterprises.

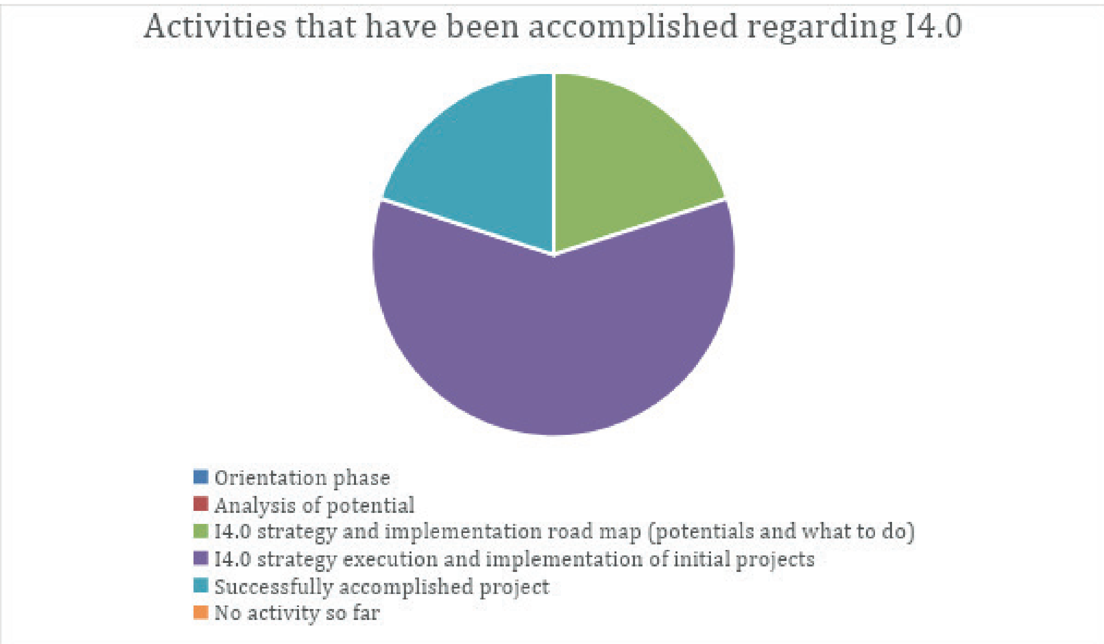
CURRENT STATUS

Most representatives participating in the survey are aware of the digital transformation and most of the companies are working on the improvement of their Industry 4.0 methods with a specific comprehensive and holistic strategy that goes across the organization. Examples of areas where a comprehensive plane is used by several organisations participating in the interviews are:

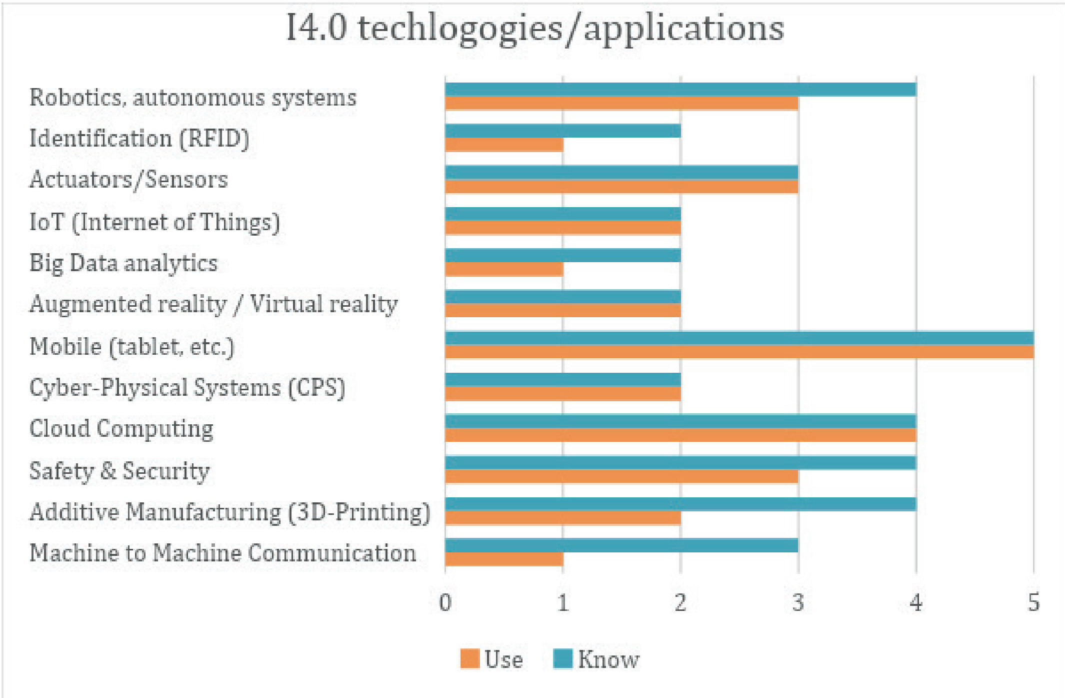
- Developing innovative/differentiated products and services
- Finding growth opportunities for existing products and services
- Identifying key areas to make effective I4.0 investments
- Investigating connected, integrated approaches in the value chain to implement I4.0 technologies

The ad-hoc approach was used by many of the companies interviewed. Areas, were ad-hoc approach was common, are:

- Utilizing new labour models
- Investigating connected, integrated approaches in the value chain to implement I4.0 technologies
- Understanding what skills will be needed



4. Graph Accomplished activities regarding I4.0



5. Graph Knowledge/usage of I4.0 technologies

This graph shows what I4.0 technologies are understood by the representatives participating in the interviews as well as what I4.0 technologies are used by the company they work on.

The most used technology was mobile, cloud computing came in second. Mobile devices were used by all companies participating in the interviews. Additive manufacturing, safety, and security, and robotics were as equally known as cloud computing but not used as frequently. The I4.0 technologies that were least used were Machine Machine communication, Big Data analytics, and RFID.

It should be added that different departments in the large companies may use more technologies that the representative was aware of.

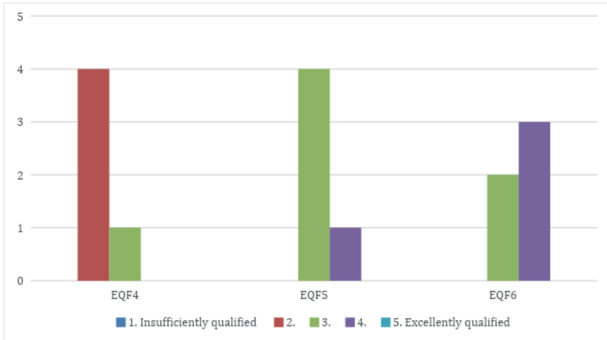
One company participating in the survey does heavily invest in Additive Manufacturing, especially metal printing. They currently have two metal printing workshops and one 3D-printing LAB where they print with continued filament fabrication technique (carbon fiber). These workshops are departments for development and do always strive to implement the newest technology.

COMPETENCES AND SKILLS

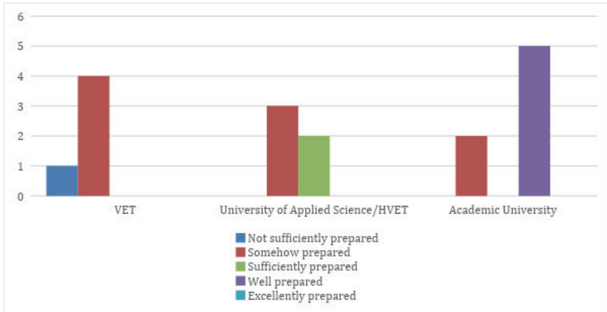
This segment is regarding the competencies that are required for an employee at an advanced manufacturing company. The competencies that will be analysed do not indicate specific assignments for employees, this must be taken into consideration. However, the questionnaire used in the interviews with representatives (60 % working in production) does not specify a specific job for each competence. Therefore, it is not the definitive method for declaring specific competencies, the competencies must be answered from a more general perspective.

The representatives were decently consenting on the requirement for education and the qualification degree for graduates. None of the representatives found a graduate fully qualified for a job at their company directly after graduating. This is a deficiency of qualification and is vital to investigate to see what changes that can be achievable to make the graduates more qualified.

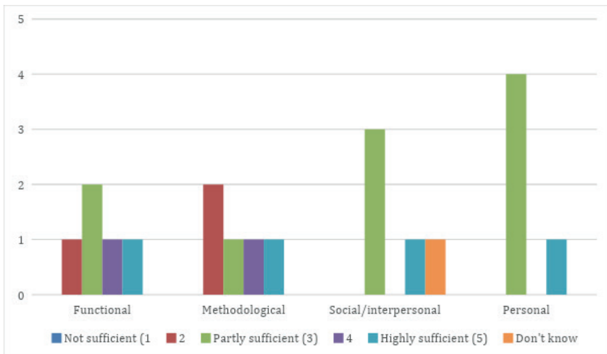
Regarding competencies that are required for I4.0, the majority of the representatives answered that the alternative competencies were either highly (5) or partly (3) sufficient. The competencies that had the highest average sufficiently were functional and personal.



6. Graph Qualification of requirements



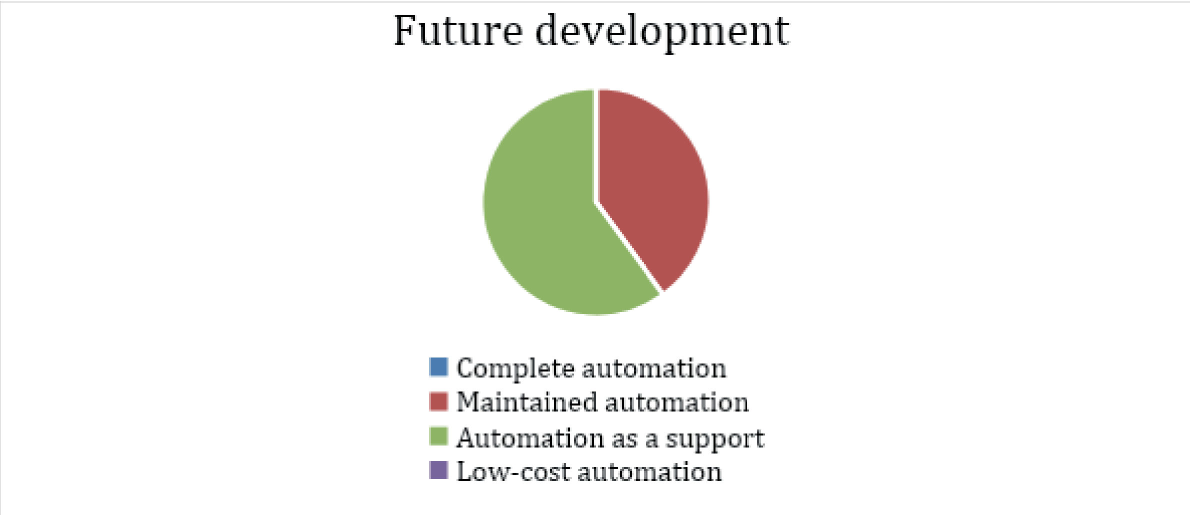
7. Graph Qualification and level of competence of graduates regarding I4.0 competence



8. Graph Competencies requirements regarding I4.0 and which is most recognizable

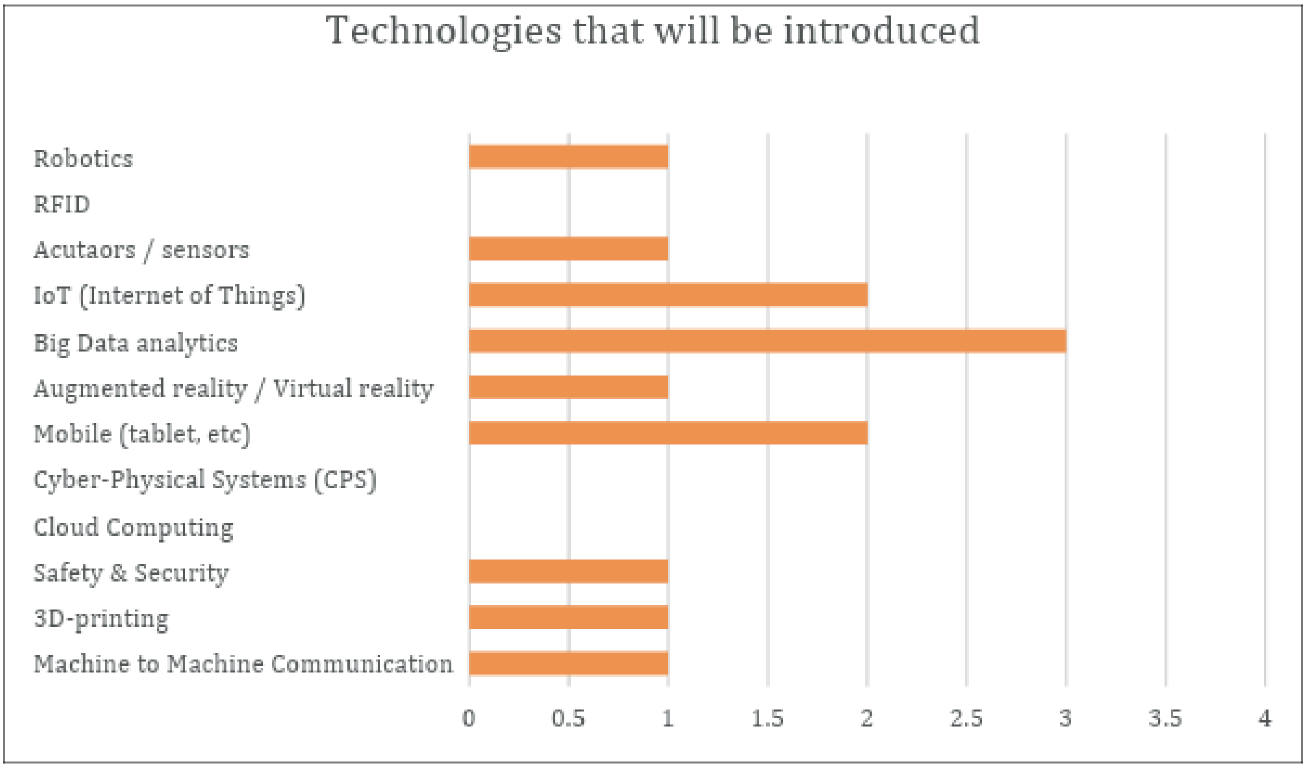
TECHNOLOGICAL TRENDS

The intended future of the companies varied regarding digitalization. Most companies thought that they would have automation as support in 10 years. The largest company participating in this survey thought that they would have 80% automation, somewhere between maintained automation and complete automation. The second-largest company thought they would have maintained automation.



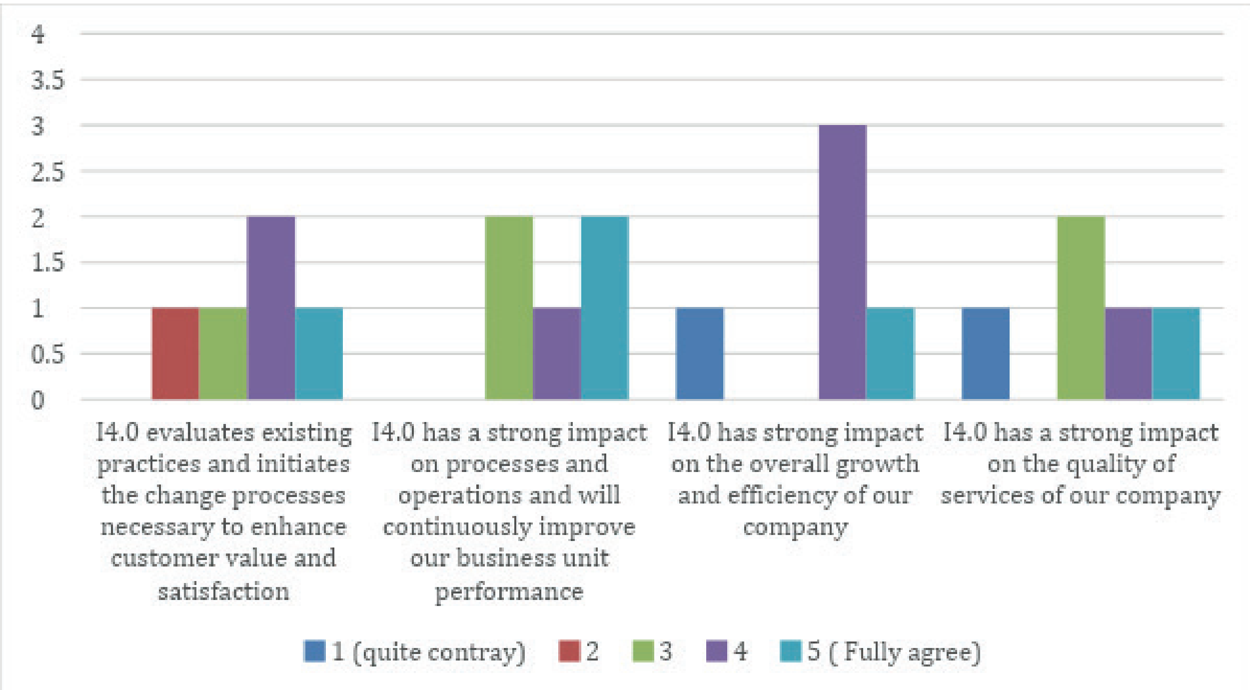
9. Graph Development regarding automation in the next 10 years

Numerous I4.0 technologies were implemented in the companies participating in the survey. The graph underneath demonstrates the technologies that companies will to some extent introduce in the future. It might be to introduce a fully new technology or deepen the use of a former technology that earlier was barely used in the company. Big Data analytics was the technology that most companies were interested in getting implemented. What stands out is that all companies answered that they used mobile devices, but they also answered that they will introduce mobile devices. This is an example of a technology that the companies wanted to deepen their use of.



10. Graph I4.0 technologies that companies intend to implement in the future

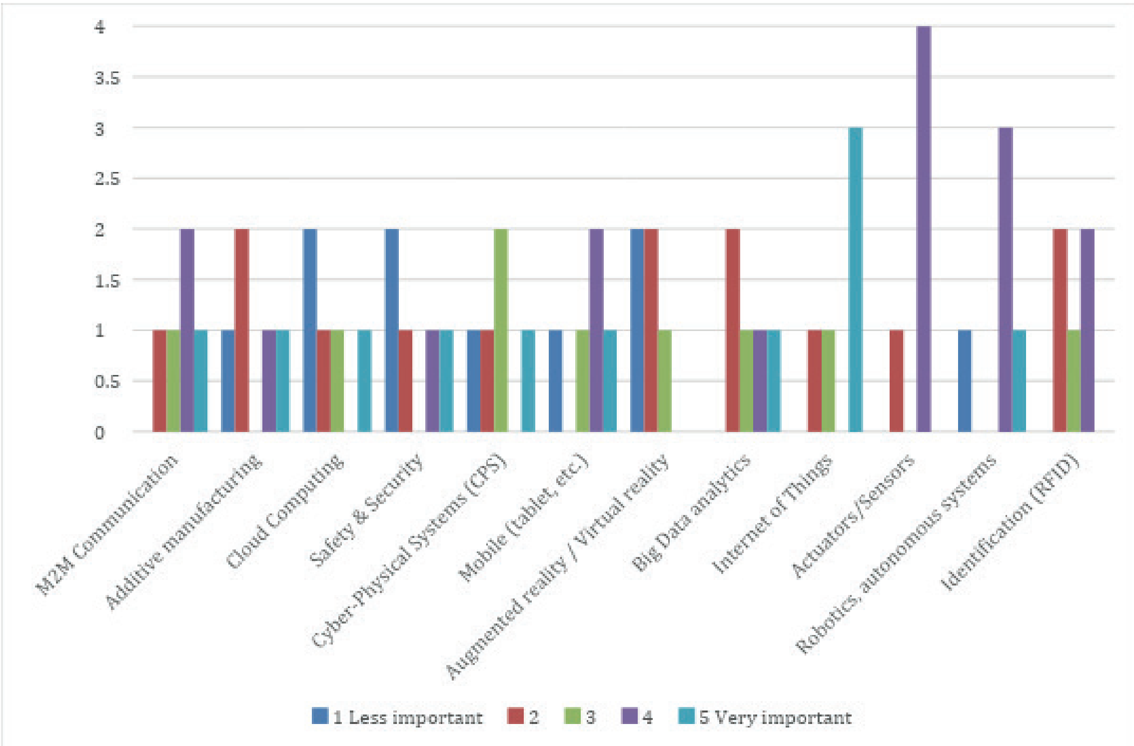
Advanced manufacturing will have an impact on all participating companies' value chains. Advanced manufacturing will on average have the most significant impact on process and operations.



11. Graph I4.0 impact on value chain

All respondents answered the importance of different I4.0 technologies in their advanced manufacturing environment. The technologies that the companies found most important were the Internet of Things, the second most important technologies were Machine to Machine Communication, Actuators/Sensors, and Robotics/ autonomous systems. The representative from the largest company in the survey found IoT and Big Data analytics as to the two most important I4.0 technologies. Virtual Reality was not significantly important for any of the companies.

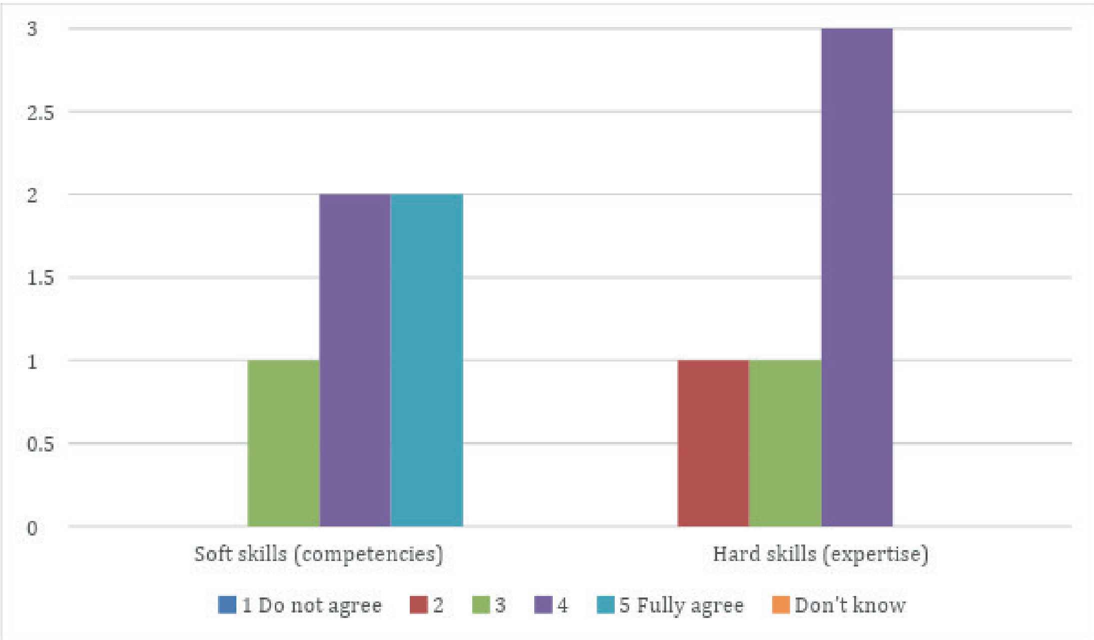
One company that contributed to the interview has a research centre/lab where different Robotics and Sensors are tested. These two I4.0 technologies were therefore important for this company. Additive Manufacturing is however their primary working area.



12. Graph: Importance of I4.0 technologies

THE FUTURE EVOLUTION OF COMPETENCIES AND SKILLS

The requirements for both soft skills and hard skills will increase according to the representatives. In general, the representatives thought that the requirements for soft skills will increase marginally more than for hard skills.



13. Graph: Future demands and changes requirements regarding I4.0 competencies

It was clear that representatives from the participating companies consent that both technical and personal skills are necessary for today's organisations. "One of the characteristics is not very versatile without the other", the representatives seemed to agree that an individual needs both qualities to be a useful part of a team. "A team with members that withholds both qualities and are willing to cooperate with each other are proven to be the most effective and consistent", which one representative said.

There were a lot of various answers when representatives prioritized what competencies they found most important. A general conclusion is that most competencies are equally important for the companies participating in this survey.

The questionnaire contained questions regarding methodological, functional, social, and personal competences. Listed underneath are the competencies with the highest importance from each competence area:

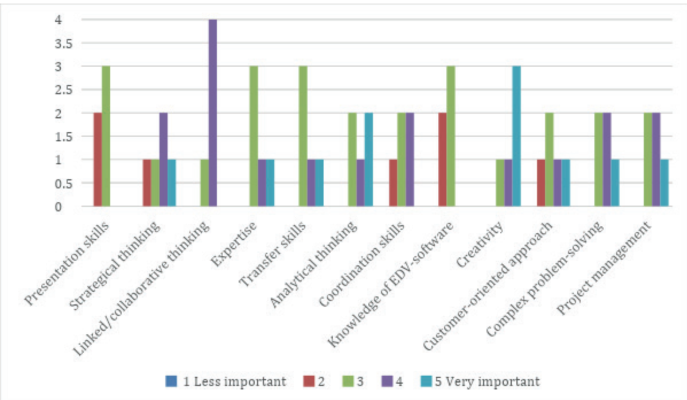
Methodological – Creativity

Functional - Technical expertise

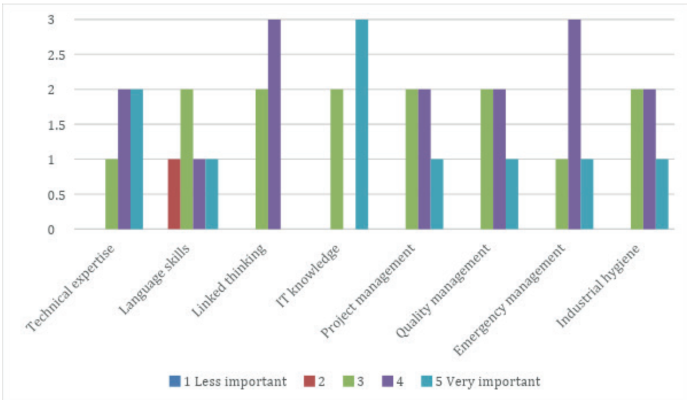
Social - Cooperation/Teamwork

Personal competences - Innovation

All the answers declaring the competencies importance are presented in the graphs below:

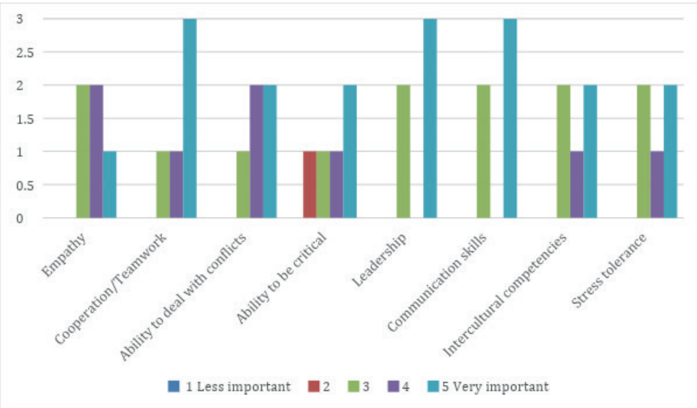


14. Graph: Importance of methodological competencies regarding future production environment of I4.0

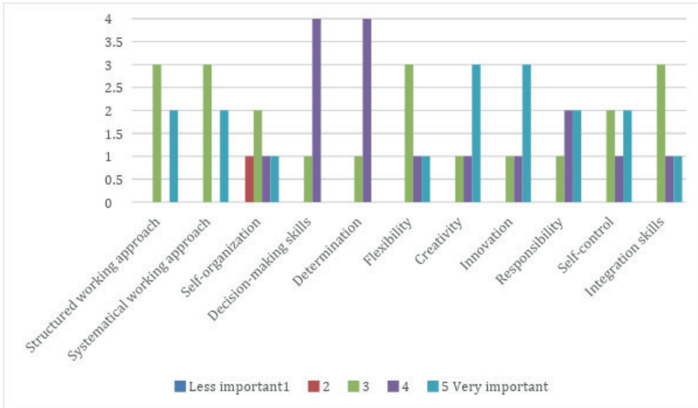


15. Graph: Importance of functional competencies regarding future production environment of I4.0

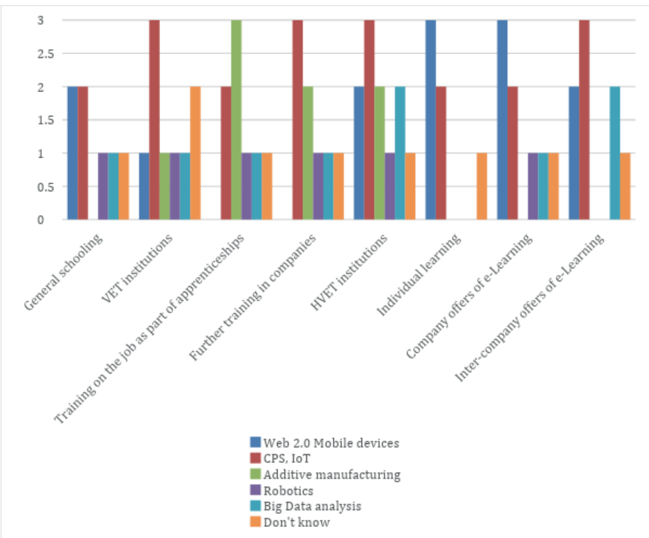
The companies were asked what type of education should be responsible for teaching certain I4.0 technologies and competencies. It was obvious that the companies were not sure where these should be educated. It was at least one "don't know" answer at each technology or competence. The other answers were widely spread amongst the different technologies and competencies. It is therefore difficult to conclude out of these answers. The only obvious answer was that no company thought individual learning was the right method for teaching Additive manufacturing, Robotics, or Big Data analysis.



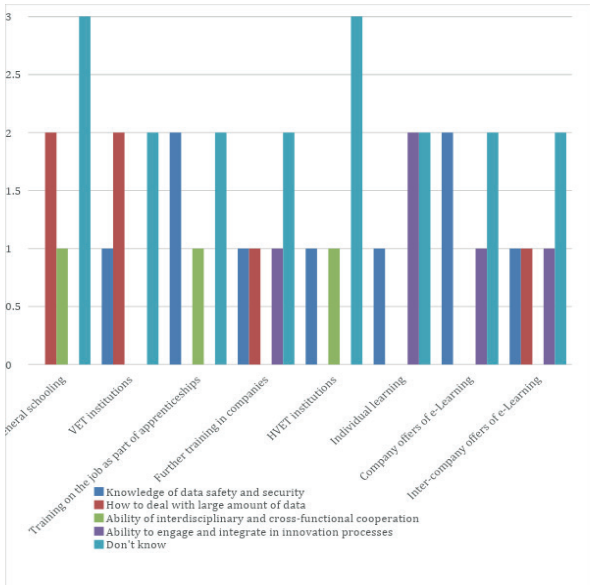
16. Graph: Importance of social competencies regarding future production environment of I4.0



17. Graph: Importance of personal competencies regarding future production environment of I4.0

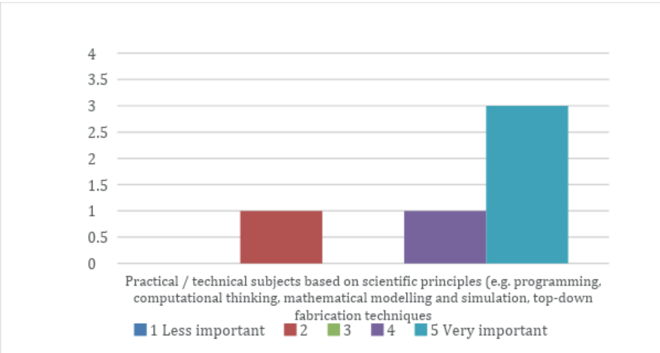


18. Graph: Responsible for teaching skills

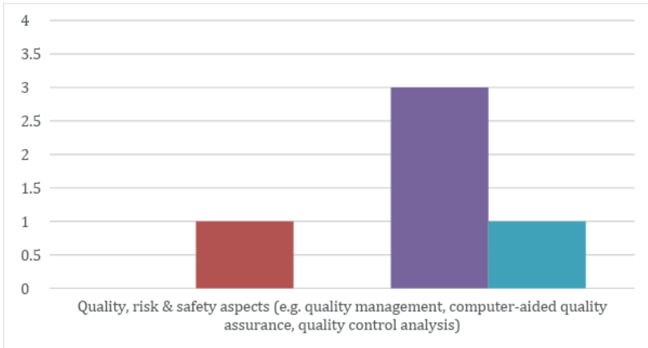


19. Graph: Responsible for teaching competencies

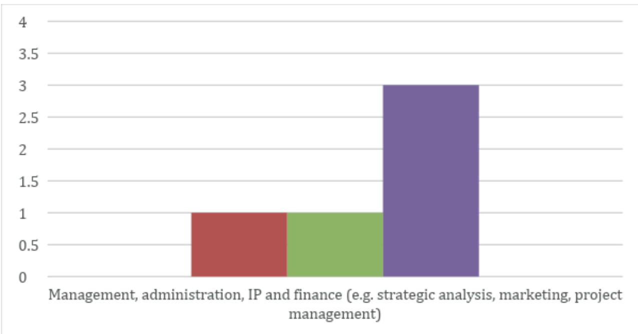
The representatives were asked about their opinion on the importance of conceptual principles in the teaching and learning of skills in an advanced manufacturing environment. The skills with the highest importance according to the representatives were practical/technical.



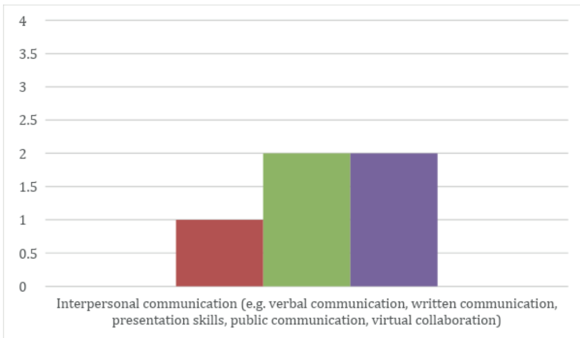
20. Graph: Importance of principles when educating skills



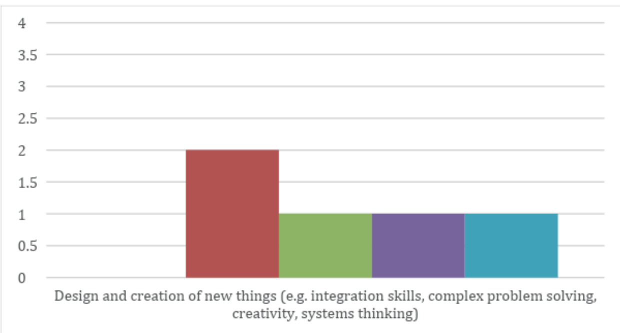
21. Graph: Importance of principles when educating skills



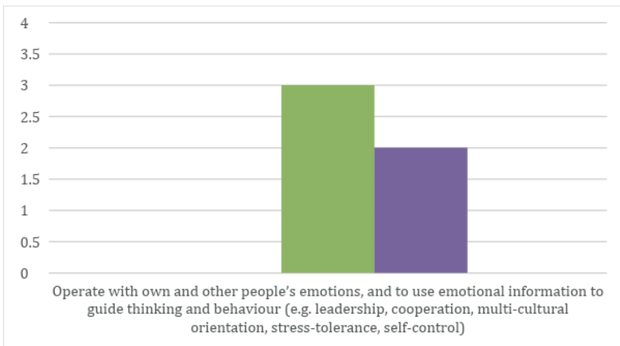
22. Graph: Importance of principles when educating skills



23. Graph: Importance of principles when educating skills



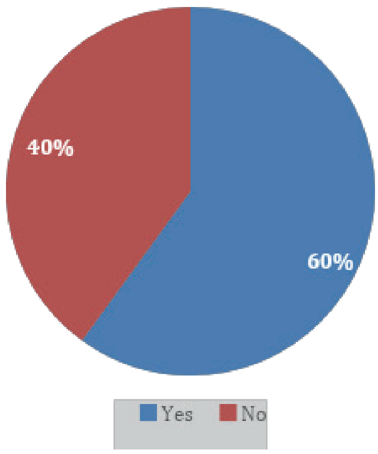
24. Graph: Importance of principles when educating skills



25. Graph: Importance of principles when educating skills

I4.0 results in adjustments for employees as well as new requirements on them. It is vital for employees that they are granted opportunities for upskilling and improvement of their competencies. The most common (38%) plan that companies have for upskilling their employees is by practical training concerning recently introduced technologies/applications.

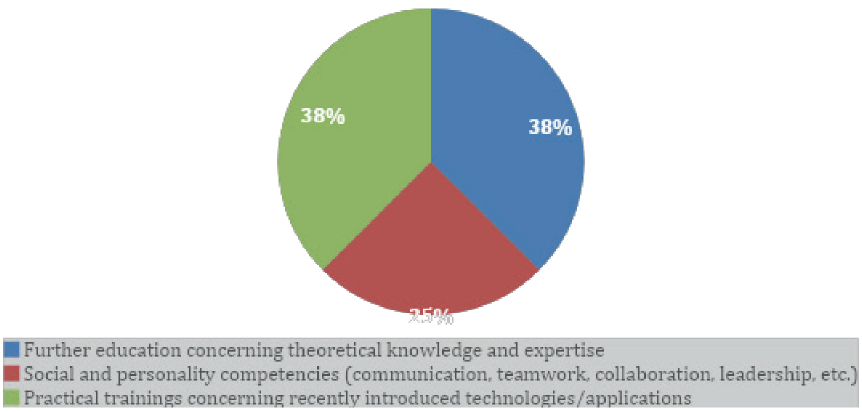
Uppskilling plan



26. Graph: Plan for upskilling current employees

60% out of all companies in this survey do work with lifelong learning. However, only one representative could explain their approach and how their policy works. "All employees participate in continuous education/training courses, working with this method our employees will always develop as workers as well as individuals. This way we can make sure that our staff fulfills upcoming requirements".

Lifelong learning



27. Graph: Lifelong learning policy

The interviews/questionnaire ended with four questions about the companies' beliefs of how digital transformation is/will affecting/affect their company. These four questions were about demands and qualifications for employees regarding I4.0 as well as advantages and dangers with I4.0. Not all companies had a detailed answer to these questions. However, the answers are listed below.

Regarding Industry 4.0, which demands will change for existing employees?

- Demands on having general knowledge about all I4.0 related topics
- Employees need to be able to handle computers/IT and computer/IT systems better
- Lifelong learning will be implemented for all workers and they need to participate in continuous learning courses regarding I4.0
- Employees need to have the competencies that are vital for an I4.0 worker

Some representatives did not have an answer to this question.

Which qualifications are essential for the transition and to be able to perform as an Industry 4.0 company?

- To have general knowledge about all I4.0 technologies and knowing how/when to implement these in the company
- To have specific knowledge and expertise in the company's working area
- It is essential to be able to adapt to new methods/technologies
- It is vital to not fall behind other companies regarding digital transformation
- Understanding the benefits of I4.0 and when to use it

Some representatives did not have an answer to this question.

Where do you see the highest benefits and chances in Advanced Manufacturing (I4.0) in your company?

- Additive manufacturing and Actuators/Sensors do affect our company significantly
- I4.0 will affect our production division
- A more effective production
- The opportunity to reduce the risks within our workshop as well as in our business model
- Finding new methods/alternatives for problems

Some representatives did not have an answer to this question.

What are the possible risks of Advanced Manufacturing (I4.0)?

- Small companies may not keep up with the new developments
- To not keep up with the development of other companies
- Employees may not be prepared for new changes
- Security risk with connecting files to the internet
- Employees that do not want to adapt to the new technologies

Some representatives did not have an answer to this question.

CONCLUSIONS

The participating companies were surprisingly agreeing to the different questions in the interview. The answers are off course variating in some areas because the companies work in different business units. Some representatives seemed to be more aware than others of their company's stage of development regarding I4.0 as well as what strategy their organisation is using to implement I4.0 technologies.

It was clearly shown in the interviews that many companies used different I4.0 technologies and what differences there were between them. However, everybody did not know the names/terms of them, for example, we could ask "do you use IoT?" and they did not know until we described IoT. This could be a source of error in the report because representatives did not know what they answered or filled in. It was clear that the answers varied depending on the level of knowledge the respondent had regarding I4.0.

Mobile devices are used by all companies in this survey. Robotics, Sensors, Cloud computing, and Safety and Security were also used a lot. This report, however, cannot determine that this is the most used I4.0 technology amongst industry companies in Sweden. The survey did not include enough participants to define the status of all companies in Sweden. It can however be used to see the general status of companies in Sweden regarding I4.0.

Companies did not determine the importance of different competencies for different professions. The methodological, functional, social, and personal competences were there for considering almost equally important by most companies, with some minor exceptions.

Source of error concerning the few amount of answers in the questionnaire:

- Companies were not sufficiently aware of I4.0 to give complete and correct information in the questionnaire.

- Companies suffered from time pressure and did not have the time to leave detailed answers in the questionnaire.

- Companies did not find any benefit to answer the questionnaire with regard to their own business.

- Companies did not want to share their development model.

- Representatives did not feel qualified to represent their company in this questionnaire.

- The questionnaire was too complex.

This was stated earlier in this report, but the further specific statement will be covered here.

It was a struggle to get five interviews for this survey. The questionnaire was sent to a variety of people during the beginning of this work. These people were from different business units, from different locations in Sweden, and with different management positions. Certain individuals were personally known by us, numerous were higher management at companies with close collaboration with Curt Nicolin High school and several companies were not related to the school but were good representatives regarding an I4.0 company. However, nobody answered the questionnaire, and no one wanted to participate in an interview. After numerous emails, calls and "nagging" five representatives were finally found to participate voluntarily. This could summarize that many companies in Sweden are not yet aware of the importance of I4.0.

The answers can however perhaps give a general picture of the industry in Sweden. Some companies do have a specific strategy for digitalisation. These are in most cases larger enterprises, there are of course many exceptions, for example, a medium-sized company in this survey had almost certainly the greatest knowledge about I4.0. It can also be established that all twelve I4.0 enablers are used to a certain degree. This survey can almost declare that all industry companies in Sweden use several I4.0 technologies, consciously or incognizant.

The result in this survey shows that Sweden requires a change of the education strategy regarding I4.0. This is because no graduate has all skills and competencies which are required to work independently according to the companies. The companies were however unaware of which education strategy should be used instead.

ABBREVIATIONS

AM = Advanced Manufacturing

AR/VR = Augmented Reality/ Virtual Reality

EQF = European Qualification Framework

EXAM 4.0 = Excellent Advanced Manufacturing 4.0

I4.0 = Industry 4.0

IIoT = Industrial internet of thing

IoT = Internet of thing

M2M = Machine to machine

MES = Manufacturing Execution System

RFID = Radio frequency identification

CONTENTS

EXECUTIVE SUMMARY

This document gathers the results of two studies on the perspective of the Basque industry on digital transformation. The first one, called "EXAM 4.0 focus groups meeting's results" is the summary of a series of interviews with 19 companies close to the Basque partners participating in the EXAM 4.0 project. The methodology used was interviews with company representatives based on a previously distributed support questionnaire.

The second study is **"Technologies and professional competences 4.0. Analysis of business demands**" was published by Innobasque, Basque Agency of Innovation in November 2019 and reflects the vision of several driving companies (medium-large) on the impact that the digital transformation is expected to have on their activities. Section 2 of this report covers the findings of that study.

In section 3, the cluster AFM, the organisation that represents Advanced Manufacturing interests in Spain, researches the equivalence of the findings in smaller firms. To give a more complete view to that report, we considered it appropriate to give another approach to the analysis, taking into consideration the relevant sectors in the scope of AFM CLUSTER and looking for differences depending on the size of the companies.

EXAM 4.0 BASQUE FOCUS GROUPS MEETING'S RESULTS

Introduction

The following report was created within the WP2 Learning Dialogues of the project EXAM 4.0. The goal of this study is to identify the status of representative companies from Advance Manufacturing in the Basque Country (Spain) regarding digital transformation. The final goal is to validate the "EXAM 4.0 technological framework" and "EXAM 4.0 competence framework" which will be used to create further results within the EXAM4.0 initiative.

The **methodology** used was interviews with company representatives based on a previously distributed support questionnaire. The same questionnaire has been used in the studies carried out with partner countries to contrast the results of different EU regions.

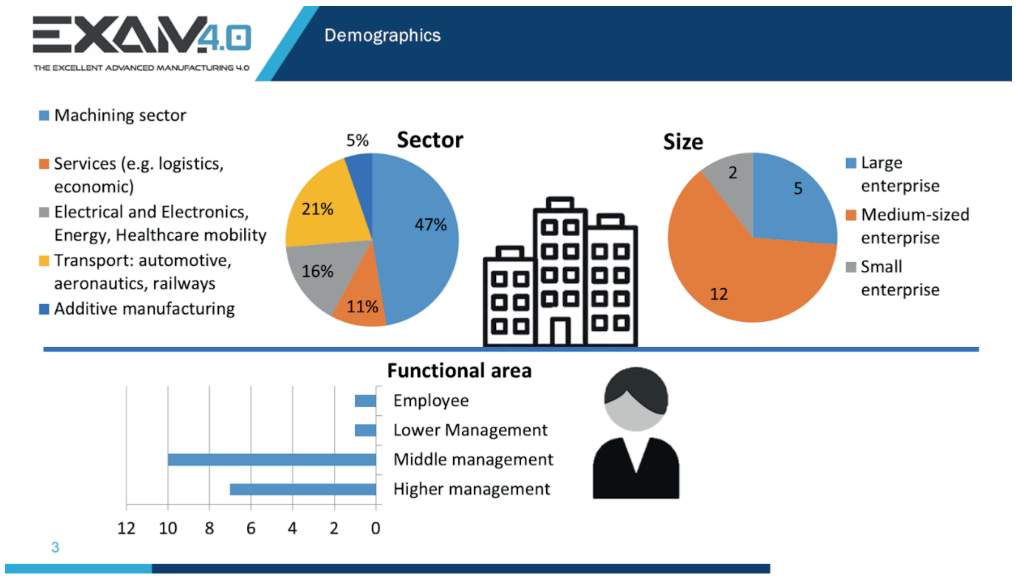
In the case of the Basque Country, **19 companies were interviewed** between April and May 2020, 13 SMEs, 3 large companies, and 3 sector representatives. All 5 organizations took part in carrying out the interviews, all of the EXAM's partners (Miguel Altuna LHII, Tknika, AFM) and affiliate partners (Bidasoa LHII, Usurbil LHII, and Imh LHII).

The number of answers cannot be considered sufficient to give a definitive picture of the Basque industrial fabric, this requires a more exhaustive study. However, the selected companies are sufficiently representative to obtain relevant information to be included in the WP2 of EXAM 4.0 and use it as a reference for Basque SMEs

The study covers two aspects of the impact of I4.0 in the companies, one technological and the other concerning competencies.

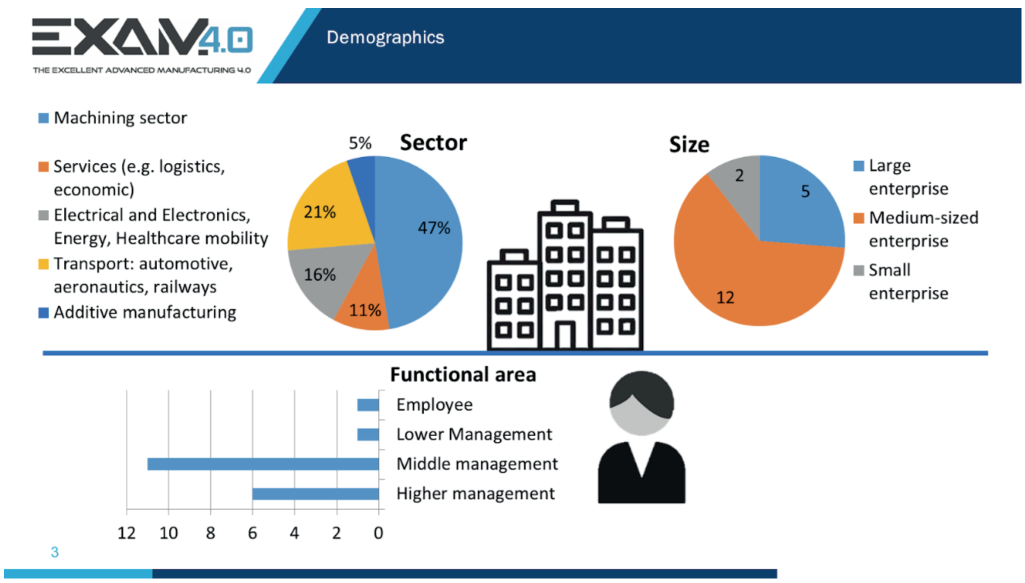
Demographics

The survey was conducted with 19 companies in the Basque Country area. Most of the respondents were medium-sized (58%) and from the machining (38%), services (23%), or electrical/electronic (19%) sectors.



1. Figure Sector and size of the respondents

The functional area of the people who answered the questionnaire was middle or upper management. The main business units to which they responded were sales (41%), production (41%).



2. Figure Functions of the respondents

CURRENT STATUS OF COMPANIES REGARDING INDUSTRY 4.0

Concerning the initiatives and priorities for digital transformation in Industry 4.0 towards which companies are moving, in most cases, they are driven by a comprehensive and holistic strategy that runs through the organization, as in the following cases:

- Developing new business models
- Developing innovative/ differentiated products and services
- Finding growth opportunities for existing products and services
- Investigating connected, integrated approaches in the value chain to implement I4.0 technologies
- Understanding what skills will be needed
- Training and developing the workforce for I4.0

Ad hoc approaches when needed were preferred in the following cases:

- Protecting our organization from disruption
- Developing I4.0 IT architecture (e.g. Cloud, Big data, IoT)
- Identifying key areas to make effective I4.0 investments
- Utilizing new labour models

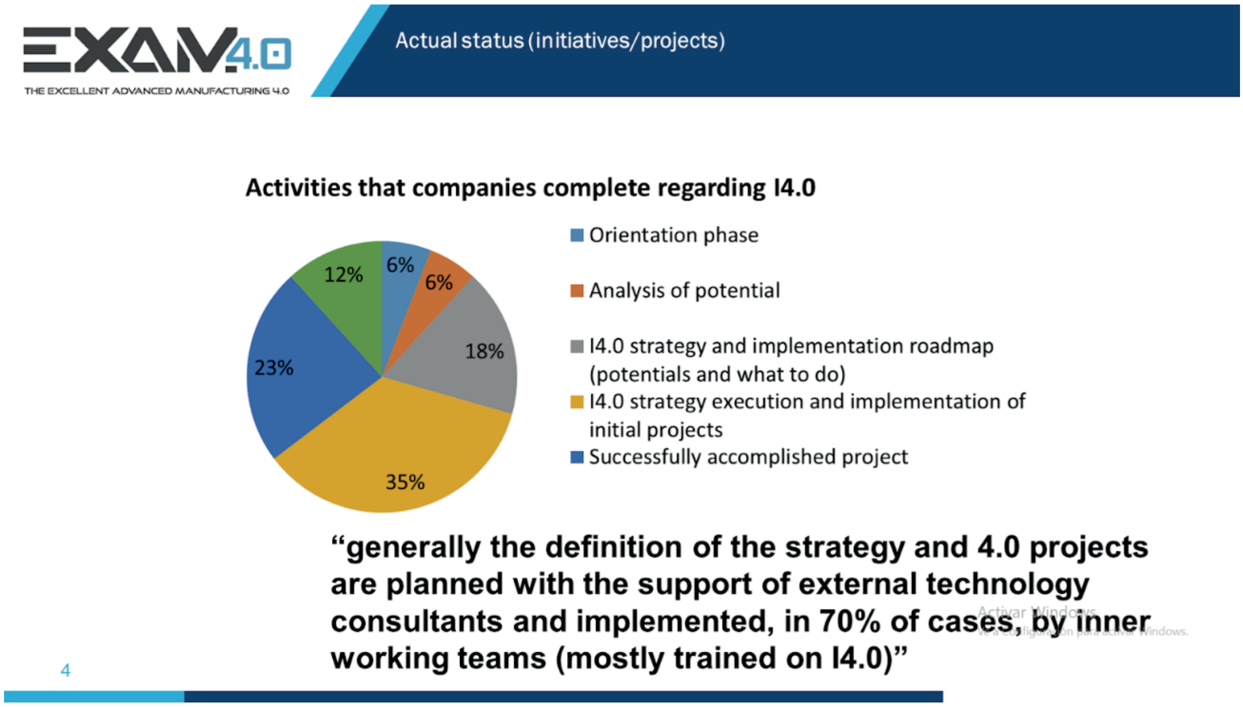
The ad-hoc approaches were confirmed as the used method in some comments: "Apart from particular cases, the companies make progress towards Industry 4.0 when they need it or when they find an opportunity. There is no clear strategy that goes across the organization."

Other comments refer to broader approaches, involving the whole organization:

- Nowadays It is crucial to adapt to changes that are happening in our world. Among them, companies are suffering many of these changes, involving new technologies, new methodologies, new plans, etc. If we want to grow and not be left behind, we have to embrace these new opportunities.

- Our company has a deep commitment to Digitalization topics.

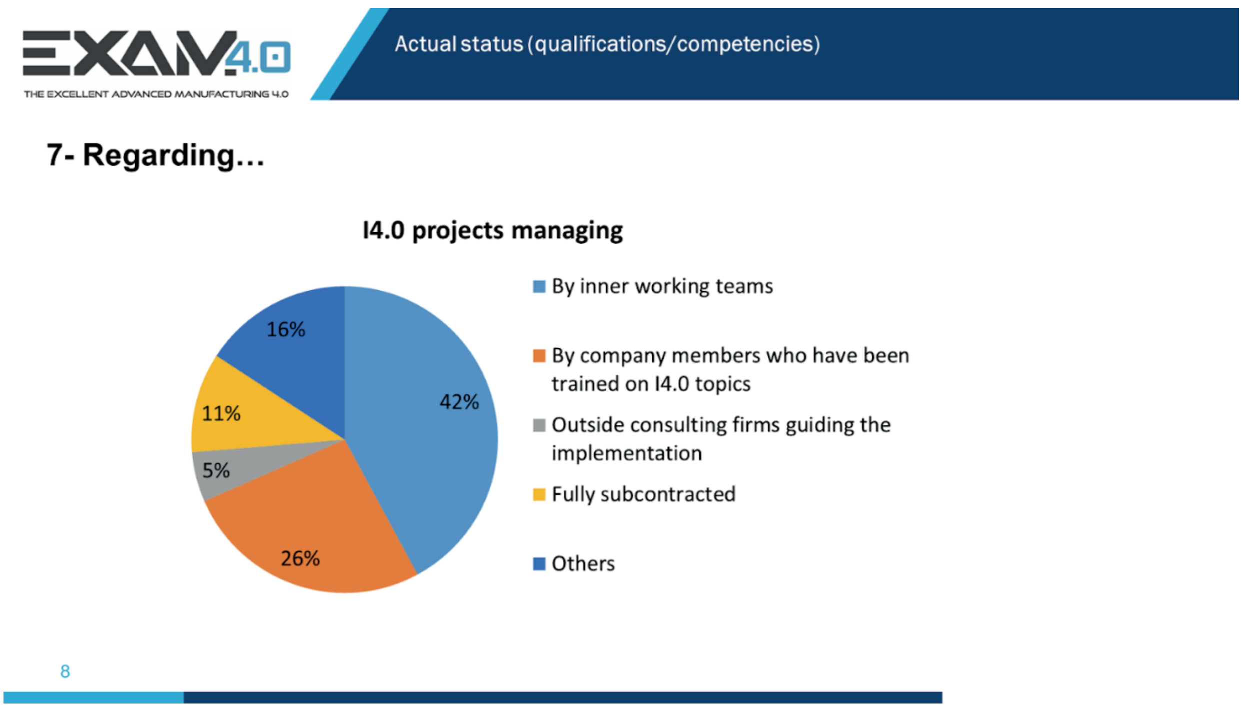
Regarding the **activities that companies are completing**, although successful projects have already been carried out, they are mostly at implementation levels.



3. Figure: Sector and size of the respondents

From a sectorial perspective, AFM cluster has analized 3 sub sectors which are: machining sector, machine tools sector, and additive manufacturing companies and for the 3 of them, the situation is very similar. It can be said that machine tool companies are one step ahead of the digital transformation with some accomplished projects.

Generally, **the definition of the strategy and 4.0 projects** are planned with the support of external technology consultants and implemented, in 70% of the cases, by inner working teams (mostly trained on I4.0 topics).

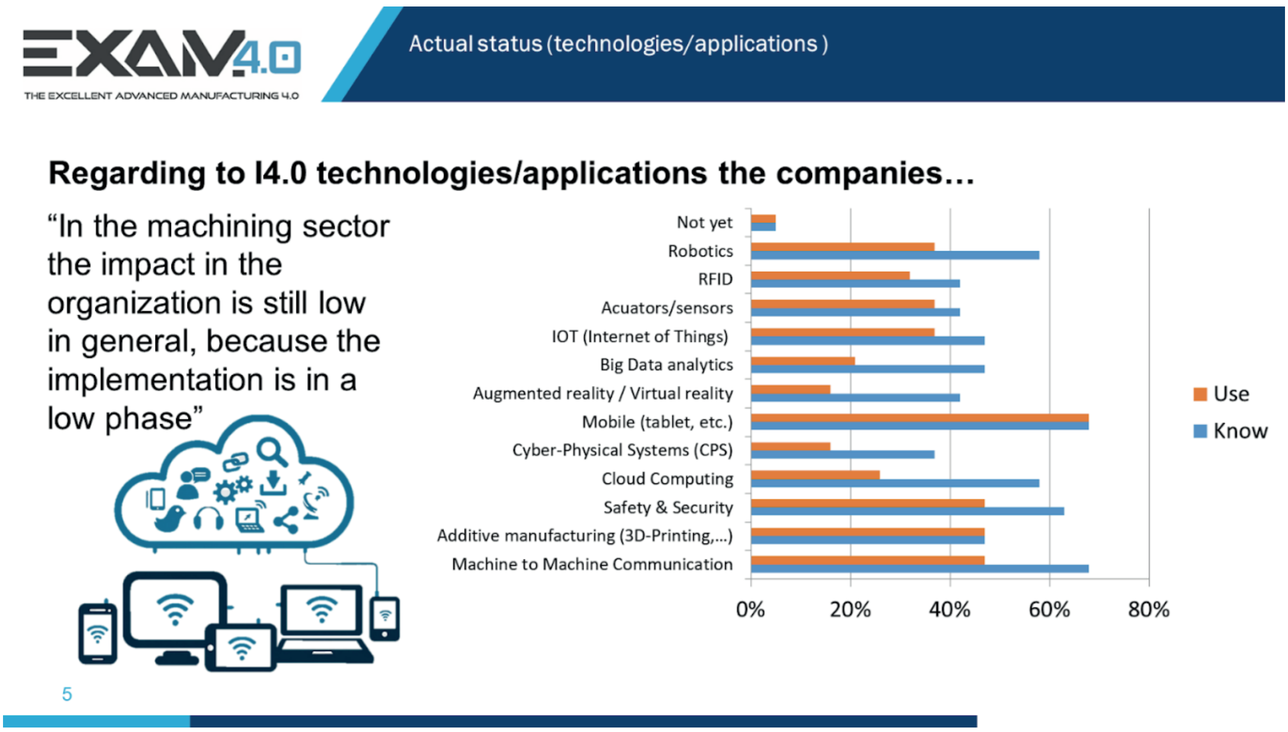


4. Figure: definition of the strategy and 4.0 projects

Some comments underline the identified approach: "In the machine tools sector, generally the definition of the strategy and 4.0 projects are planned with the support of external technology centres or consultants, and implemented by inner working teams."

Regarding **I4.0 technologies/applications**, the companies were asked about the I4.0 technologies that they have evaluated (know) and those which they are already using in their companies (use).

The use of mobile/tablets and information exchange channels are the most commonly used technology by those who have evaluated them. The same happens to additive manufacturing to a lower extent. The potential of M2M communications and robotics to a lower extend is also widely evaluated although its use is not so widely implemented so far.



5. Figure: I4.0 technologies/applications,

Other evaluated and used I4.0 technologies are

- Intelligent sensors, Energy Efficiency, Manufacturing Execution System
- Machine Learning
- Tablets to visualize drawings and documents. Computers connected to the machines
- All of them are being used in machine tools companies, maybe with two exceptions, Augmented Reality and Big Data, that are at a lower level of use.
- In the 6additive manufacturing sector, safety & security would be the ones that they are still not using.

The typology of project examples given by respondents is very diverse. Technology developers, solution suppliers, and engineering firms have shown the most advanced examples whereas productions driven companies are in a more early stage. Among those, a rather recurrent topic is the use of tablets and communication devices in production plants. Companies from the machine tool manufacturing sector are also introducing advanced technology.

Some examples are shown in the following lines:

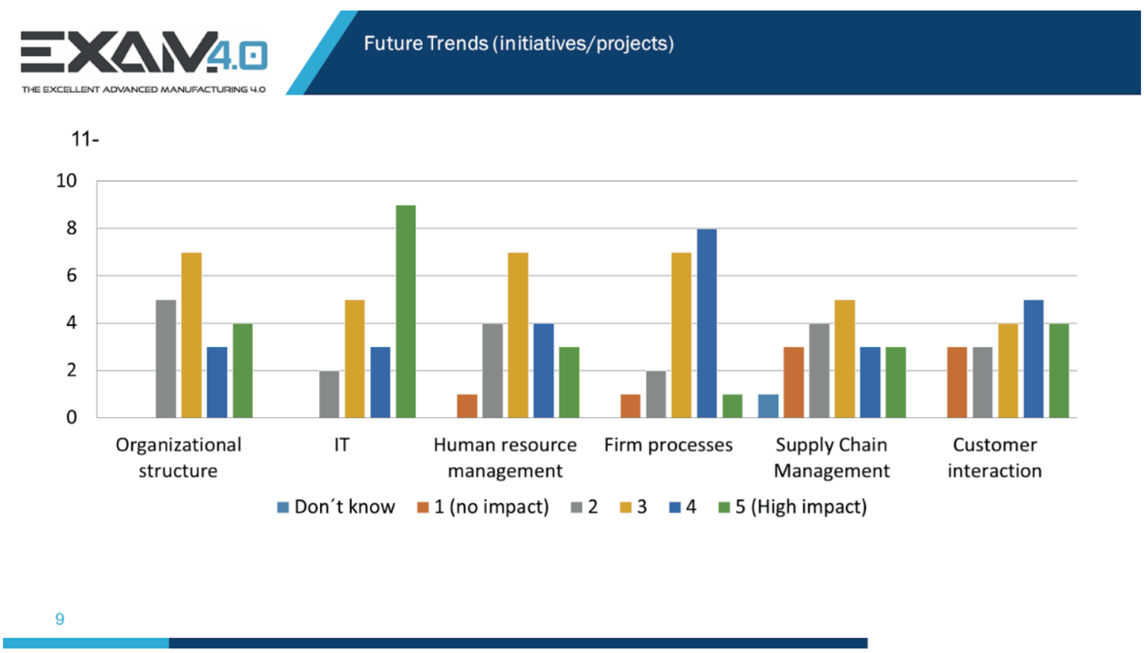
- Predictive maintenance: due to the digital control of the different parts of the train they can interpret the information received and predict that it will break down so they can repair or change it before it happens. Predictive maintenance; real-time data acquisition; indoor beacons localization.
- SIF-400: SMART INNOVATIVE FACTORY: didactic equipment for capacitation in Industry 4.0 technologies. Among others: Identification systems (RFID, QR, BCR, NFC), collaborative robot, Energy Efficiency, IO-Link sensors, Electrical Actuators, MES (Manufacturing Execution System), SCARA Robot, Ethernet Communication, Mobile robot, Augmented Reality, Artificial Vision, etc.
- Machine to Machine Communication: Implementation of standardized protocols: OPCUA, MTCONNECT, UMATI 2.- IoT (Internet of Things): CNC connectivity pack integration 3.- Big Data analytics: Reconnect - Development of a connectivity system for CNCs without communication technologies 4.- Actuators/Sensors: Integration in CNC of machine sensorization inputs: accelerometers, etc. 5.- Machine to Machine Communication: Connectivity and remote monitoring of machines 6.- Cloud Computing: Development and integration in CNC, machine information recording, and sending to the cloud. (Big data) Many others can be integrated into a CNC.
- Mobile / Tablets OEE Analytics and data capture Robotics Fully automation production cell/machine
- Tablets to visualize drawings and documents. Computers connected to the machines

- CPS. ONA Smart Connect: a cloud-based platform for connected products (machines).
- Industrial Analytics / Machine Learning. New sensors to manage analysis and optimize the production process and predict unexpected events/failures.
- 3D printing in metal, cybersecurity OT and IT, IIoT (Industrial Internet of things), cloud computing at different levels, Digital Twin of products, production, and plant
- SMART CONTRACT: Technology development to do relocated transactions in a cybersecurity way (implementation of blockchain, cybersecurity, and new business models)
- ADDISPACE: aditive technology application to the aerospace sector
- Sensors on the machine: The grinding machine is controlled remotely by the supplier so, if something fails or an error occurs, they are instantly notified and what they have to repair.
- The machine tool supplier can remotely monitor the performance of the machine so that when an incident/failure occurs, they inform about what they need to repair.

Implications in the organization of implemented I4.0 technologies

As mentioned earlier, the majority of interviewed companies, except for I4.0 technology suppliers and machine tool manufacturers, are in an early level of implementation of I4.0 technologies, so the impacts on the company are still rather undefined. At this stage, it is understandable that the implication of IT departments is high in most cases.

Some of the comments confirm this interpretation "In the machining sector the impact in the organization is still low in general because the implementation is at an early phase



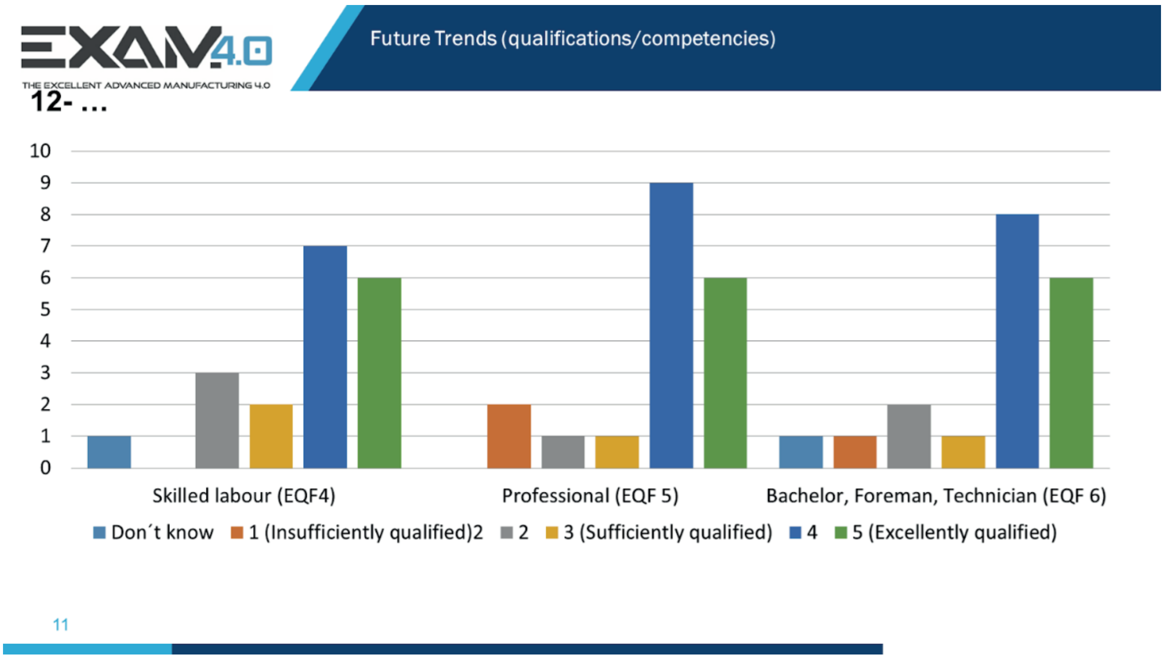
6. Figure: Implications in the organization of implemented I4.0 technologies

COMPETENCES AND SKILLS

This section refers to the competencies required in advanced manufacturing companies, their typology, and relevance. The description of competences refers to people in specific tasks and jobs so the answers have to be analysed taking into account these aspects.

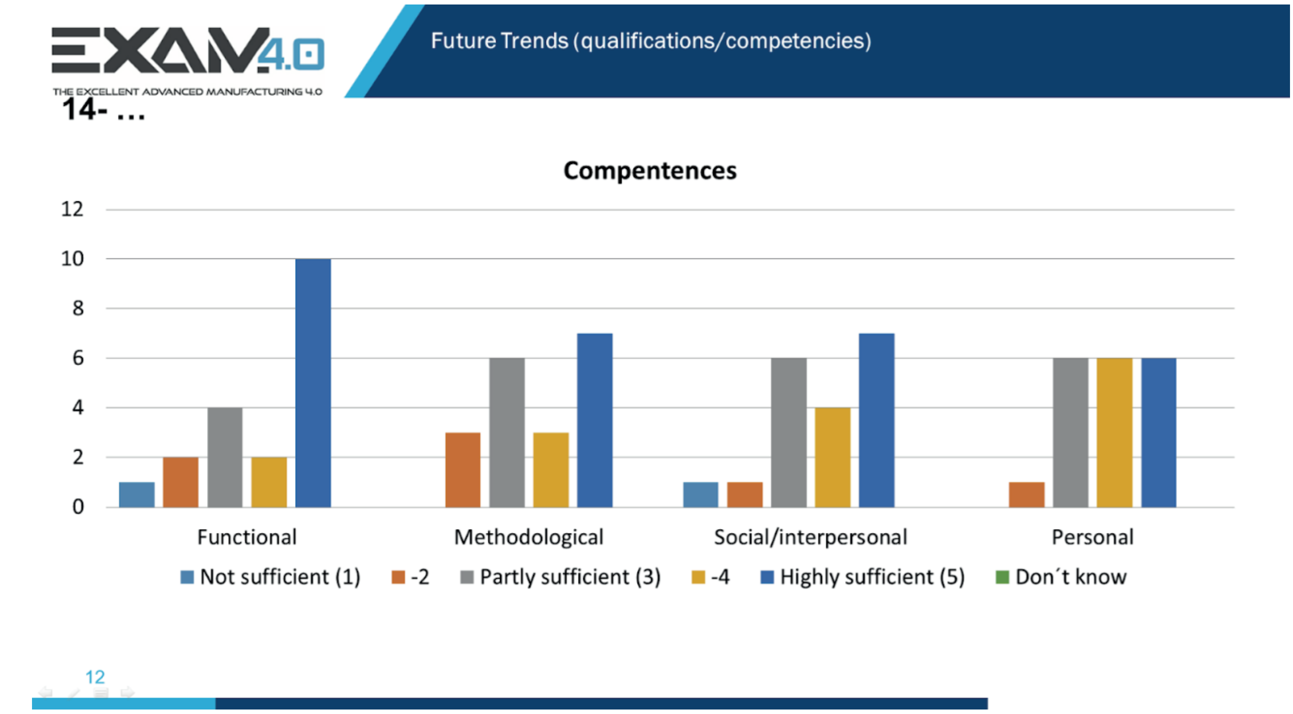
The majority of the respondents (42, 9%) are in manufacturing operation, followed by engineering and product designers (35,7%). Since the questionnaire does not define the specific job for which particular competences are required, the answers must be interpreted from a more generic perspective.

Concerning the **requirements of the types of qualifications for the different departments/units**, most of them require highly qualified people, although they could be more flexible for EQF4.



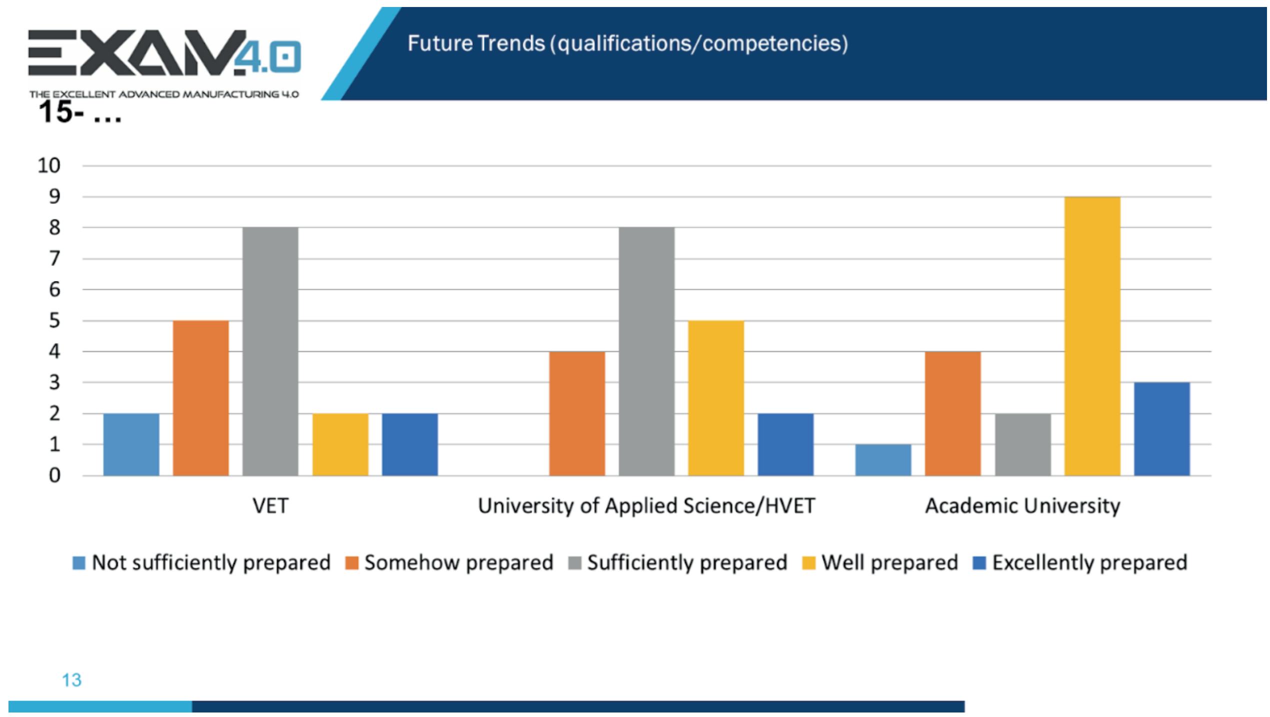
7. Figure: Requirements of the types of qualifications for the different department/unit

When asked about the **current requirements of Industry 4.0** at the company, the majority of the respondents assessed that the functional requirements are highly sufficient, whereas for other competences such as the methodological, social, or personal ones the answers are not so unanimous.



8. Figure: Current requirements of Industry 4.0

Furthermore, looking at the results, it could be said that the general opinion is that people with an academic background are better prepared for the demands of I4.0.

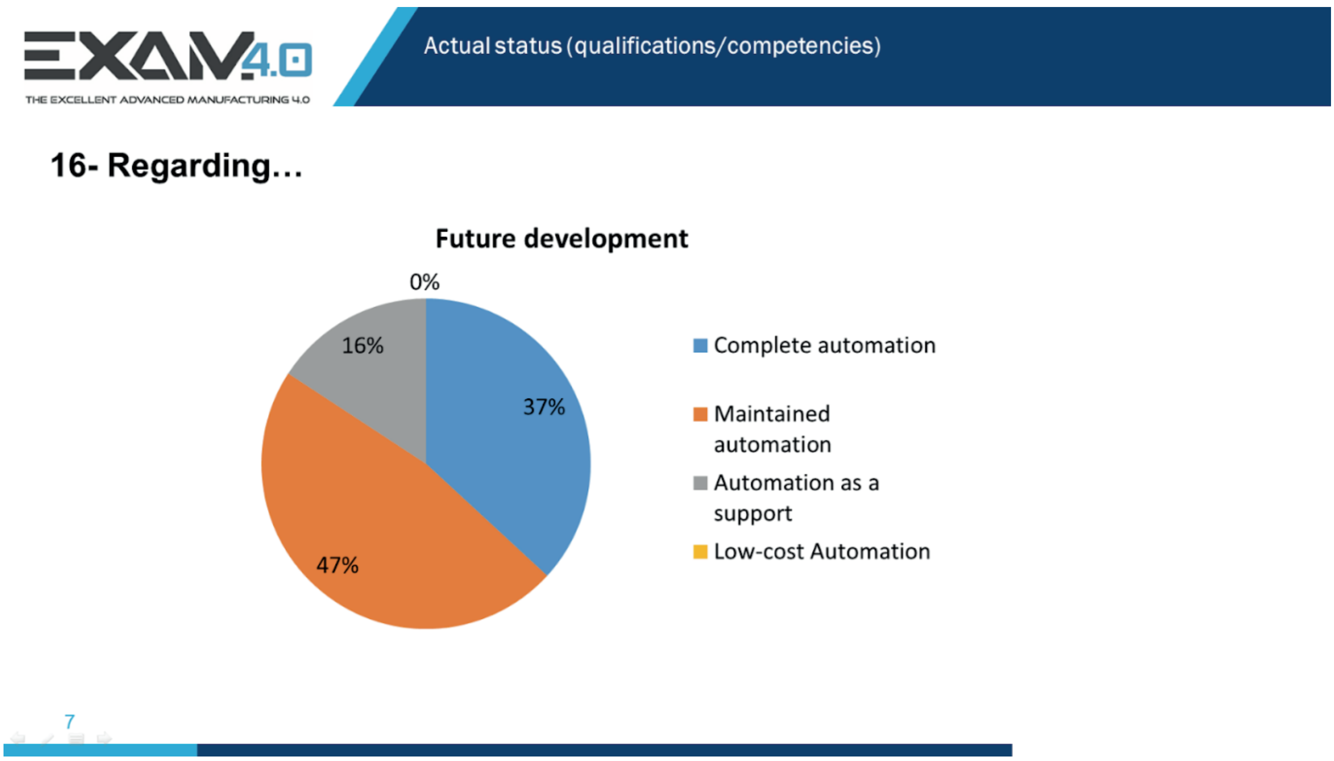


9. Figure: Qualification and competence level of the VET and HVET graduates regarding the I4.0 requirements

FUTURE TECHNOLOGICAL TRENDS

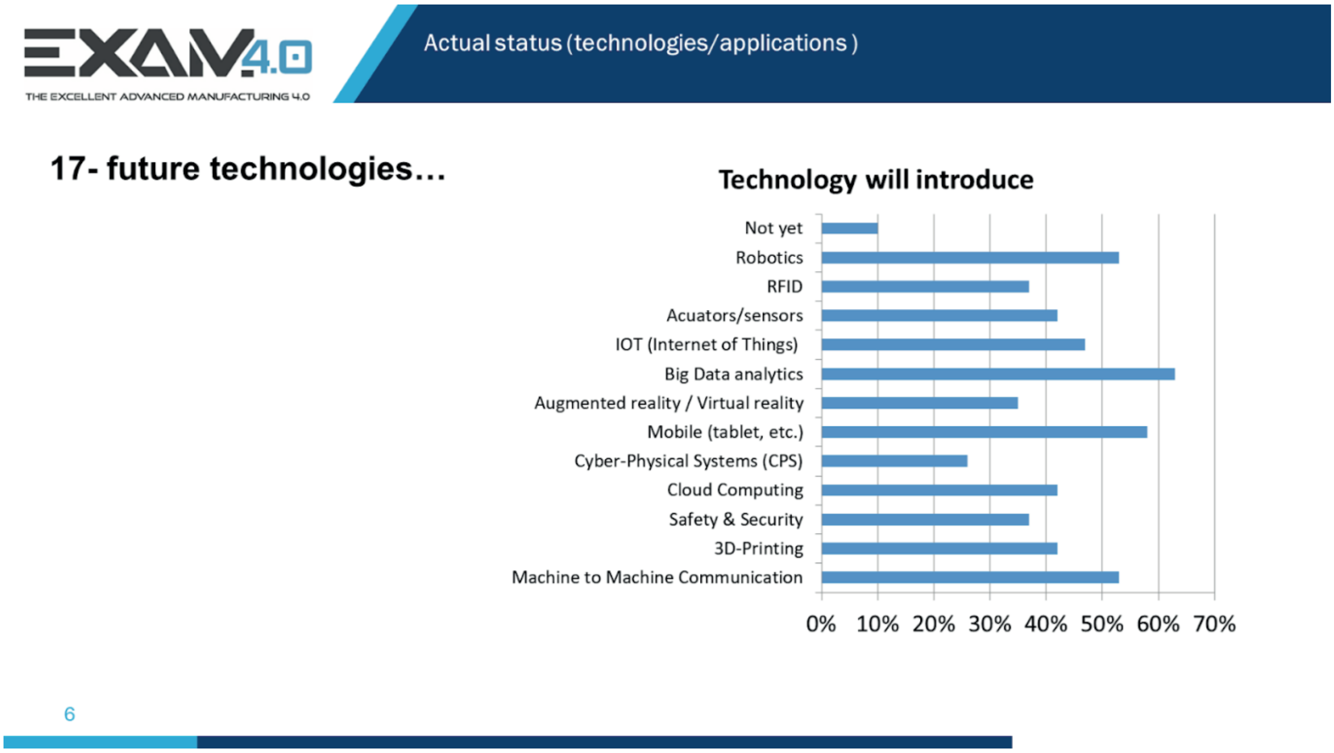
When asked about the **development of the company in the next ten years**, digitalization is a general view. In most cases, the expectations are towards maintained automation (48%). The percentage of those who consider themselves as a complete automated company is also significant (%37). So there is a clear tendency towards digitalization.

The machine tool sector's representative considers that their sector will reach the maintained automation level. At that time, many processes will be automatized but the support and optimization of engineers will still be necessary because complete automation remains difficult.



10. Figure: Development of the company in the next ten years

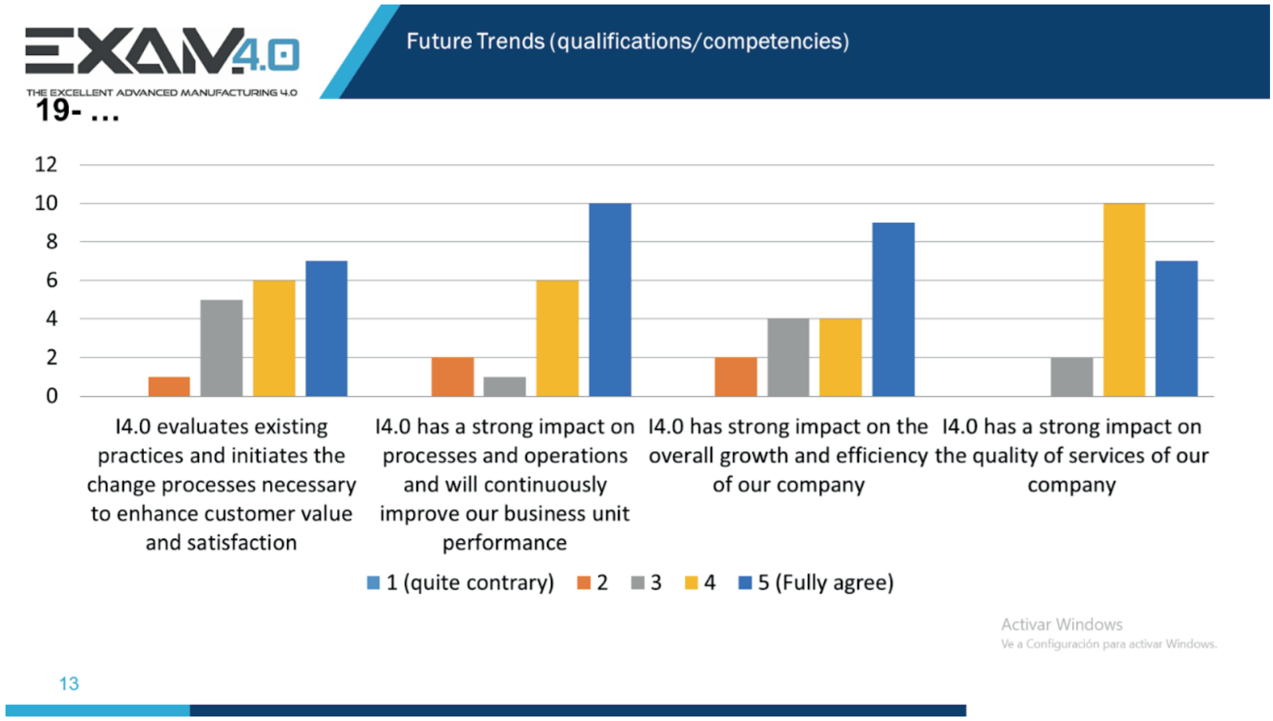
Concerning the I4.0 technology enablers that are foreseen to be introduced in the companies, all the technology enablers mentioned above are intended to be implemented to some extent: However, the ones that show the biggest interest, compared with those that are already being used (M2M and tablets), are robotics, RFID, Actuators/sensors, big data, and AR/VR.



11. Figure: I4.0 technology enablers foreseen to be introduced

Some of the opinions are worth mentioning: "all of them will be introduced with a higher or lower impact. For example, in the machine tools sector safety & security and Big Data analytics will have a big development"; "in the machining sector, machine to machine communication should have a big development"; "in the additive sector robotics and autonomous systems will have a big development"; "more prescriptive models will be introduced in the next years, 4.0 Maintenance, QR Video (AR/VR)"

That is why they believe that the **impact that advanced manufacturing will have on their entire value chain** will be big, as can be seen in the graph below. The expected impact appears to be "on processes and operations and efficiency" and not so much on "services".

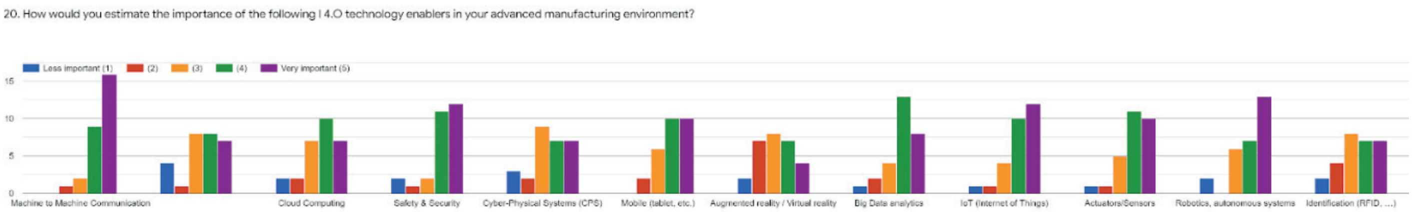


12. Figure: Impact on the entire value chain

In the following lines, there are some **examples of different projects and technology enablers related to I4.0 that are intended** for the interviewed organizations

- DIGITAL TWINS: Application of the digital twins in the manufacturing sectors.
- INTELLIGENCE: Use of artificial intelligence to optimize processes, providing decentralised services, predictive maintenance, etc.
- CAD/CAM software -- ERP systems
- Predictive maintenance
- Implement virtual reality to organize a virtual trade fair
- New equipment with Industry 4.0 technologies integrated. maintenance machine communication; RFID; IoT, Sensors
- Specific use-cases in areas of condition monitoring and predictive maintenance)
- Machine Learning / Industrial Analytics

When asked about their estimation **on the importance of the I 4.O technology enablers** in an advanced manufacturing environment, as in previous answers, all the enablers are well-considered. Additive manufacturing and AR/VR may be a bit lower rated. M2M communication, robotics, safety, IoT, tablets… to some extent are all considered important.

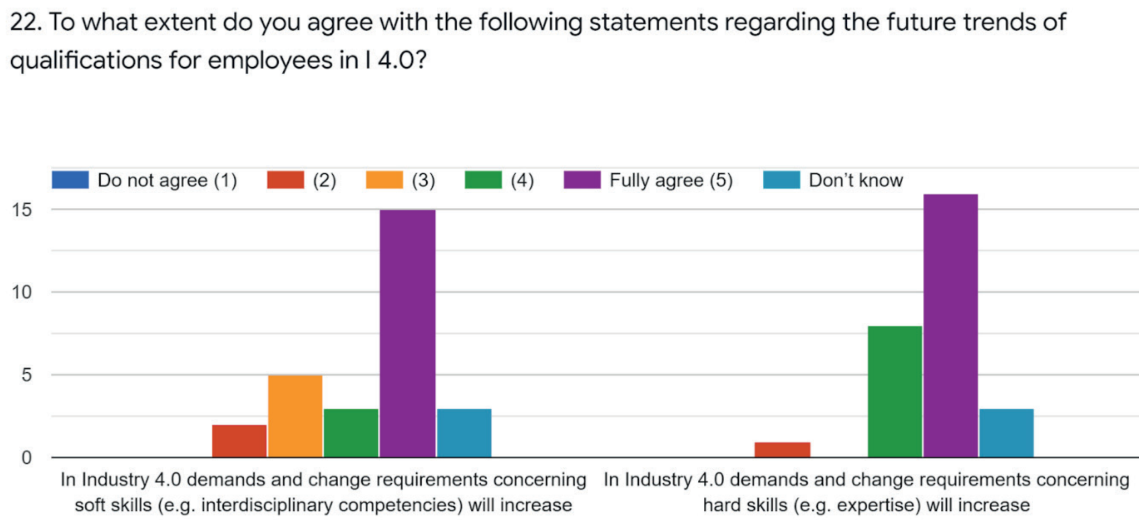


13. Figure: Importance of I 4.O technology enablers

As a comment, a respondent company is planning to implement a pilot centre with many of the mentioned technologies to test them and afterward, implement the best ones in the rest of the facilities.

The future evolution of Competences and skills

Considering the **future evolution of the competences related to I4.0**, the results of the survey show that not only technical competencies (hard skills) remain important but the requirements on soft skills will increase with digital transformation.



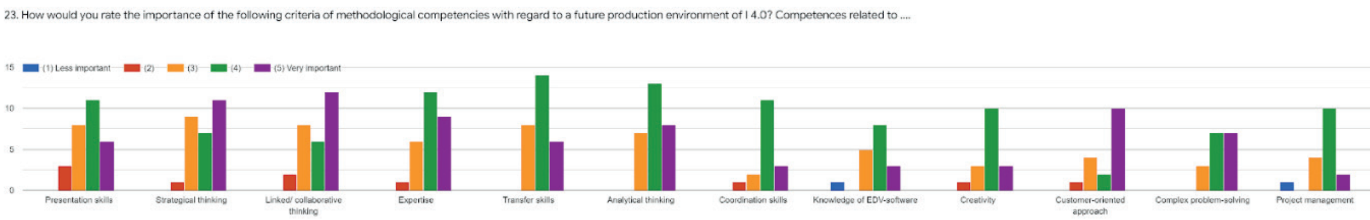
14. Figure: Future evolution of the competences related to I4.0

Some of the opinions to reinforce the conclusions are: "Both technical and personal skills are crucial in the world of today. It is important to focus on both of them and not just on one" and "It has been proved that a team working together, in the same direction, is more likely to succeed compared to one that does not. Therefore, it is important to focus on communication competences and foster teamwork".

When prioritizing among different types of competences, there was not a clear identification of the most relevant competences, as all of them were considered very important.

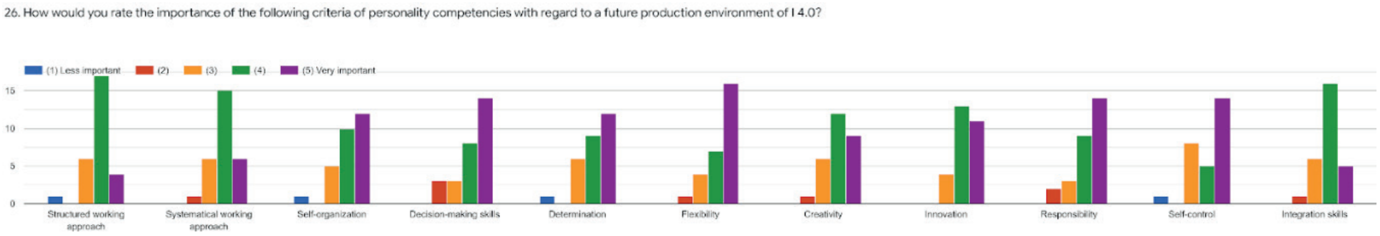
The questionnaire differentiates between methodological, functional, social, and personal competences. The participating companies considered all the competences proposed as important or very important with few exceptions. In the following graphs, the importance of different competences is shown.

15. Figure: Importance of methodological competencies with regard to a future production environment of I 4.0



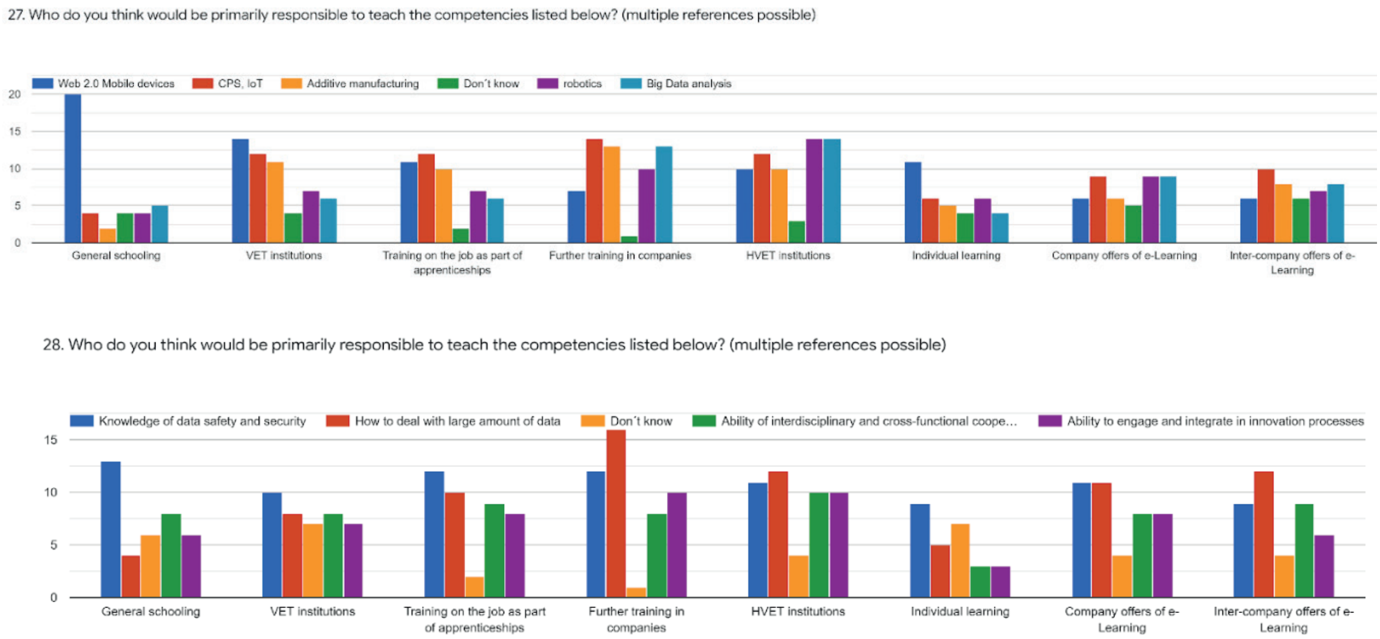
16. Figure: Importance of funtional competencies with regard to a future production environment of I 4.0

17. Figure: Importance of social competencies with regard to a future production environment of I 4.0



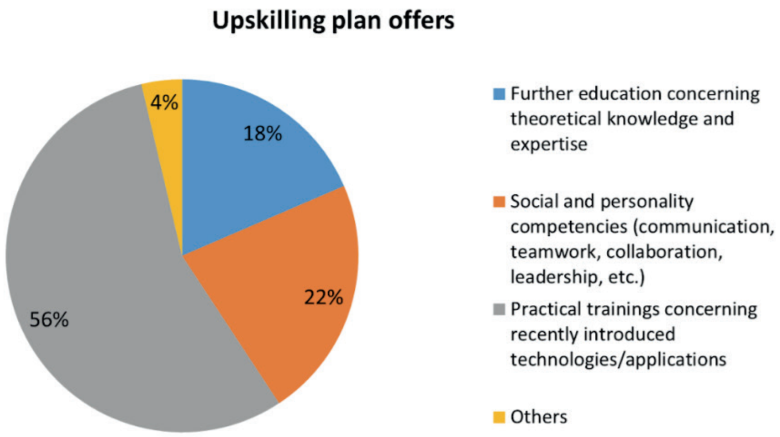
18. Figure: Importance of personality competencies with regard to a future production environment of I 4.0

When pointing out the main **education organizations responsible for teaching competencies**, there was no clear answer. The answers were divided quite equally between different institutions. This suggests that the responsibility was collective. The questions could have been ambiguous and have led to different interpretations.



19. Figure: Main responsible for teaching competencies

What is clear is that Industry 4.0 causes changes concerning the requirements of employees. Because of this, it is very important to give them plans for upskilling or further education. Concerning these plans, most of the interviewed companies are planning on developing functional competences (56% practical and 26% theoretical contents).



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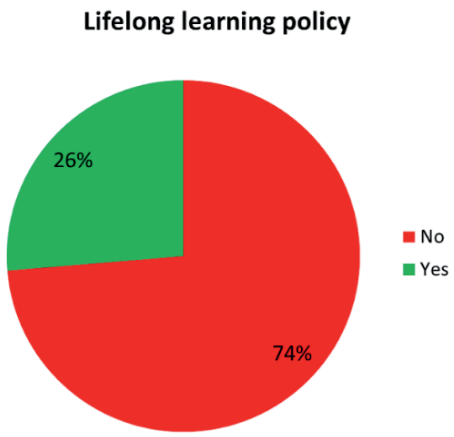
20. Figure: Offers of upskilling or further education and training for existing employees in order to meet the demands of Industry 4.0

Even so, it could be said that although companies give courses for the improvement of their employees, there is still no clear policy to implement lifelong learning approaches.



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21. Figure Existence of strategies describing how to implement the approach of lifelong learning for employees concerning i4.0

To conclude the interview, the company managers were asked about their views on the impact of the digital transformation in their companies in 4 areas: demands for employees, essential qualifications for the digital transition, highest benefits and chances, and risks.

Below, the complete list of comments

Demands that will change for existing employees in the course of Industry 4.0

- Need for adaptation Use of new tools and technologies
- Cross integration from the sensor to ERP to the manufacturing cloud will change the demands
- Flexibility
- Connectivity
- More Technical qualifications in the 4.0 Techniques
- Safer working places, flexibility, training with updates
- The data will do changes
- Learning and mastering new technologies
- Digital skills
- Complementing current knowledge with new design rules focused on advanced manufacturing
- Basic IT skills are no longer enough for most the people
- Interdisciplinary abilities
- IT skills, as well as other competences, as systematical working skills, linked thinking, etc, will be a requirement for employees working in an Industry 4.0 environment
- Nothing
- 1.- data analysis, 2.- work in mobility, 3.- adapt to constant changes
- More learning based on soft skills
- Teamworks
- Versatility

The **essential qualifications** for the digital transition and to be able to perform as an Industry 4.0 company

- Understanding data/connectivity/integration and business purpose of it all
- IT skills
- Cloud system work
- It depends on the Company strategy related to Smart Factory, which means people need qualifications according to the implemented techniques on the factory.
- Big Data Management Safety Energy efficiency Automation
- Big data analysis
- Innovation
- Knowing well the advantages that industry 4.0 offers to implement in the company
- Adaptability
- - IT, Technological knowledge, management skills.
- To pass from a machine provider to a solution partner concept requires flexibility and a focus on service and customer satisfaction,
- IT qualifications are a baseline. Other qualifications, like project management, lean manufacturing, etc will also be required, AV, AR, collaborative robotics, etc.
- Being able to bring technologies together.
- A good technical base. another one of knowing how to learn. and ability to work as a team and resilience
- Digitalization is necessary to be competitive but people are the most important asset. We should take care of them and train them.
- Multidisciplinary teams

The **highest benefits and chances** in Advanced Manufacturing (I4.0) in the company.

- New ways of getting incomes, improve relations with customers, optimization of processes and consumptions, environmental impact reduction, better-prepared employers, and higher-value jobs.
- Vendor independence
- Tracking on time
- Efficiency, productivity, database tool for analyzing a big amount of data.
- Efficiency, added value to the customer or market. Competitiveness
- Service, new products, and efficiency in the process
- Predictive maintenance, correction of production
- Flexibility
- Big potential for our clients to automate their production and for us to enable this.
- Productivity, Product quality, Competitiveness
- Avoid human failures, save time and reduce costs
- Advanced digital services for the life cycle of the product (business recurrency).
- Efficiency, high-value manufacturing, cost-effective production, high supply chain quality,…
- New services to our customers.
- Increasing automation and efficiency
- To understand the new business models
- Balance costs vs profit
- Integration

Possible risks of Advanced Manufacturing (I4.0) the comets gathered are the following

- Loss of non-digitalized data. Substitution of non-qualified employment by machines
- Low skills for analyzing big amounts of data. Meaning cybersecurity is ownership, that people are not prepared enough.
- Not to change the culture through people and prepare them to become "Digital Native" before starting with an I4.0 strategy
- High levels of cybersecurity are needed. Data on the cloud "implies" possible external Access Social Isolation. That is why it is necessary to foment team working High qualification needed-still not many qualified students
- Too much information
- Security risks
- For the success of advanced manufacturing, public institutions have to support entrepreneurship and education in the implementation of new industry technologies 4.0
- Too high expectations that technology will solve all problems.
- Safety, Cyber Security, lack of trained employees, difficulty implementing digital transformations.
- Security privacy and trust compliance, manufacturing data ownership, and interoperability concerns. Risk of I4.0 becoming a commodity that will not make any real difference among competitors.
- Human resources, skill acquisition, high investment, impact in business, …
- Cyber Crime.
- Loss of contact and initiative between people in the company and total dependence on technology
- Fall behind and not being competitive
- Losing the reality of physical manufacturing

CONCLUSIONS

Digital transformation in most cases is driven by a comprehensive and holistic strategy that runs through the organization. However, as is expected, the level of implementation of I4.0 enablers is not the same for all the interviewed companies. Three profiles of companies are identified concerning the level of implementation: machine tool sector, technology providers, and component production-driven SMEs.

The companies that develop I4.0 technology are logically the ones that show the highest degree of maturity. Companies in the machine tool sector are incorporating different solutions and technology enablers into their products, which is why the level of testing and validation of i4.0 solutions is much higher among those companies. Finally, component manufacturing SMEs are implementing I4.0 technologies at an early stage, testing different solutions and starting (and in some cases implementing) the first digitization projects.

All of the I4.0 technology facilitators included in the study are being used to varying degrees. As a first conclusion in this context, it is relevant to comment that none are ruled out. The use of mobile/tablets and information exchange channels are the most used technologies, used by all those who have evaluated them. The same happens to additive manufacturing to a lower extent. The potential of M2M communications and robotics to a lower extent is also widely evaluated although its use is not so widely implemented so far.

It should be noted that most of the participating companies see their organizations in a high degree of digitalization in a period of ten years. Only 16% of the companies foresee digitalization as support.

With regards to the possible risks that I4.0 may pose, a recurrent risk among respondents is security, data security, and connected machines and processes.

With reference to competences, it is important to stress that they are linked to specific jobs and tasks. This makes it difficult to generalize the answers obtained. In any case, the companies interviewed unanimously emphasize the importance of functional competences and underline the importance of transversal competences in the context of digitalization. The interviews dealt with methodological, functional, social, and personal competences and the participating companies considered all the competences proposed as important or very important with few exceptions.

12 Detailed Country Report – Germany

This document summarizes the results of focus group meetings of EXAM 4.0. The focus group meetings of the DHBW Heilbronn and Heidenheim implied 21 filled-in questionnaires and six expert interviews with 16 interviewees. In advance of the interviews, the participants received the questionnaires as support.

ABBREVIATIONS

AM = Advanced Manufacturing

AR/VR = Augmented Reality/ Virtual Reality

EQF = European Qualification Framework

EXAM 4.0 = Excellent Advanced Manufacturing 4.0

I4.0 = Industry 4.0

IIoT = Industrial internet of thing

IoT = Internet of thing

M2M = Machine to machine

MES = Manufacturing Execution System

RFID = Radio frequency identification

CONTENTS

EXAM 4.0 FOCUS GROUP MEETING'S RESULTS

The following national report was prepared within WP2 Learning Dialogues of the European research project EXAM 4.0. The pursued objectives of the study are to identify statues of representative companies in Germany with regard to digital transformation as well as to validate the two frameworks "EXAM 4.0 technology framework" and "EXAM 4.0 competence model".

The methodology used in the report firstly was creating a universal questionnaire which was used in every partner country to contrast and compare results of the different EU regions and countries. The questionnaire was previously distributed to attendees as support before carrying out expert interviews with the concerned participants.

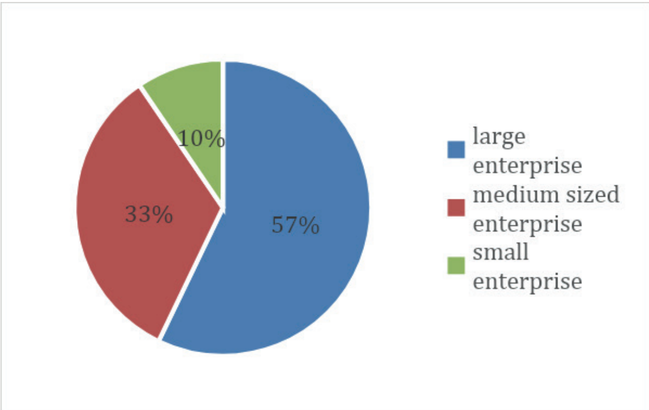
In the case of the German research group, 21 participants filled in the questionnaire in total, 16 of whom partook the expert interviews. Overall, 6 expert interviews have taken place online between June and August 2020. The participants represented 12 large companies, 4 medium-sized companies, 1 small company, and 4 institutions (DHBW, Chamber of Industry and Commerce Eastern Wuerttemberg, Association of German Chambers of Industry and Commerce, Chamber of Handicrafts Ulm).

The results of this study do not represent quantitative but rather qualitative research. However, the selected companies are sufficiently representative to obtain and represent relevant information to be included in WP2 of EXAM 4.0.

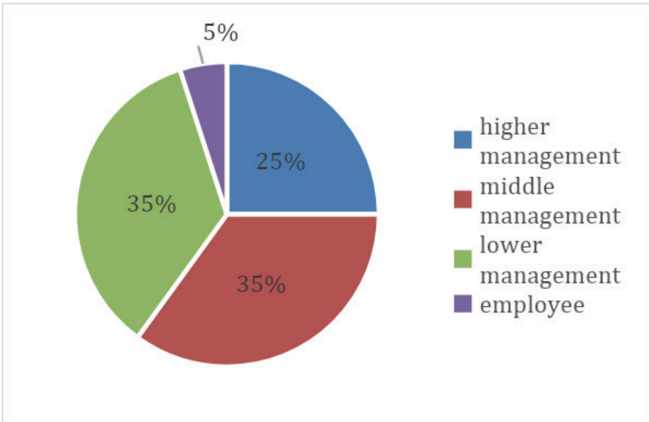
The study examines two aspects of the impacts of Industry 4.0. These two aspects are technology impacts and competences.

DEMOGRAPHICS

The survey was conducted with 20 companies, the majority of whom located in the south of Germany, in Baden-Wurttemberg and Bavaria. Most of the representatives were working in large companies (60%) and working in middle (35%) or lower management (35%). The majority of participating representatives are working in machine tools (29%) or service sectors (23%).



1. Figure Sector and size of the respondents



2. Figure Functions of the respondents

CURRENT STATUS

In the first part of the study, the attendees were questioned about the current status and situation of their companies concerning technological developments, qualifications, and current demands of employees.

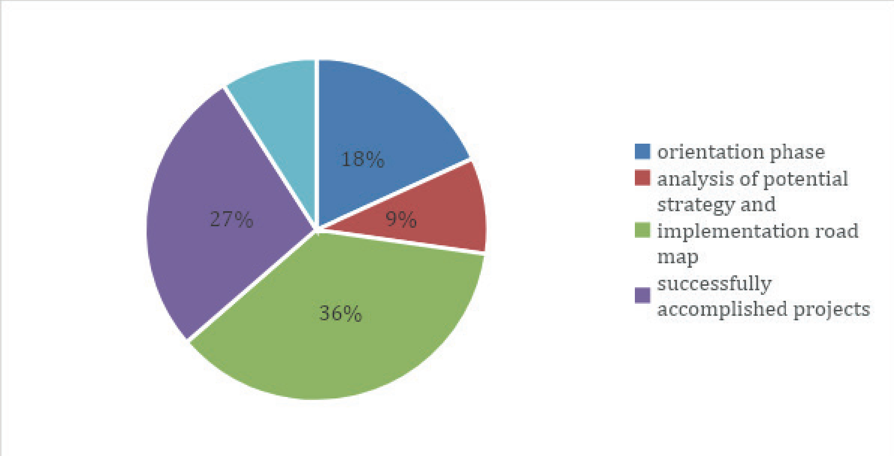
With regard to initiatives of digitization and companies' progress towards Industry 4.0, most of the companies present a comprehensive and holistic strategy across the organization regarding:

- Developing innovative and differentiated products and services
- Identifying key areas to make effective I4.0 investments
- Finding growth opportunities for existing products and services
- Developing new business models
- Protecting their organization from disruption
- Understanding which skills will be needed

In addition, about utilizing new labour models, few companies already developed a comprehensive and holistic strategy towards the topic of digital transformation. Furthermore, the interviewed companies also show an ad-hoc strategy regarding the following areas:

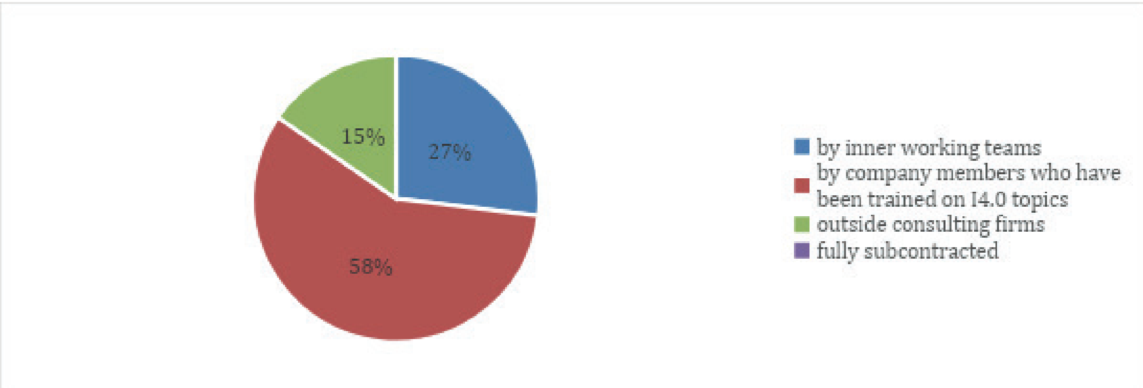
- Development of an I4.0 architecture (e.g. Big Data, cloud, IoT,…)
- Investigation connected and integrated approaches in the value chain
- Training and developing the workforce for I4.0

The majority of participants indicated to already have completed an I4.0 strategy and implementation of a road map or executed I4.0 initial projects.



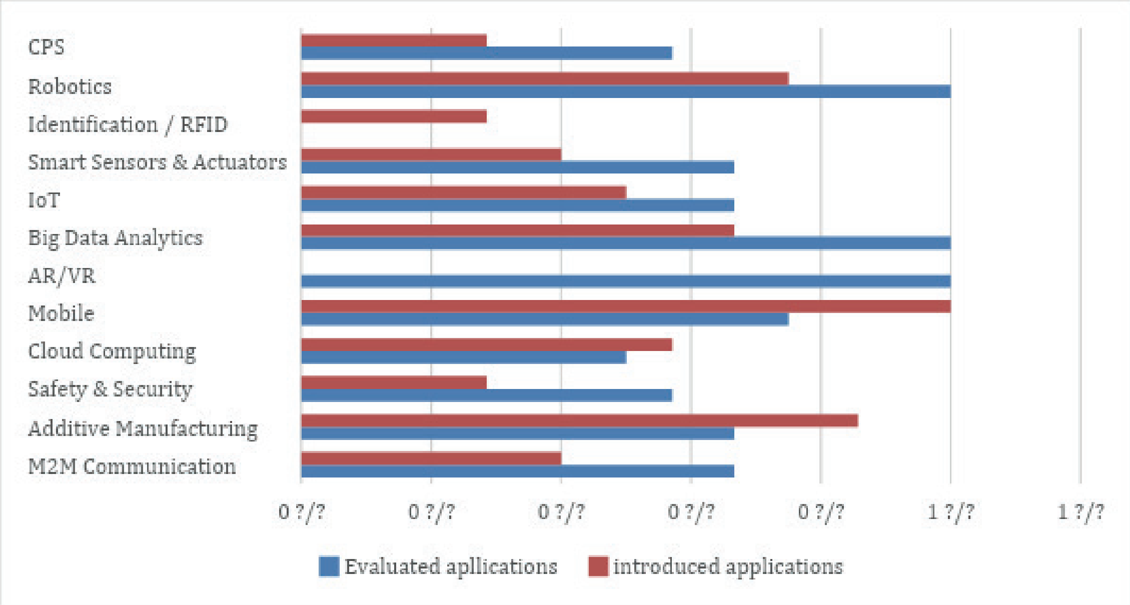
3. Figure: definition of the strategy and 4.0 projects

Most of these projects were managed by company members who have been trained on the topic of I4.0 of the projects were managed by inner working teams. Only a few company projects were led by outside consulting firms guiding the implementation.



4. Figure: executed projects managed by

Regarding technology enablers or Industry 4.0 applications, all listed technologies were evaluated by the companies whereas not all technologies are already introduced in companies. Technologies that are already often used by companies imply mobile technologies and tablets, additive manufacturing, robotics & autonomous systems, Big Data Analytics, and cloud computing. AR/VR technology as well as cyber-physical systems, RFID & identification, safety & security, and smart actuators & sensors present technology enablers that are not frequently implemented in companies by now. The interviewees also added further technologies they have implemented in their companies such as artificial intelligence, distributive ledger technology, manufacturing analytics, and online systems for teaching and research. Moreover, it can be observed that primarily large enterprises have already introduced several or more than three technology enablers, whereas small and medium-sized companies use 1 to 3 technologies.



5. Figure: I4.0 technologies/applications,

During the interviews, the participants added more information and explanation of their use of technologies. According to one interviewee, the implementation of mobile technologies is more advanced in a private environment than in the industry. A similar observation of the interviewee goes with safety and security. A participant instanced the example of discussions and concerns about the Corona App. People are much more aware of data safety in their private environment than in a professional environment. Moreover, several companies mentioned that they start early to implement mobile devices and introduce them to employees. For example, companies equip trainees with mobile devices to document and use during their apprenticeships. Another example of introducing trainees and graduates to technology is presented through learning factories. One participating company provides a learning factory for trainees where they can build miniature versions of hydroelectric power stations and evaluate data, so they learn how to deal with a big amount of data and interpret them correctly. Another company cited the example of using AR/VR technology. This technology enables workers of different plants to communicate and even guide the other person to repair or maintain systems without the need to travel or huge time exposure. Furthermore, participants emphasized introducing new technologies and applications in small steps. So, employees can get used to the idea and a change of consciousness can take place. As a result, employees show greater acceptance of implementing new technologies.

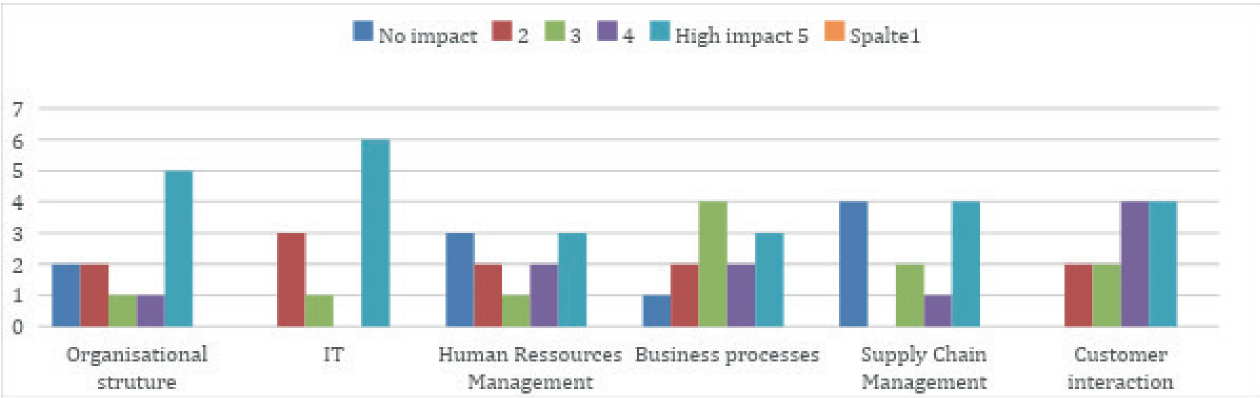
The participants were asked to name and describe projects of technologies and applications they already initiated. The listed and described projects were widely spread amongst technology enablers and applications. However, two companies pursued the objective of prediction with analytical technologies. Further two companies listed projects referring to robotics. It can be observed that the largest companies already initiated and executed projects. Only a few medium-sized companies noted their projects. Some of the projects and explanations are listed below:

In the following lines, some examples are shown:

- Mobile operation
- Mobile HMI, wireless including machine safety
- Human-robot collaboration
- Safe robotics
- Festo Motion Terminal
- First pneumatic valve for the factory by using apps
- CP Factory as universal research & learning platform

  reflects new developments in I4.0 networked production & offers modular Smart Factory systems for teaching & research purposes
- IO-Link
- Member of IO-Link consortium
- 3D Printing
- Printing equipment and tools for desks
- Robot controller as IoT smart device
- Remote administration
- Big Data Analytics
- Performance prediction & fault prediction
- Hermes Standard
- Vendor independent system for line integration
- VICON applications
- Manufacturing execution
- Streaming analytics
- Predictive maintenance
- Machine learning (batch analytics)
- Ensure production quality

) Since the majority of participants did already implement some I4.0 technologies, the results of the questionnaire display high-impact technologies on IT. Moreover, the implication regarding customer interaction was also assessed with a higher impact. A further impact and benefit of I4.0 technologies were confirmed in expert interviews. The timeliness of data has a huge impact on organizations. I4.0 enables companies to provide clients with real-time data, which can be a decisive condition to participate in projects. As a result, I4.0 technologies enable companies to participate in more projects due to facilitated data exchange and real-time insights. However, an interviewee mentioned, that it is not that easy to evaluate the impact of technology enablers on an organization, because some technologies, especially mobile technologies, have been introduced years before. Their impact on the organization is not as easy to detect years later.

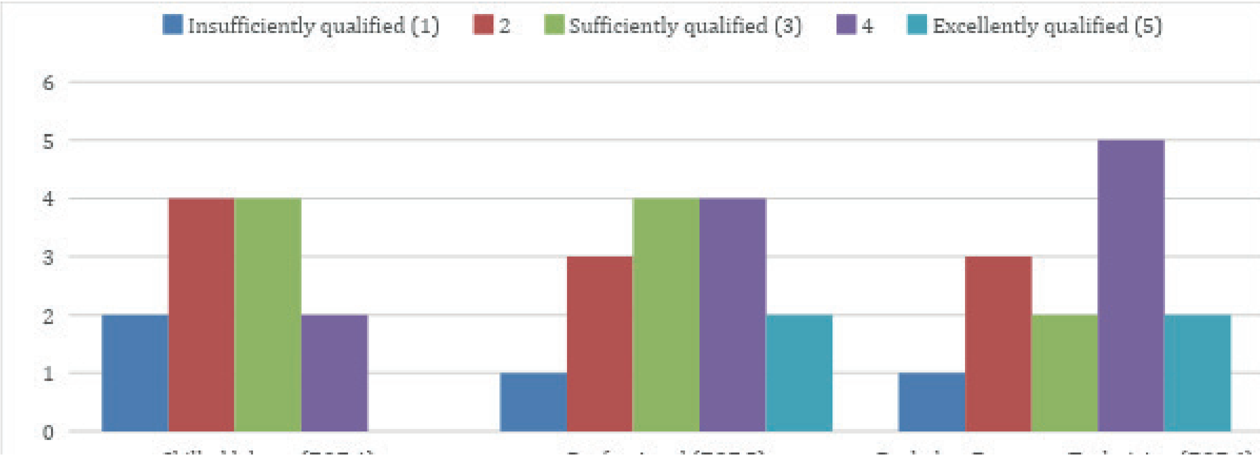


6. Figure: Impacts on the organization of implemented I4.0 technologies

Competences and skills

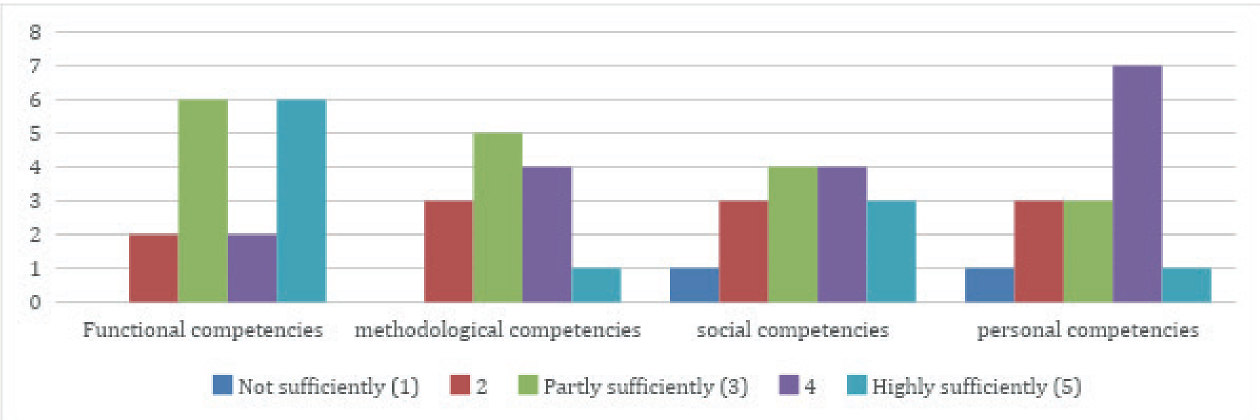
This chapter refers to the competences required of employees working in an advanced manufacturing environment. Competences can be general applying to all occupations and workers or they can refer to specific jobs or occupations. Therefore, the participants were asked to indicate their function. The majority of participants are working in engineering and product design, administration, manufacturing, and operations.

Concerning qualifications required for actual demands in their units, the results show tendencies in types of qualification. For example, regarding EQF level 4, participants were asked to indicate if skilled labour is prepared for the actual requirements of the department or unit. The results show that skilled labour is sufficiently qualified. Further, bachelor, a foreman, or technicians, referring to EQF level 6, tend to be well qualified for current demands.



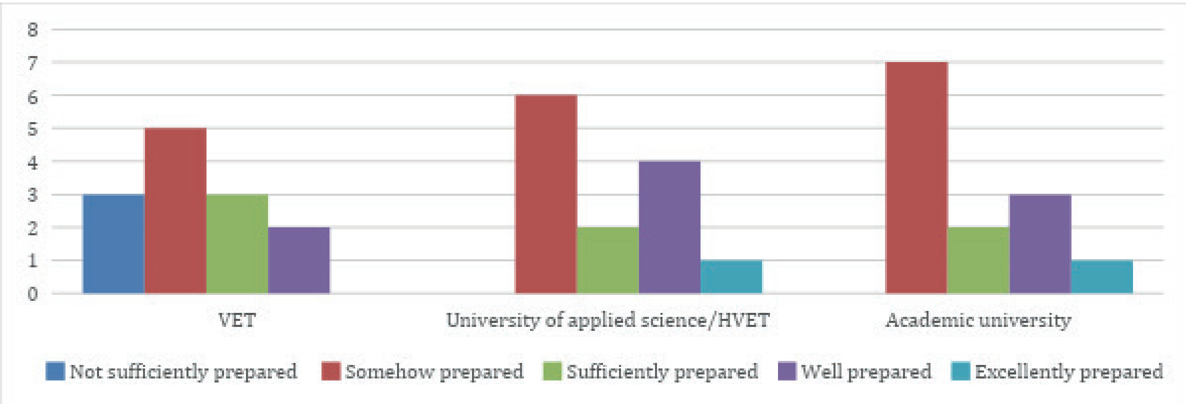
7. Figure: Requirements of qualifications for different department/unit

The majority of company representatives indicated that functional competencies are highly sufficient, whereas methodological and social competencies present a lower tendency. Within the expert interviews, the majority of attendees agreed to the results. "Functional and IT competences are crucial to achieving decisive progress", whereas methodological competences, for example working in teams, already present a working reality in companies. Moreover, interviewees emphasized a blending of competences.



8. Figure: Current requirements of Industry 4.0

Similar to question 12, the participants were asked to evaluate graduates regarding Industry 4.0 requirements. As the results show, graduates of VETs are evaluated as not or somehow prepared such as graduates of academic universities who also are rated to be somehow prepared. Graduates of HVETs or universities of applied science tend to be better prepared for requirements in an advanced manufacturing environment. Participants of the expert interviews indicated, graduates provide new impulses in companies and forward certain topics. However, interviewees also agreed to the statement, that graduates have to complement their competences, though companies do not expect graduates to be excellently prepared. One of the interviewees also emphasized the great potential of mixed teams, including employees of different qualifications, age, gender, culture, and occupational background. According to him, those mixed teams lead to incredibly, thrilling energy.



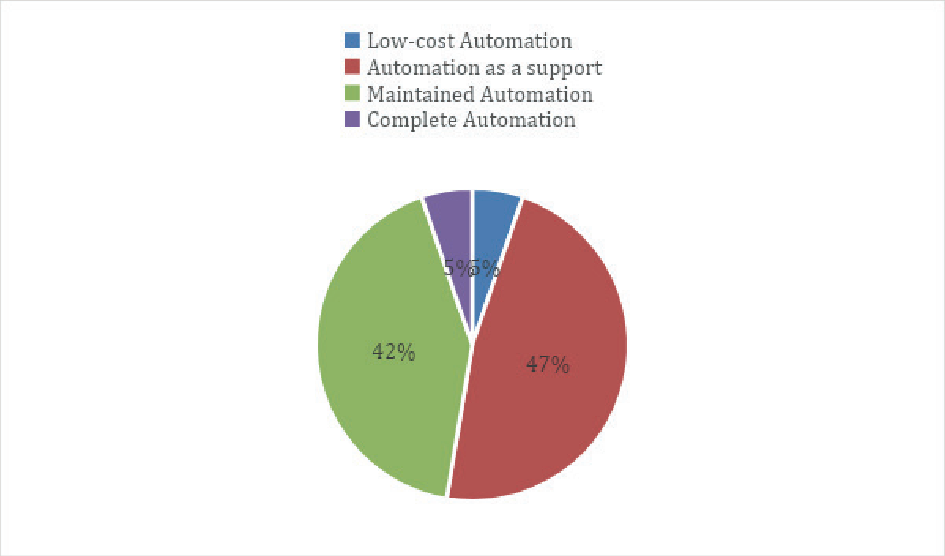
9. Figure: Qualification and competence level of the VET and HVET graduates regarding the I4.0 requirements

FUTURE TRENDS

The second part of the study explores future technological trends, changed demands due to Industry 4.0, and how to prepare and reskill employees for the AM.

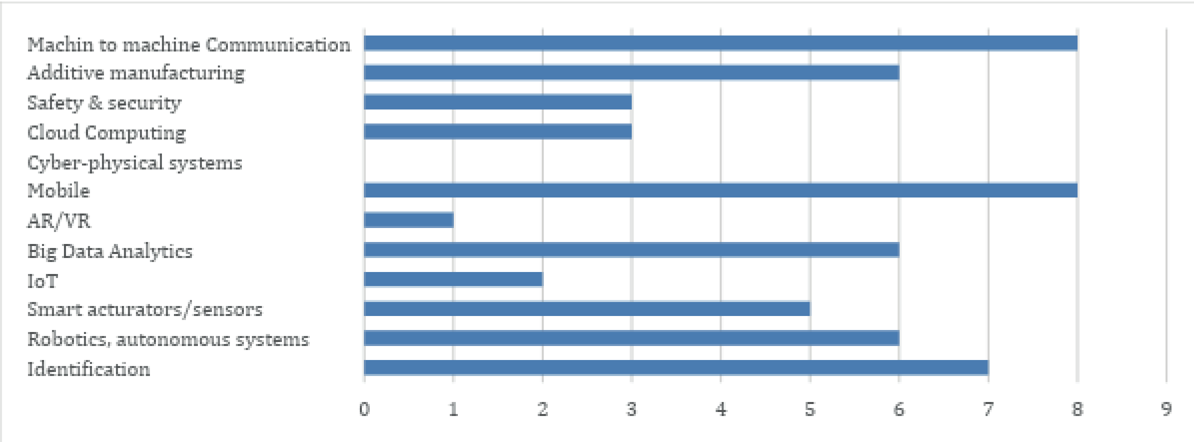
Technological Trends

Concerning further developments on I4.0, the majority of participants forecast their companies to develop towards automation as support or maintained automation in ten years. One company referring to the industry of machine tools even pursues a development towards complete automation.



10. Figure: Development of the company in the next ten years

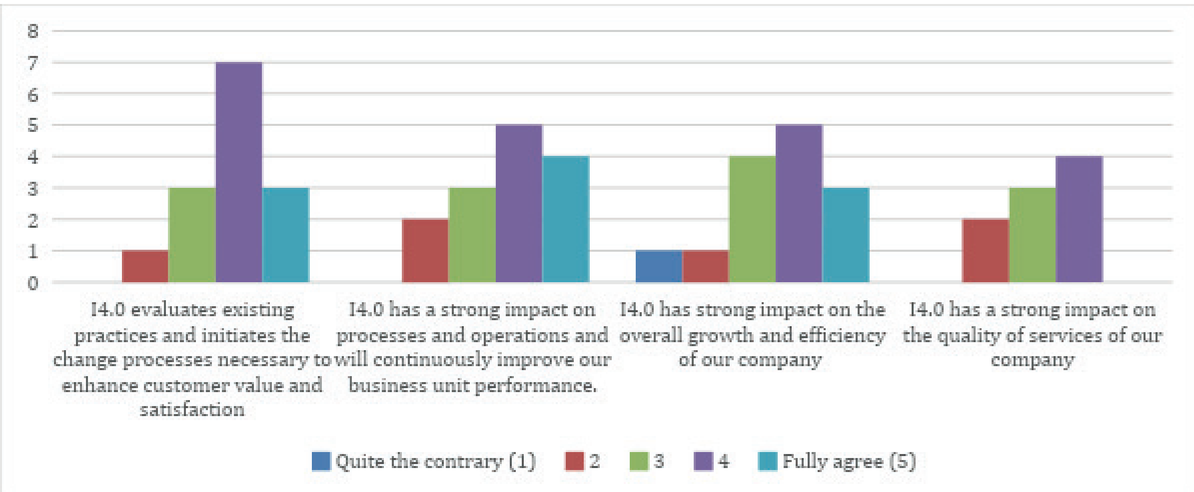
Regarding technology enablers that will be introduced in the future, technologies, and applications such as M2M communication, mobile technologies, identification & RFID, robotics, Big Data Analytics as well as additive manufacturing, and smart actuators and sensors were often mentioned. However, safety and security, cloud computing, AR/VR, and IoT will be introduced in just a few companies.



11. Figure: I4.0 technology enablers foreseen to be introduced

Moreover, the participants added further technologies, their company will introduce in upcoming years. For example, they listed artificial intelligence, smart services, MES and IIoT.

Concerning the business impacts of the AM, the majority of representatives noticed a strong impact on the quality of services, processes, and operations as well as the evaluation of existing practices leading to change processes. However, they do not notice as much of an impact regarding overall growth and efficiency.



12. Figure: Impact on value chain

The participants were also asked to describe projects related to I4.0 that will be initiated in their companies. Similar to already initiated projects, especially large companies described planned projects of their companies, although, significantly fewer companies could name and describe projects for the future. The examples given by companies show a great variety of technologies and applications, just technologies referring to data analytics occur as examples of two different companies. Some examples of projects which will be introduced in the future are listed below:

- Artificial intelligence

  Implementation of decentralized technical intelligence
- Digital learning portals

  Roll out Festo learning experience
- Automatically generation of quotations, Big Data Analytics

  The customer gets automatically generated quotation employing IT solutions (options, delivery date)
- Big Data Analytics

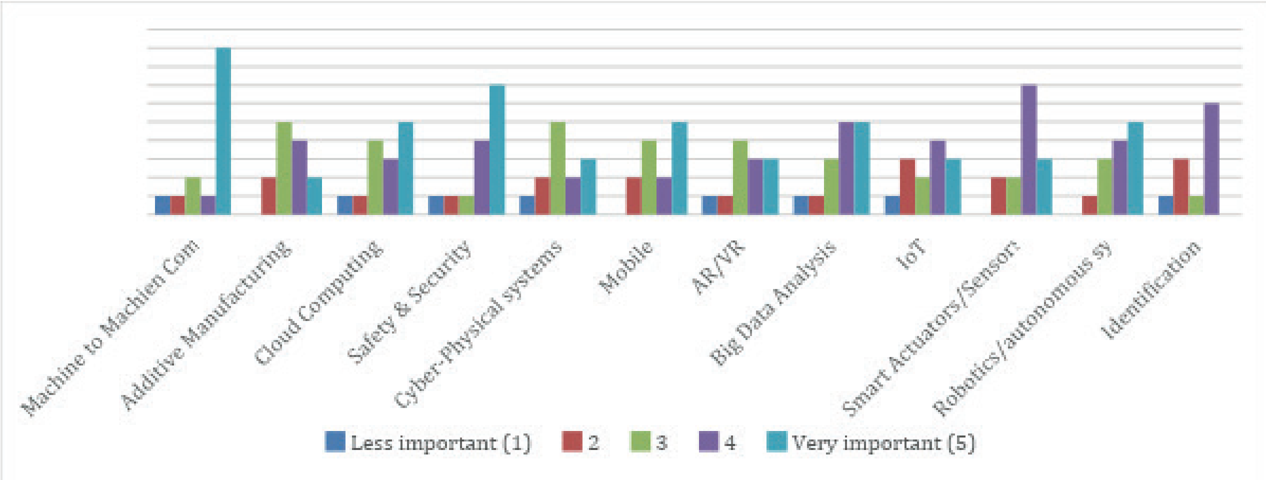
  KPI cockpit & analytics
- Vendor evaluation

  360-degree evaluation for vendor management and sourcing strategies
- Machine learning

  Increase production efficiency
- Data analytics

  Predictive maintenance
- Machine Learning / Industrial Analytics

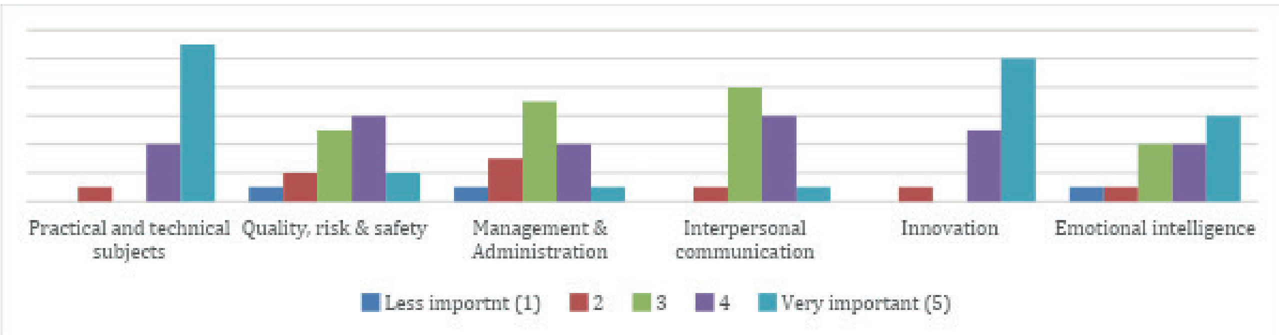
As the results of the study display, participants expect several technology enablers to increase in importance in an advanced manufacturing environment. These include M2M communication, cloud computing, safety and security, mobile, robotics as well as smart actuators & sensors, and RFID & identification.



13. Figure: Importance of I 4.O technology enablers

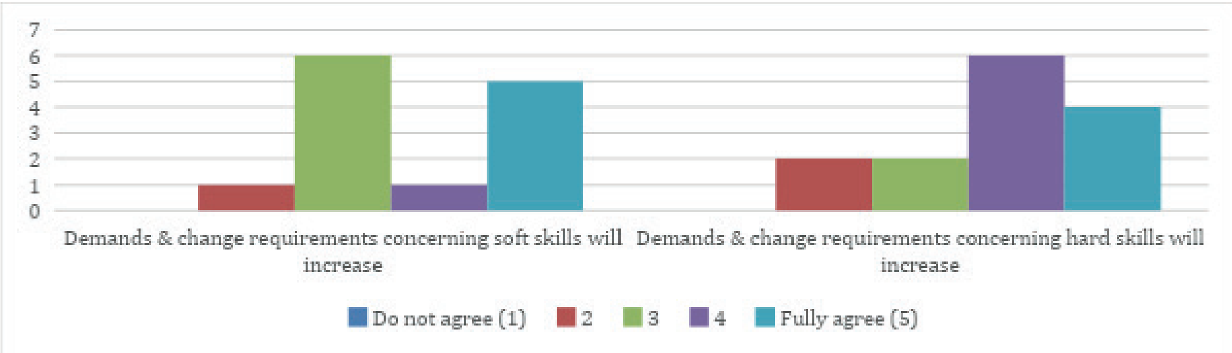
The Future Evolution of Competences and Skills

The digital transformation causes new competences required of employees working in the AM. The majority of interviewees expect competences concerning practical and technical subjects as well as design and creation of new things to become more important. Furthermore, the increasing importance of competences and the ability to deal with one's own and other people's emotions can be observed. Competences referring to management & entrepreneurship and interpersonal communication tend to be as important as today.



14. Figure: importance of competences related to I4.0

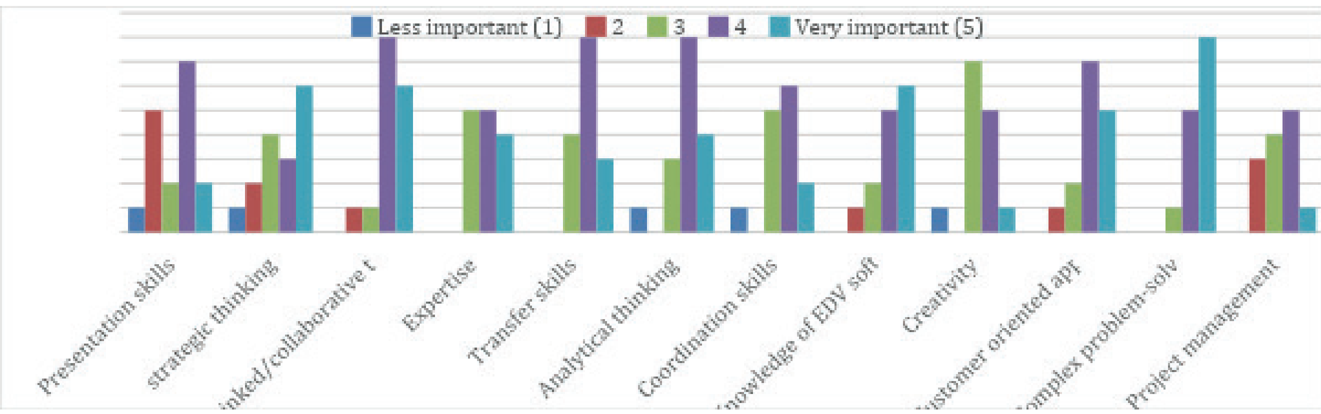
Moreover, interviewees expect a stronger increase in demands concerning hard skills than soft skills. During the interview, the participants discussed the future importance of soft skills and mentioned that those skills are already important and taught in school. Whereas, due to the increasing complexity of processes it would be important to focus on hard skills for the future.



15 Figure: Demands & change requirements concerning soft & hard skills

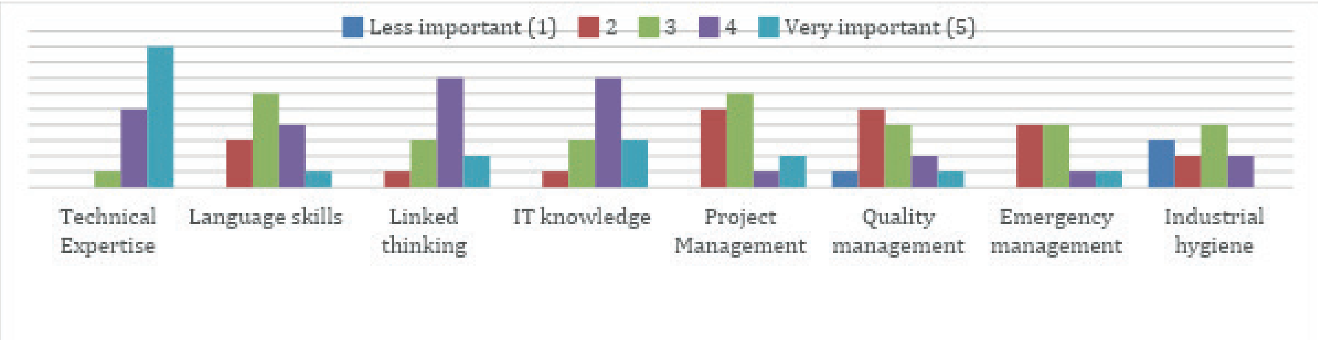
Concerning competence typologies, all four types of competences will be important in an advanced manufacturing environment. However, some competences tend to increase in importance.

Regarding methodological competences, competences such as linked/collaborative thinking, transfer skills, analytical thinking, knowledge of EDV software, customer-oriented approach as well as complex problem solving were rated to be more or very important. Besides, an interdisciplinary working approach will be increasing because problems are not discipline-specific and future employees of AM will be working with different coworkers from all over the world and different departments.



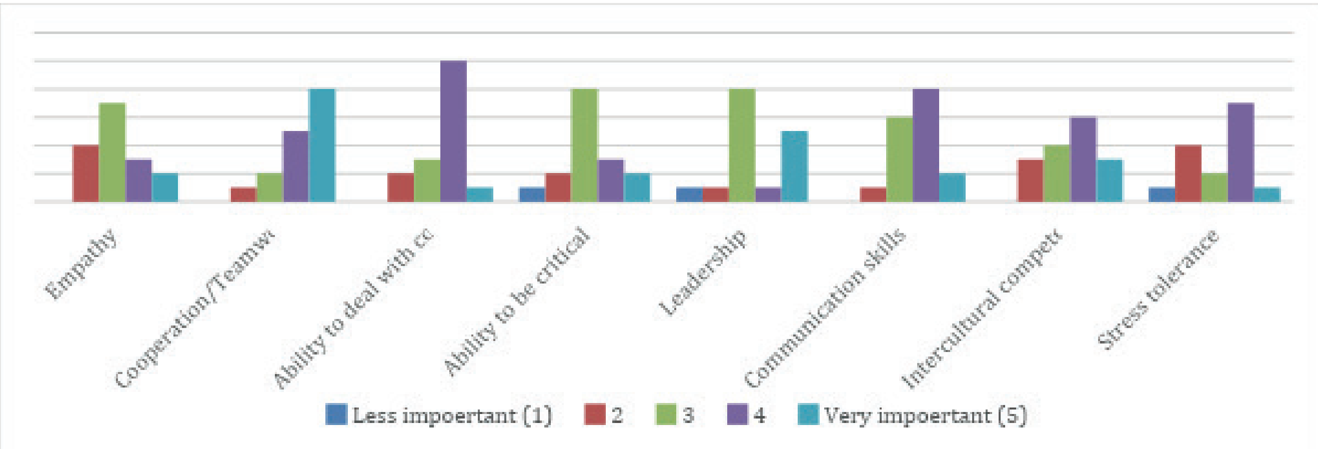
16. Figure: Importance of methodological competencies with regard to a future production environment of I 4.0

Moreover, the majority of interviewees rated technical expertise as very important (9 out of 15) and indicated increased importance concerning linked thinking and IT knowledge. In comparison, industrial hygiene as well as project, quality, and emergency management display the lower half of this ranking.



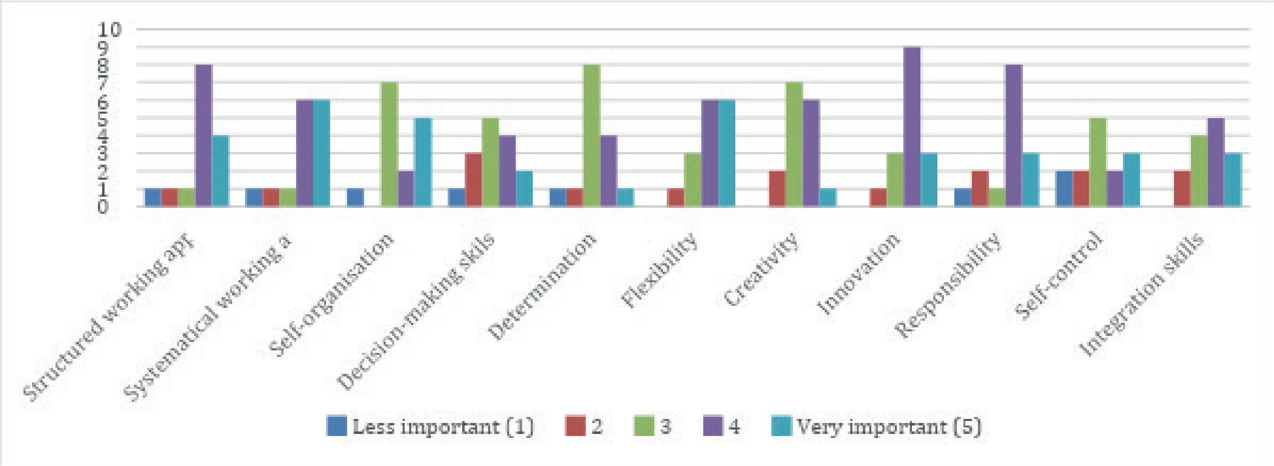
17. Figure: Importance of functional competencies with regard to a future production environment of I 4.0

With regard to social competencies, competences such as cooperation /teamwork, ability to deal with conflicts, communication skills as well as stress tolerance will be required of employees working in advanced manufacturing. Regarding communication skills, in the interview, a participant emphasized the importance of systematic and structured communication. "Every unit has their technical terms and even "language", therefore employees in AM must provide information understandably", according to him.



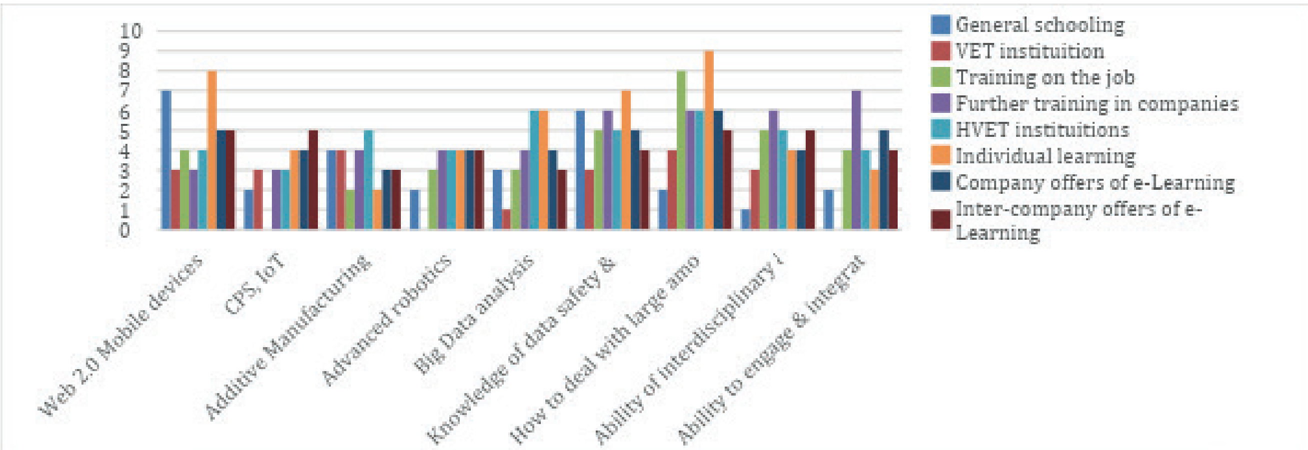
18. Figure: Importance of social competencies with regard to a future production environment of I 4.0

The interviewees also expect certain competencies referring to personality to be required of future employees. Those competencies imply a structured and systematic working approach, as well as flexibility, innovation, and responsibility. Concerning flexibility, the interviewees emphasized the importance of lifelong learning. In I4.0, topics change rapidly, therefore employees have to become acquainted with developments. Moreover, to develop new topics, they are demanded to be creative, accepting, and to listen closely.



19. Figure: Importance of personality competencies with regard to a future production environment of I 4.0

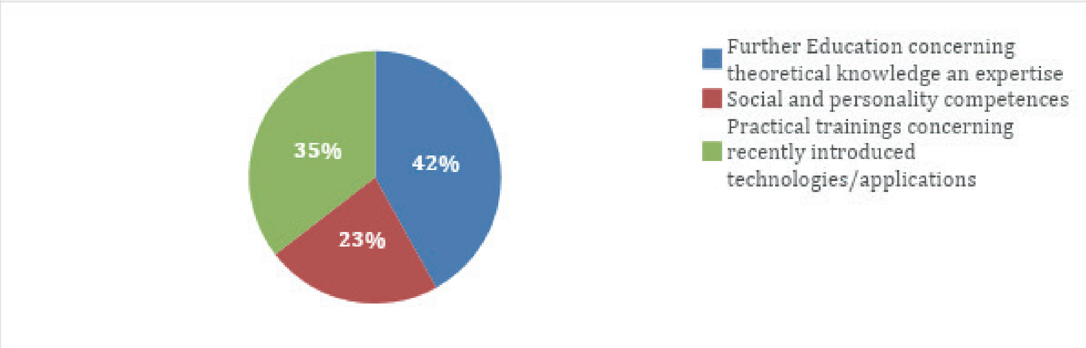
Asking the participants which institution would be primarily responsible to teach competences concerning I4.0, the results show that the training of competences on Web 2.0 mobile devices should be performed by all institutions. A similar observation can be made regarding knowledge transfer of data safety and security. Whereas these competences should be trained early on starting in general schooling, other competences such as how to deal with large amounts of data, the ability of interdisciplinary and cross-functional cooperation as well as the ability to engage and integrate into innovation processes and big data analytics should be trained in combination with practical application, starting as training on the job as part of an apprenticeship. The interviewees also indicated company or inter-company offers of e-learning as a great option for employees to acquire the listed competencies. However, they added e-learning offers should be referred to practical examples or projects of the company, so there should be a combination of learning methods. Combining theory and practice enables learners to apply their knowledge.



20. Figure: Main responsible party for teaching competencies

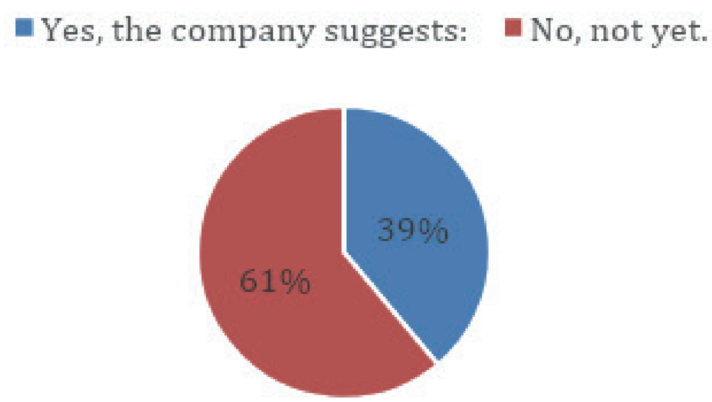
Furthermore, one group of interviewees proposed an alternative structure, resembling a pyramidal structure. In their opinion, all listed competences should be taught to pupils, so graduates occupy a foundation of basic knowledge and skills of all subjects. There are certain topics such as safety and security considered essential by interviewees, also in a private environment. Depending on their interests and occupational paths they will follow, certain students will acquire further competences in technological subjects such as Big Data analytics, CPS, VR/AR, etc, according to the demands of their professions and tasks. The top of the pyramid presents specific subjects required in only a few professions or sectors, for example working in sales to discuss and explain niche products to clients. This alternative structure proposed by interviewees does support the estimate, competences can be job-specific. Moreover, one interviewee emphasized the importance of general schooling to impart drive, persistence, motivation, and how to give feedback or lead conflict discussions to learners. This competency is missing among graduates according to interviewees.

With regard to offers of upskilling or further education and training for existing employees, the vast majority of participants indicated their companies plan to further educate their existing employees concerning theoretical knowledge as well as practical training for newly introduced technologies.



21. Figure: Offers of upskilling or further education and training for existing employees

However, a minority of companies can already present a concept on how to implement the approach of lifelong learning. Those few companies offer qualification programs for skilled labour, knowledge transfer tools, offers of in-house courses, and mentor menti program. Furthermore, the participants of the expert interviews accentuated supporting employees in their personal development and taking into account their strengths and interests. For example, one interviewee cited the example of a timid employee, voluntarily managing a youth soccer team in her free time but did not do well integrating herself in teams or executing leadership tasks in a professional surrounding. Being offered the function to manage and organize the deployment of trainees, the respective employee prepared new plans and projects for trainees and interns to sufficiently prepare them for exams and tasks.



22. Figure Existence of strategies describing how to implement the approach of lifelong learning for employees concerning i4.0

According to the results of the questionnaire, **demands for existing employees** will increase concerning flexibility and adaptability to changes, as well as **holistic thinking** and **cross-functional cooperation** will be needed. The interviewees also noted changes regarding **customer approach, design thinking, lifelong learning, supply chain needs,** and the **ability to acquire knowledge** on one's own.

Essential qualifications for the transition towards I4.0 imply primarily **IT skills, flexibility, and expertise management.** Furthermore, participants added **learning skills** (critical thinking, creativity, collaboration, communication), **literacy skills** (information, media, technology), a general understanding as well as competencies such as **leadership, initiative, productivity, and imagination**. Moreover, the interviewees added the importance of rethinking leadership pertaining information. For example, the information should be shared and distributed with respective persons to be valuable. Therefore, the head of the department does not have to have all information but to distribute the right information to the respective employees.

The highest benefits and chances in AM imply **highly efficient processes and production, new products/opportunities, transparency** as well as greater **customer orientation.** Besides, participants noted the exchange and learning from data, **process safety, facilitation of tasks, flexible production, tracking on time**, no downtime, and a change towards **lifelong learning.** Furthermore, one of the interviewees cited the example of how the current pandemic situation accentuates the benefits of Industry 4.0. Technology enablers and applications used in an advanced manufacturing environment provide information and real-time data, which leads to a more precise prediction for production. In the case of panic purchases, the respective company noticed a greater demand for upright freezers to keep goods fresh. As a result, the company increased their production of freezers and could meet the needs of increasing customers. However, an interviewee indicated projects which are hindered due to a lack of IT capacity. There is a great demand for IT professionals to realize projects and developments in AM.

However, the majority of participants see **possible risks** of AM concerning **data and cybersecurity, mismatch** of existing employees, and the difficulty **to integrate all existing employees** in change processes. Furthermore, the answers include risks referring to investments and **false decisions**, highly **complex technology**, **transparency**, and a loss of traditional trading.

Being asked about what companies do **expect from VET and HVET institutions** in the future, the participants of the expert interviews cited the example of **better cooperation** between institutions, companies, and the economy. Furthermore, they listed competences that are currently lacking and will be required when working in advanced manufacturing. These additional competences imply **determination, giving feedback, being innovative, resilience, stress tolerance, perception by others as well as introspection**, and representing one's opinion. In addition, attendees expect companies to **establish a new mindset towards failure and mistakes.** "Fail but fail early" is a premise to create an environment in which to learn from mistakes and thrive through them. One of the interviewees also emphasized to "Accept permanent change as the only invariable. Industry 4.0 evokes rapid changes regarding the professional life and therefore we as companies should raise awareness to this fact and intrigue future employees". The interviewees agreed on the proposition of a bottom-up strategy to adapt and rethink current graduation programs. They pitched the idea to carry out a survey, questioning graduates and new employees what additional competences, skills, and subjects they need, to feel prepared for working life. It will be important to discover the drive of GenZ and awaken their interest in occupations and professions. As a result, the approach of adapting vocational programs by now was to ask what companies need, but requests and interests of the opposite party should also be taken into account and will be crucial to make decisive developments regarding vocational programs and recruiting future employees.

CONCLUSIONS

The results of the study with 20 companies contribute to insights into the current status and future trends of German companies concerning technology, competences, and demands. The digital transformation in most cases is driven by a comprehensive and holistic strategy that goes across the organization. However, it can be observed that especially large companies did already implement several technology enablers and applications. In the questionnaire, SMEs could not indicate and explain as many executed projects referring to I4.0 technologies as larger companies. This observation could be explained by greater financial and human resources in large companies and their possible uses of I4.0 technologies.

Certainly, there are technologies used by the majority of participating companies such as mobile, additive manufacturing, and robotics. However, all companies plan to introduce more technology enablers to stay competitive and to be able to react to customer and market demands. Therefore, it comes as no surprise that interviewed companies indicated the strongest impact of I4.0 regarding IT, customer interaction, and organisational structure.

With regard to future requirements, current graduates and employees are not fully prepared for working in the AM independently of their qualifications. The participants forecast increasing demand for functional competences and hard skills to perform in an advanced manufacturing environment. As a result, companies indicated to be concerned about how to integrate existing employees and prevent great mismatch in the future. As seen in the study, companies will introduce more technology enablers and complex systems in I4.0 requiring employees to obtain technical expertise and complex problem-solving. In addition, working life will change for all employees in the future, for example working in diverse and intercultural teams. Therefore, competencies of the interpersonal exchange of information will be crucial.

Due to constant changes and developments in an advanced manufacturing environment, employees need to be open-minded towards lifelong learning and to be able to adapt quickly including skills such as stress tolerance, resilience, and determination.

However, it is important to stress that competences are linked to specific occupations, tasks, and sectors, making it difficult to generalize the answers obtained. Concerning the EXAM 4.0 competency model, the statements of interviewees have to be taken into account, providing all students and trainees with general competencies and specifying and deepening knowledge and skills in certain fields according to their occupation and tasks.

13 Detailed Country Report – Netherlands

This document summarizes the results of focus group meetings of EXAM 4.0.

ABBREVIATIONS

AM = Advanced Manufacturing

AR/VR = Augmented Reality/ Virtual Reality

EQF = European Qualification Framework

EXAM 4.0 = Excellent Advanced Manufacturing 4.0

I4.0 = Industry 4.0

IIoT = Industrial internet of things

IoT = Internet of things

M2M = Machine to machine

RFID = Radio frequency identification

CONTENTS

EXAM 4.0 FOCUS GROUP MEETING'S RESULTS

The Dutch national report was prepared within WP2 Learning Dialogues of the European research project EXAM 4.0. The objectives of the study are to identify the status of representative companies in the Netherlands with regard to digital transformation as well as to validate the two frameworks "EXAM 4.0 technology framework" and "EXAM 4.0 competence model".

The methodology used in the report was first to create a universal questionnaire, which was used in every partner country to contrast and compare results of the different EU regions and countries. Attendees received the questionnaire beforehand as support before we carried out expert interviews with the participants concerned.

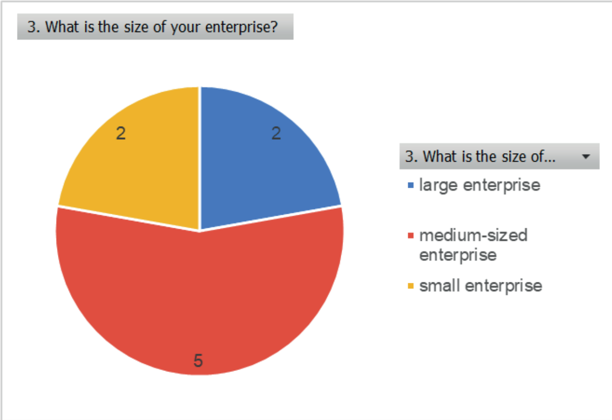
In the case of the Dutch research group, 9 participants filled in the questionnaire in total, 3 of whom partook in the expert interviews. Overall, 6 expert interviews took place online between June and August 2020. The participants represented 2 large companies (1 extra in the interviews), 5 medium-sized companies, 2 small companies, and 1 institution (Innovation Quarter program manager Smart Industry).

The results of this study do not represent a quantitative but rather a qualitative research approach. However, the selected companies are sufficiently representative to obtain and represent relevant information to be included in WP2 of EXAM 4.0.

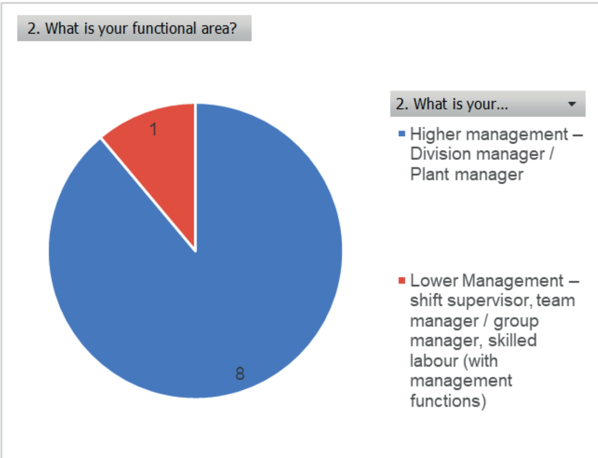
The study examines two aspects of the impacts of Industry 4.0. These two aspects are technology impacts and competences.

DEMOGRAPHICS

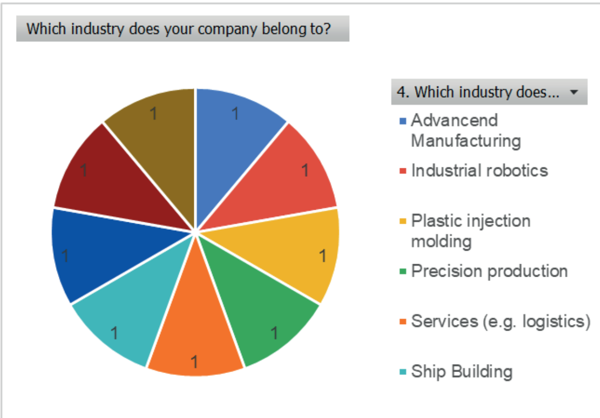
The survey was conducted with 9 companies, the majority of which are located in the South Holland province of the Netherlands.



1. Figure Sector and size of the respondents



2. Figure Functions of the respondents



3. Figure Industry

CURRENT STATUS

In the first part of the study, the attendees were questioned about the current status and situation of their companies concerning technological developments, qualifications, and current demands for employees.

With regard to initiatives of digitization and companies' progress towards Industry 4.0, most of the companies present a comprehensive and holistic strategy across the organization regarding:

- Developing innovative and differentiated products and services
- Finding growth opportunities for existing products and services
- Developing new business models
- Protecting their organization from disruption
- Understanding which skills will be needed
- Training and developing the workforce for I4.0

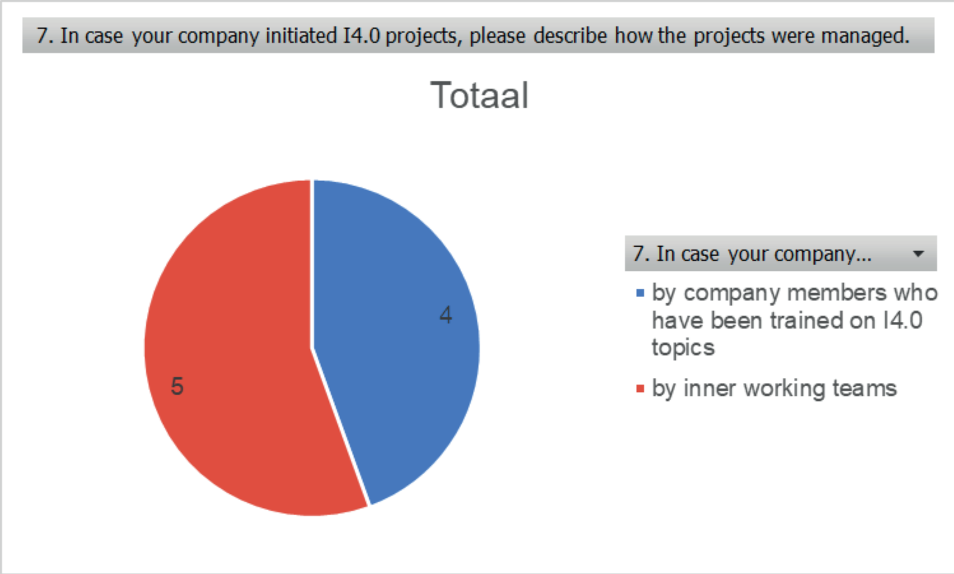
On average between holistic/ad-hoc approach:

- Identifying key areas to make effective I4.0 investments (4 – 4 – 1)
- Research into connected and integrated approaches in the value chain (4 – 4 – 1)

In addition, with regard to utilizing new labour models, few companies have already developed a comprehensive and holistic strategy towards the topic of digital transformation. Furthermore, the interviewed companies also show an ad-hoc strategy regarding the following area:

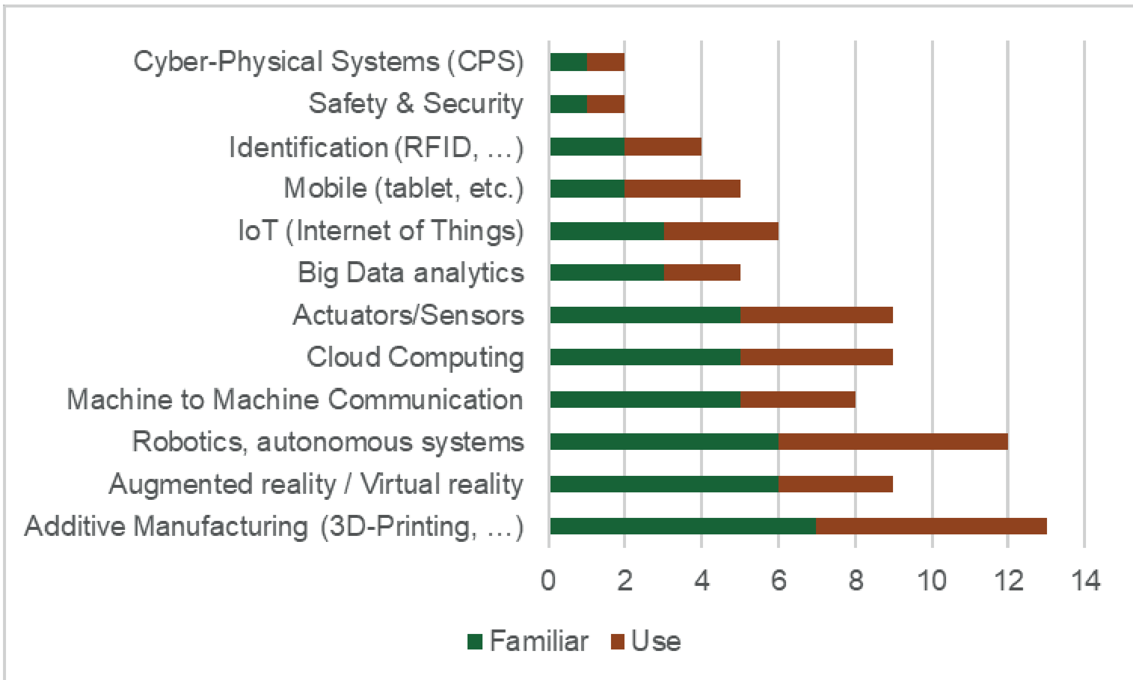
- Development of an I4.0 architecture (e.g. Big Data, cloud, IoT,…) (5 – 4)

Most of these projects were managed either by company members who have been trained on the topic of I4.0 or by internal working teams. Not one company project was led by outside consulting firms guiding the implementation.



4. Figure: executed projects managed by

Regarding technology enablers or Industry 4.0 applications, all listed technologies were evaluated by the companies whereas not all technologies have already been introduced in companies. Technologies that are often used by companies imply AR/VR technology, additive manufacturing, robotics & autonomous systems, Big Data Analytics, and cloud computing. Cyber-physical systems and smart actuators & sensors present technology enablers that are not frequently implemented in companies by now. Moreover, we may conclude that all companies have already introduced several or more than three technology enablers.



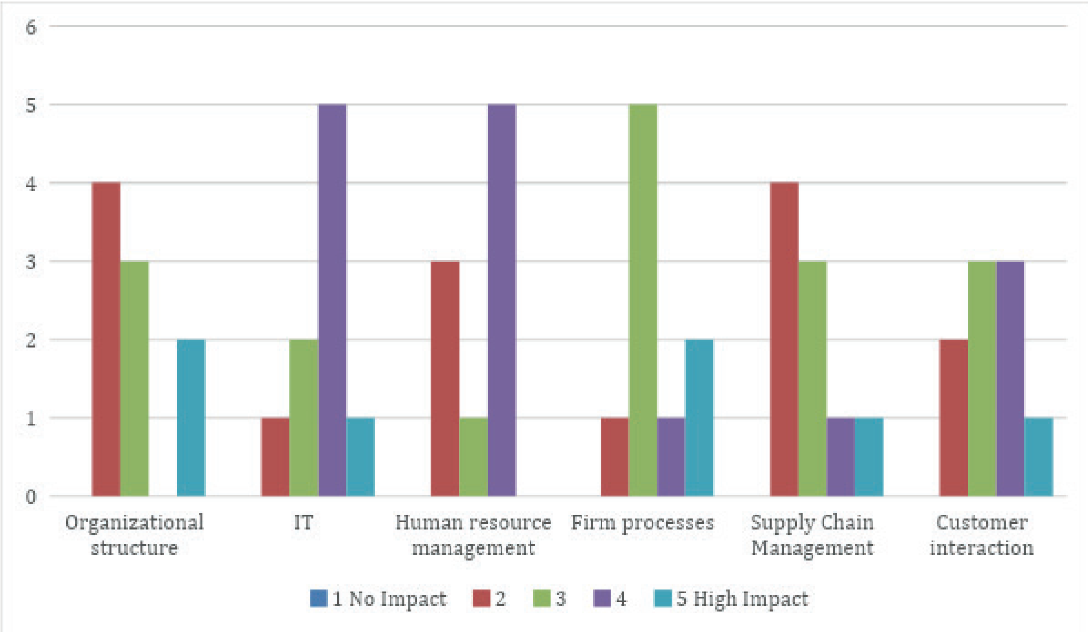
5. Figure: I4.0 technologies/applications,

An example of introducing trainees and graduates to technology is presented through learning factories in the sustainability factory (Duurzaamheidsfabriek). One participating company provides a learning factory for trainees where they can practice with robotics and measurement and control systems and evaluate data, so they learn how to deal with large amounts of data and interpret them correctly. Another company cited the example of using AR/VR technology. This technology enables workers to train on the systems in the field. Furthermore, participants emphasized the importance of introducing new technologies and applications in small steps. So that employees can get used to the idea and a change of consciousness can take place and be a part of the life-long learning strategy. As a result, employees show greater acceptance of implementing new technologies after being part of the project in the learning factory.

(10) The participants were asked to name and describe projects of technologies and applications they already initiated. The listed and described projects were widely spread amongst technology enablers and applications. However, two companies pursued the objective of prediction with analytical technologies. Further two companies listed projects referring to robotics. It may be observed that almost all companies have already initiated and executed projects. The medium-sized companies noted their projects. Some of the projects and explanations are listed below:

- Open Industry 4.0 Alliance adapters, Description: alignment to the practical standards/guidelines developed by the alliance that eases cross-vertical integration.
- Industrial Analytics / Machine Learning. New sensors to manage, analyze and optimize the production process and predict unexpected events / failures.
- Advanced production quality planning by automation
- Purchase and implementation of cutting robot and welding robot
- Tablets on the production workfloor to aid workers in using 3D models
- Tested two different types of augmented reality systems to assert the main benefits of use. One system was chosen to continue testing.
- IO-Link sensor data to Diagnostics & Prognostics. Description: adaptation of IO-Link in the process industry.

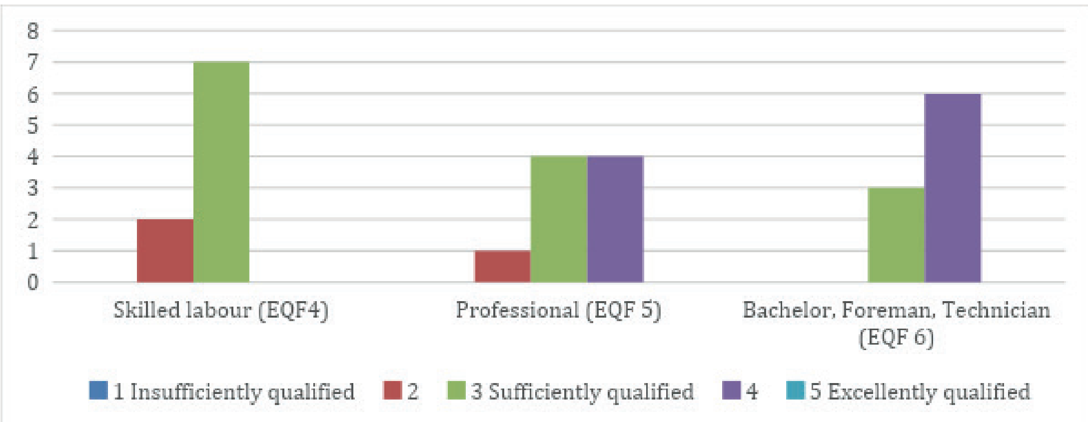
The results of the questionnaire show high IT impact. This, because that most companies interviewed, have already implemented some of the I4.0 technologies. The management of real-time data enabled by these technologies facilitates data exchange and makes it possible for companies to participate in the project. The high impact was also shown for Human Resource Management and to a lesser degree for customer interaction.



6. Figure: Impacts on the organization of implemented I4.0 technologies

Competences and skills

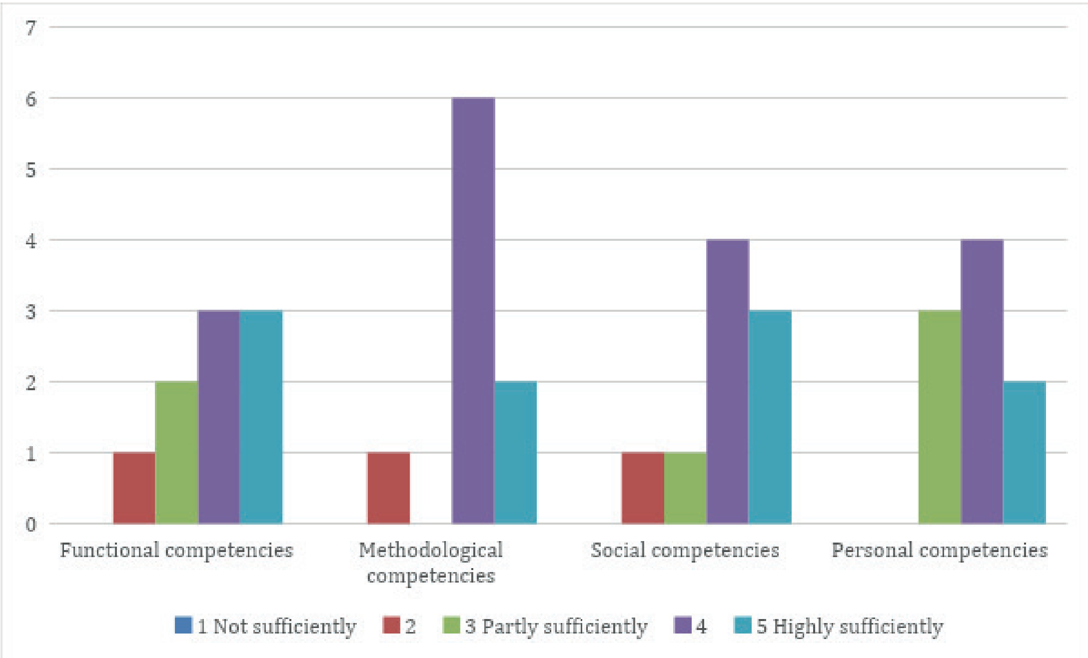
The following findings in the questionnaire were confirmed in the expert interviews: For EQF level 4 skilled workers were deemed sufficiently qualified for actual requirements. Functionaries at level 6 were considered well qualified. EQF level 5 workers scored average.



7. Figure: Requirements of qualifications for different department/unit

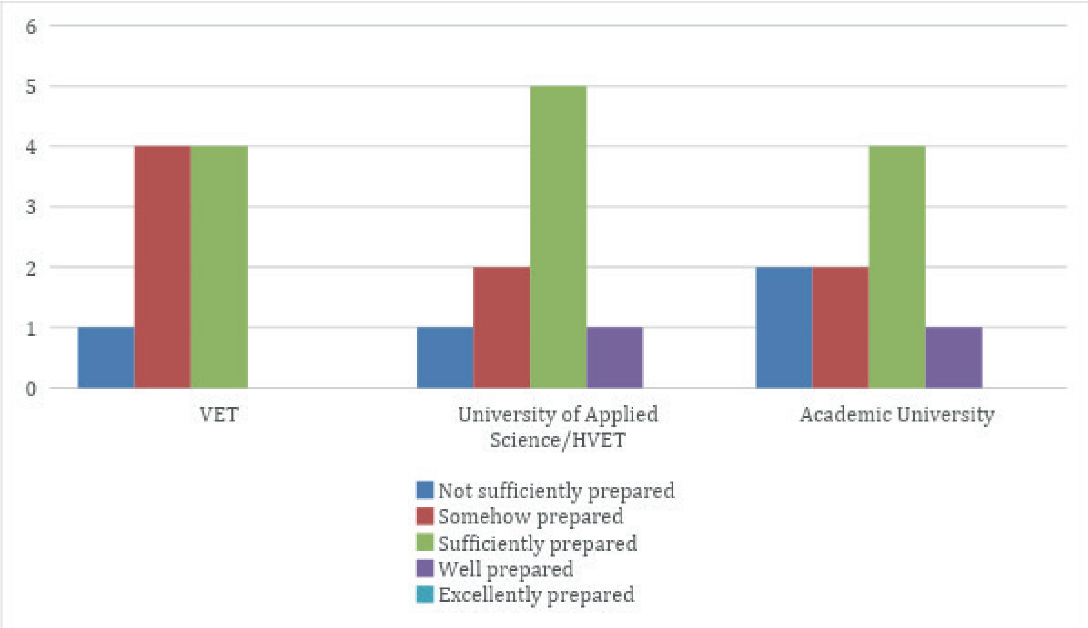
The majority of company representatives indicated that functional competencies are sufficient, whereas methodological and social competencies scored higher.

In the interviews, it was mentioned that Functional and IT competences are crucial for progress. The interviewees were also of the opinion that competences such as working in teams and communication are important, and that in The Netherlands such competencies seemed to be well-developed, requiring more balance to be found with functional and technical competences. Blending these types of competencies is important, both in individual persons and in teams.



8. Figure: Current requirements of Industry 4.0

Similar to question 12, the participants were asked to evaluate graduates regarding Industry 4.0 requirements. VET graduates are considered to be less well-prepared in the field of functional competencies, confirming the comments to the previous question. Graduates of academic universities scored better in this respect. Graduates of HVET and universities of applied science are sufficiently prepared for advanced manufacturing. Some interviewees indicated that VET students were generally good at communication skills, so-called 21st-century skills, but less well trained in functional competences. From level 5 upwards they noticed the opposite tendency. Graduates do introduce new impulses to the companies they enter and help to bring innovation into the company. Again, the need for balancing the different types of competencies was stressed.



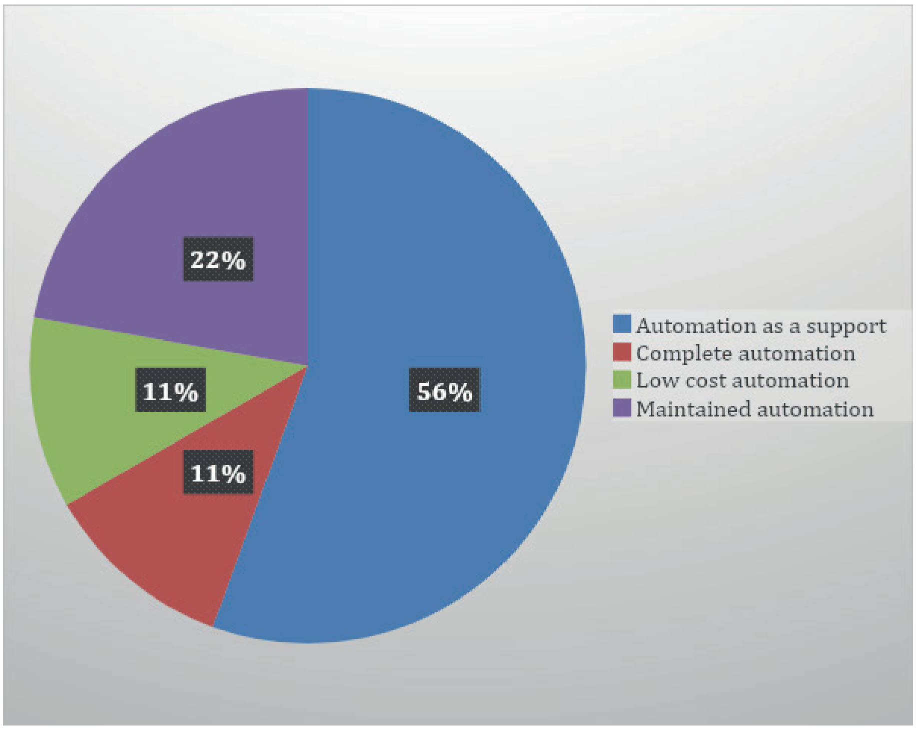
9. Figure: Qualification and competence level of the VET and HVET graduates regarding the I4.0 requirements

FUTURE TRENDS

The second part of the study explores future technological trends, changed demands due to Industry 4.0, and how to prepare and reskill employees for AM.

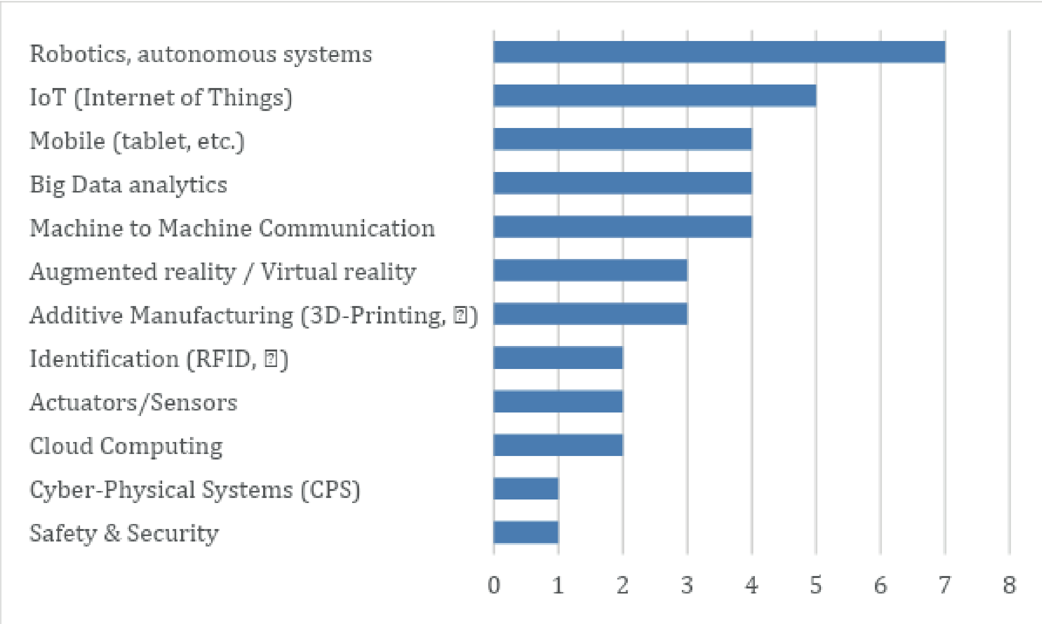
Technological trends

With regard to further developments pertaining to I4.0, the majority of participants forecast their companies to develop towards automation support or maintained automation in years. One company referring to the industry of machine tool even strives for development towards complete automation.



10. Figure: Development of the company in the next ten years

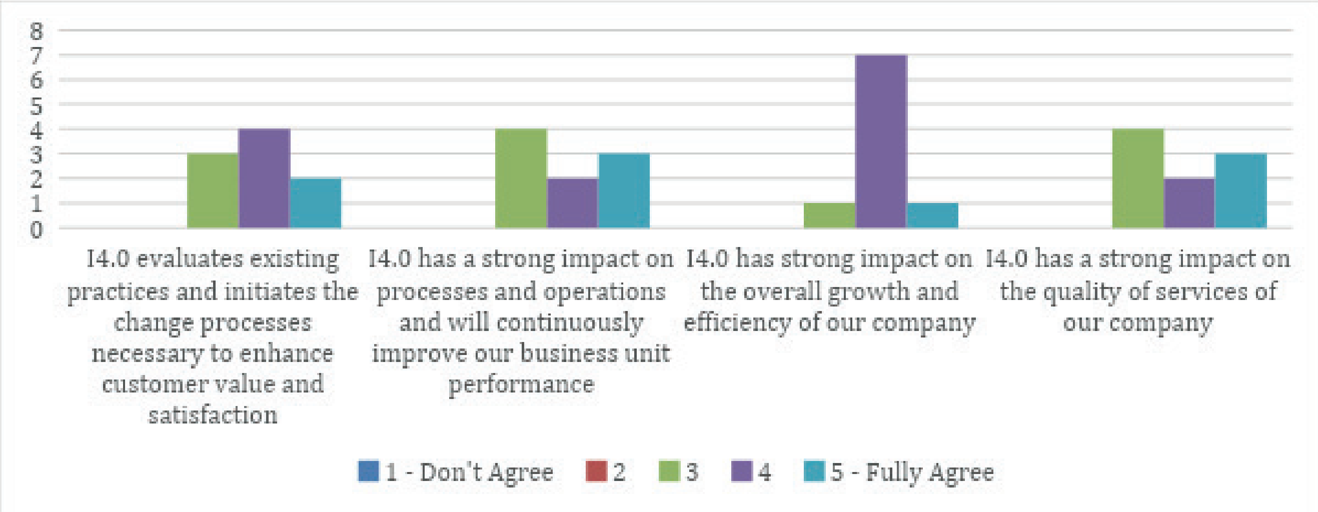
In the interviews a number of technology enablers for future introduction were frequently mentioned: robotics and autonomous systems standing out, followed by the concept of the Internet of Things, increased use of tablets during work processes, Big data analytics, and Machine to Machine communication. AR / VR and additive manufacturing are being introduced at a smaller scale. The other technology enablers from the table below were mentioned less frequently.



10. Figure: Development of the company in the next ten years

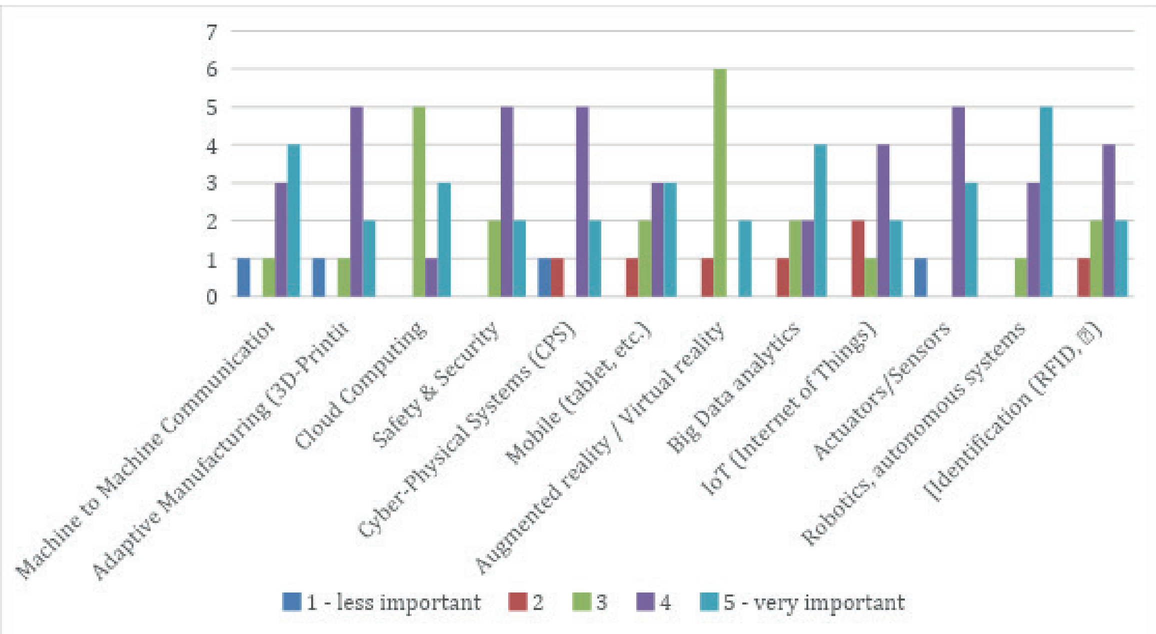
Moreover, the participants added further technologies that their company will introduce in upcoming years. For example, they listed artificial intelligence and machine learning, smart services, and IIoT.

With regard to the business impact of advanced manufacturing the interviewees mentioned especially the positive effect it would have on overall growth and efficiency, partly due to the evaluation of existing practices and improving on them to create greater customer satisfaction.



12. Figure: Impact on value chain

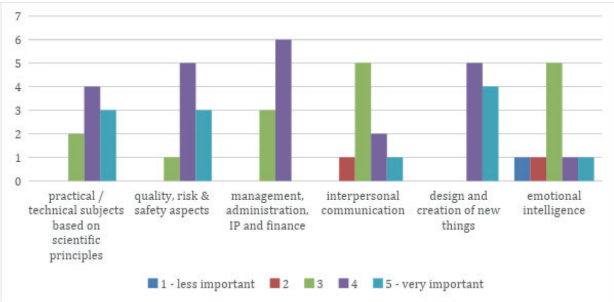
The participants were also asked to describe projects related to I4.0 that will be initiated in their companies. Larger companies indicated plans for future projects, but not all smaller companies were generally able to do so. In line with earlier questions indicating increased attention to robotics and autonomous systems, machine to machine communication, and increased use of adaptive manufacturing. According to the interviewees, technology enablers such as 3D manufacturing, cyber-physical systems and actuators, and sensors will be more widely introduced, and because of the increase in cloud computing and the impact of IT, also safety and security will require greater attention.



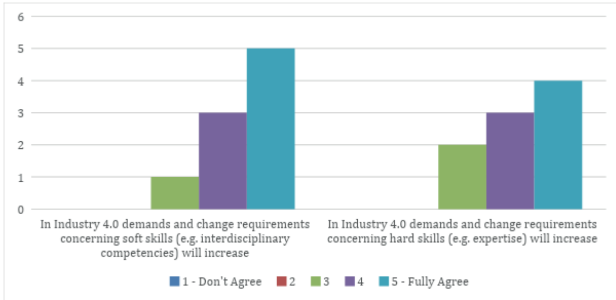
13. Figure: Importance of I 4.O technology enablers

The future evolution of Competences and skills

The digital transformation will require new competences of employees working in AM. In line with earlier questions, they are seeking for more balance between functional and technical competences and the so-called interpersonal competencies. The latter seem to be well-developed in The Netherlands, whereas in VET more attention is deemed necessary for the operational technical skills. This is underlined by the table below: figure 14. An extra topic that companies mentioned was the knowledge on regulation needed for development and especially implementation of new technologies.



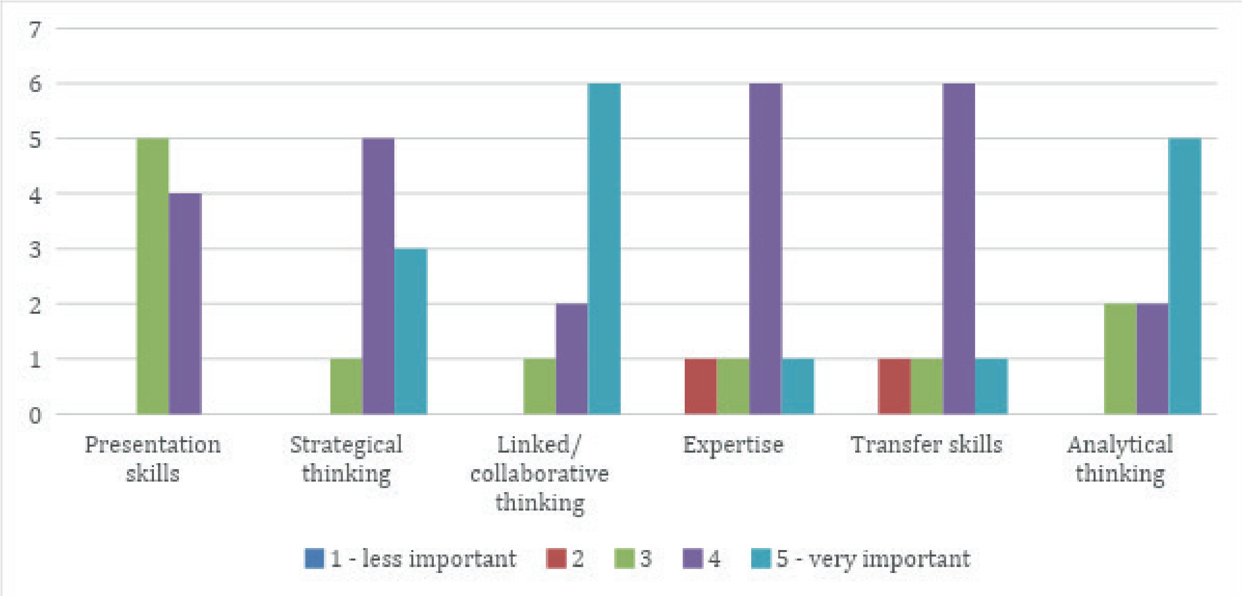
14. Figure: importance of competences related to I4.0



15. Figure: Importance of methodological competencies with regard to a future production environment of I 4.0

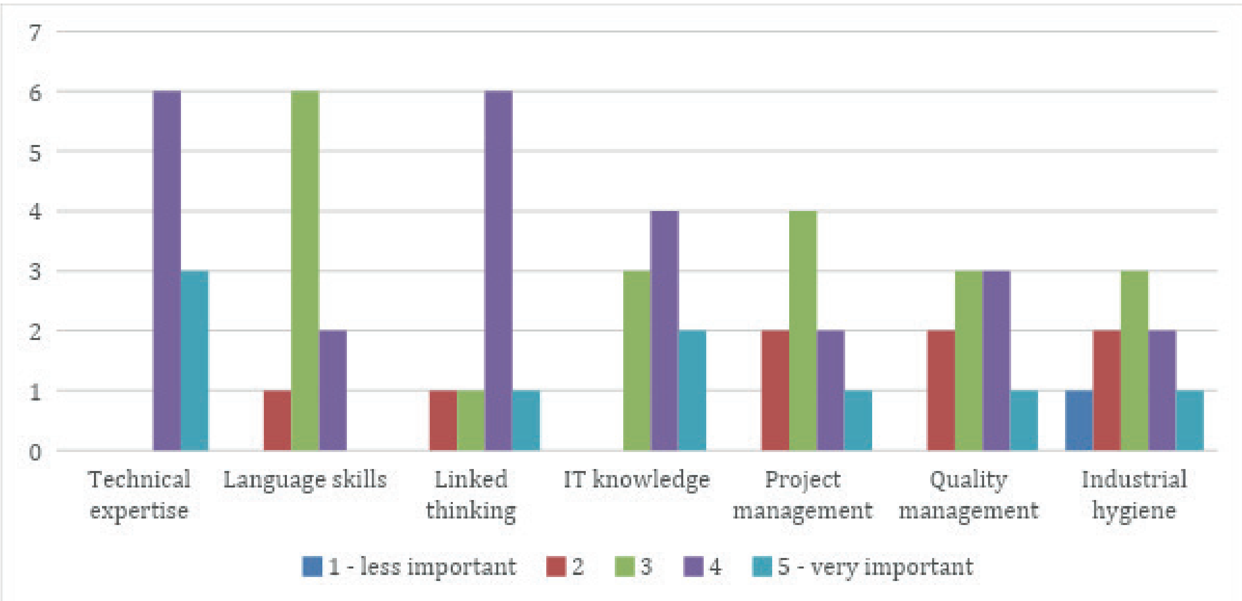
Concerning competence typologies, all four types of competences will be important in an advanced manufacturing environment. However, some competences tend to increase in importance.

Due to the increased complexity of AM working environments, there will be more emphasis on the development of analytical thinking, collaborative thinking, and transfer skills to be able to work in interdisciplinary work processes. Presentation skills are rated as sufficient. Some experts stressed that the composition of teams with the right mix of competences would be more effective than high-level individual competences in stand-alone settings. They also stressed the importance of having new workers tackle problems and coming up with possible solutions as a method of bringing about innovation.



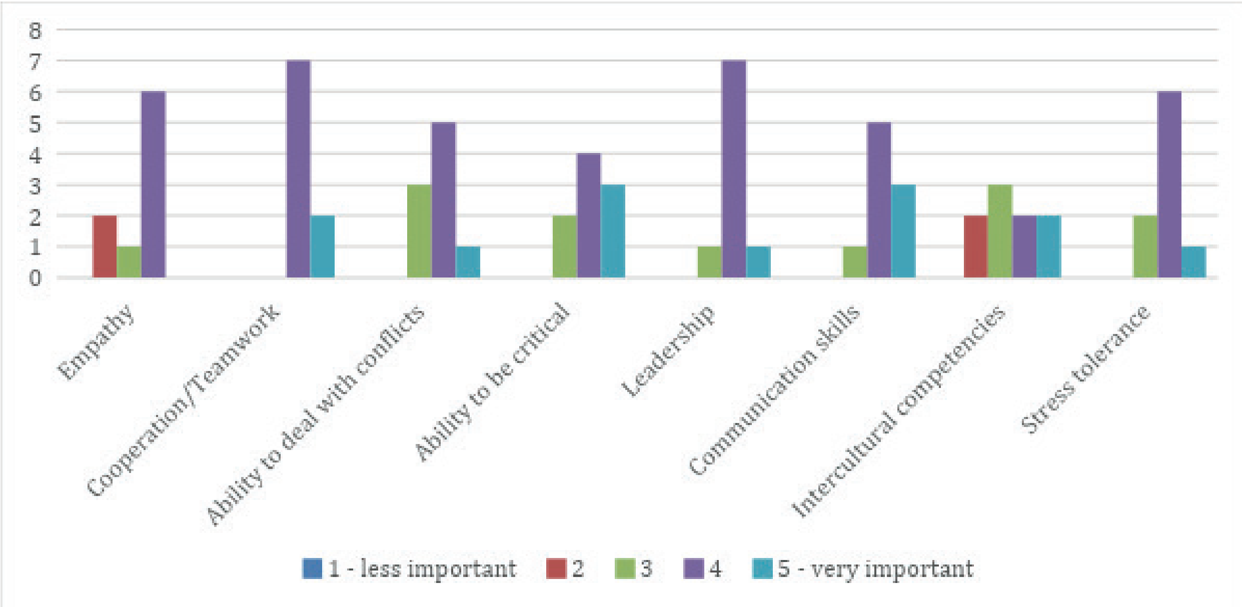
16. Figure: Importance of funtional competencies with regard to a future production environment of I 4.0

The above table shows that more collaborative thinking is required in the future, combined with increased transfer skills and analytical thinking. Again, some interviewees are looking for more balance in presentation skills and technical expertise, especially at a VET level.

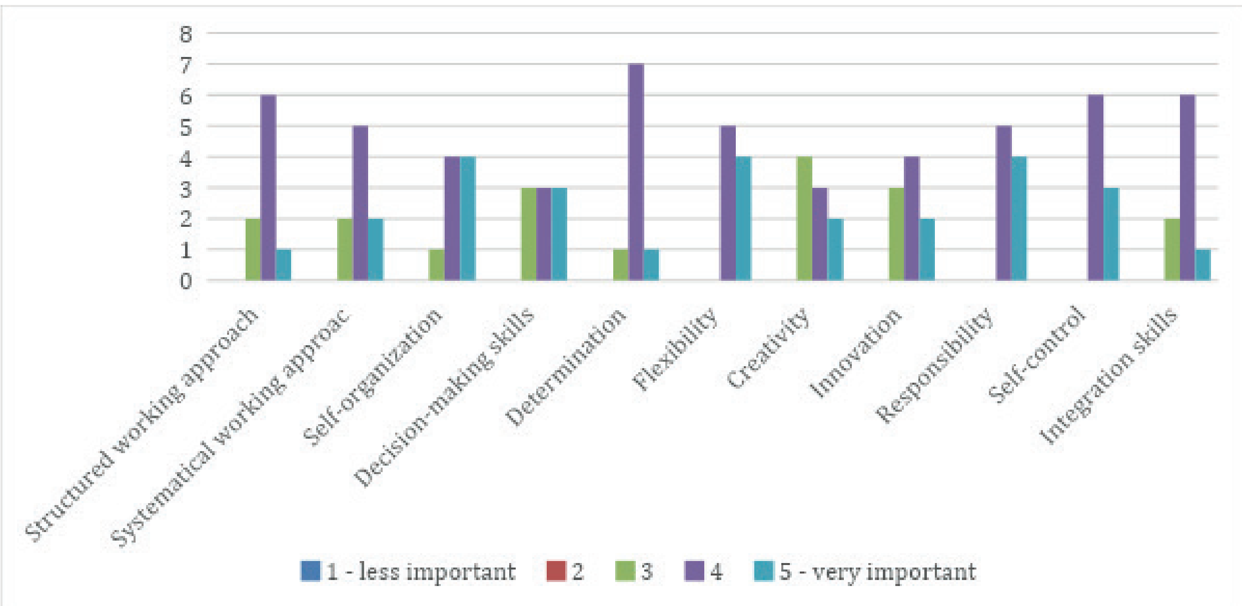


17. Figure: Importance of social competencies with regard to a future production environment of I 4.0

With regard to social competencies, competences such as cooperation /teamwork, ability to deal with conflicts, communication skills as well as stress tolerance will be required of employees working in advanced manufacturing, but this is a broad message also heard in other industries than AM.

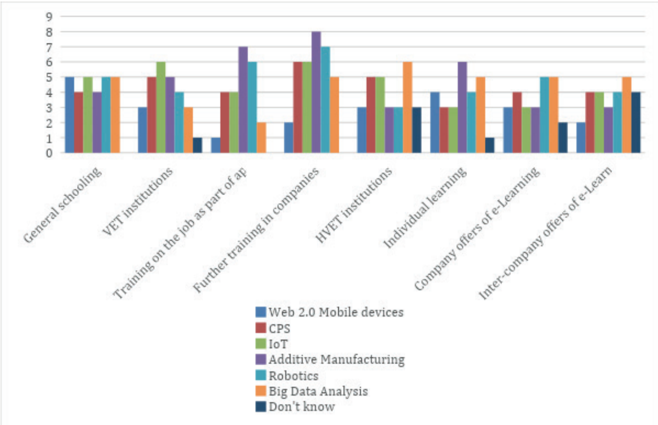


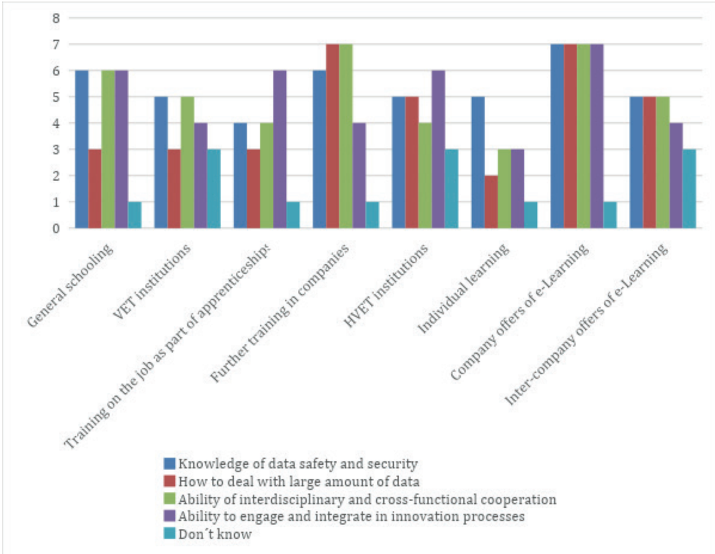
Personal competencies such as being able to cooperate with others in a team, showing leadership, empathy, and stress tolerance will be required of future employees. Since there will be continued gaps between the requirements of the labour market and the ability of schools to provide the right number of workers able to operate in AM environments, there will have to be a focus on recurrent training and upskilling, combined with re-skilling of those in danger of losing their job, or of those having difficulty entering the labour market. A company told in the interview that is not "only about the hands", but also about "the mental capacity" of the employee.



18. Figure: Importance of personality competencies with regard to a future production environment of I 4.0

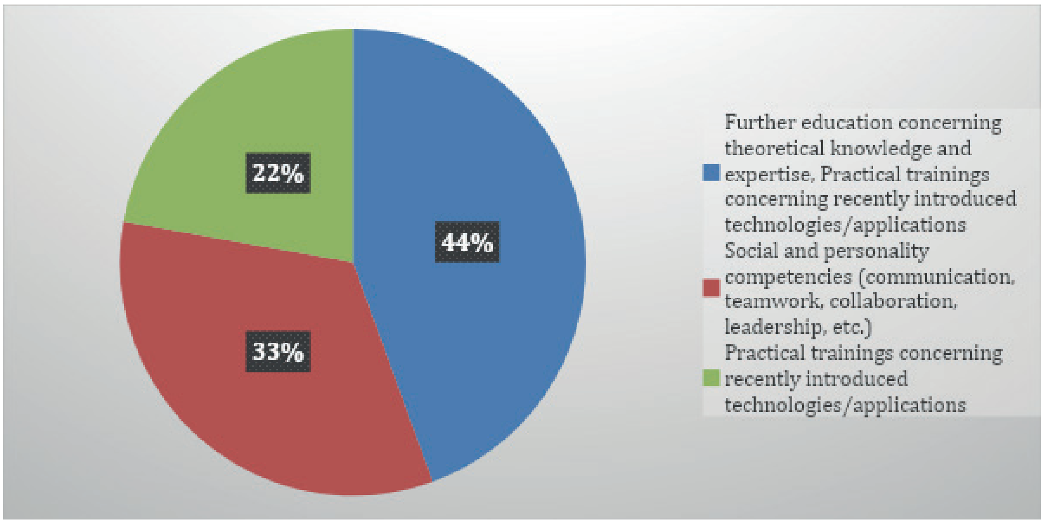
Initial education (both vocational and general) should train competences such as structured and systematic working. Personal qualities such as determination and self-control are also important qualities to develop. Some interviewees indicated that the development of interdisciplinary cooperation, the use of mobile devices during the execution of work processes, and taking part in projects are important in on-the-job training, or maybe practiced during apprenticeship periods in dual settings of work and education. The use of short interactive training through for instance e-learning should be linked directly to company projects or practical challenges, so that a more powerful learning experience may be had.





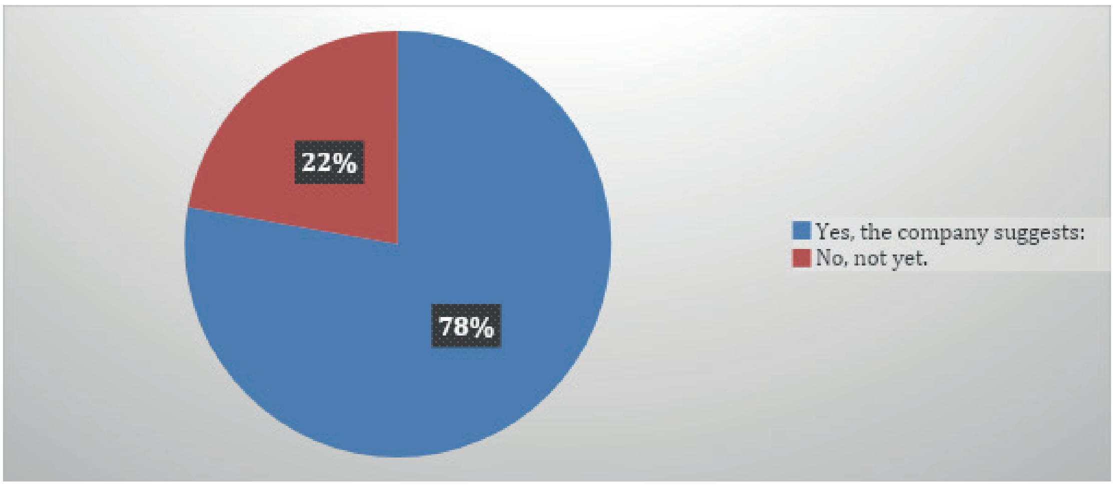
19. Figure: Main responsible party for teaching competencies

With regard to offers of upskilling or further education and training for existing employees, the vast majority of participants indicated their companies plan to further educate their existing employees concerning theoretical knowledge as well as training for social and personality competencies, such as teamwork, collaboration, and leadership.



20. Figure: Offers of upskilling or further education and training for existing employees

The majority of companies interviewed are thinking about concepts of training their employees for the future, the larger companies more so than others, in a more structured manner. Again, some interviewees indicated that providing employees with practical challenges and asking them to come up with solutions is a powerful tool for personal growth because in this manner they can show their strengths and interests. It will also help them to make decisions about their career, even by not pursuing certain paths in the future.



21. Figure Existence of strategies describing how to implement the approach of lifelong learning for employees concerning i4.0

CONCLUSIONS

The results of the study provide insights into the current status and future trends of Dutch companies concerning technology, competences, and demands. Larger companies generally have adopted more structured strategies company-wide. Also, the smaller companies have experimented with a range of technology enablers and applications, more often than not a combination of those. The implementation shows various stages of maturity. All the interviewees have indicated plans for introducing technology enablers, though not all of them have adopted a structured approach to this. It is mainly through experimentation that they are developing this approach. The importance of IT in many shapes is evident.

This also goes for the increase of 3D technologies and the increase of AR and VR during work processes. This requires the competence of using mobile devices as part of the production process.

Current employees and graduates entering the companies will constantly need to upgrade their competences and skills. Their starting qualifications are generally sufficient to provide a basis for further development of functional competences. Several interviewees have stressed the importance of balancing the personal skills that graduates usually acquire in initial education and the functional and technical expertise they still have to acquire in a working AM environment. The training institutions are insufficiently able to fill the gap between the demands of the labour market and the number and quality of the graduates entering the labour market.

There is a great challenge for (H)VET to cater for this gap and to train future employees for the rapid changes in the working environment both technically and as far as interpersonal skills are concerned. The Dutch government and the educational institutes are thinking about concepts of life-long development. This will require huge investments by companies, the government, and workers themselves. For traditional VET institutions, this also requires forward-thinking and training their staff to combine traditional educational paths with modern concepts of life-long development of non-traditional student groups. It may also involve the addition of new types of qualifications instead of traditional diplomas and certificates.

The interviews we held were qualitative rather than quantitative. This makes it difficult to describe THE state of the art in AM in The Netherlands, but the interviewed companies were a comprehensive group of the Dutch AM sector. We believe that the answers provided by the interviewees do represent several relevant developments and thoughts for the future of AM in the Netherlands, combined with the general trend report about the Smart Industry provided in the second part of this report.

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