EXAM 4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

ENGLISH

List of AM relevant skills required to work in an AM Workshop 4.0

Advanced manufacturing 4.0 LABs

03

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TKNIKA – Basque VET Applied Research Centre, CIFP Miguel Altuna, DHBW Heilbronn – Duale Hochschule Baden-Württemberg, Curt Nicolin High School, Da Vinci College, AFM – Spanish Association of Machine Tool Industries, 10XL, and EARLALL – European Association of Regional & Local Authorities for Lifelong Learning.

Abstract

Industry 4.0 sets new demands on workers, new technologies require innovative solutions, thus innovative workers who can adapt to the required adjustments and provide value to the Industrial sector. The new demands on workers does in turn generate new requirements on education. Research regarding methods for development of Industry 4.0 education have been carried out by Curt Nicolin Gymnasiet and the EXAM 4.0 consortium partners within Work Package 4 because of the new requirements. Work Package 4, in EXAM 4.0, includes definitions of requirements that a VET/HVET centre must fulfil to be able to provide students with key enabling skills and competencies that are crucial in the Advanced Manufacturing Sector. Models for describing institutions and LABs are included and tested by all partners of the consortium. The models and descriptions can be beneficial when defining new LABs, designed for excellent Advanced Manufacturing. Work Package 4 also contains information regarding relevant Advanced Manufacturing technologies, important aspects of Industry 4.0 and learning processes, such as methodologies and learning content regarding Industry 4.0 education. This report, Work Package 4.3, includes skills and competencies that are essential to success in the Advanced Manufacturing sector. Information regarding the most important competencies for Industry 4.0 and relevant skills are included in this report. The information is mainly based on a study carried out within EXAM 4.0, answers of representatives from companies in the consortium partners countries, accordingly Sweden, Germany, Netherlands and Spain.

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• Abbreviation

AM = Advanced Manufacturing

AR = Augmented Reality

CAD = Computer Aided Design

EXAM 4.0 = Excellent Advanced Manufacturing 4.0

HVET = Higher Vocational Education and Training

I4.0 = Industry 4.0

ICT = Information and communications technologies

IoT = Internet of Things

IIoT = Industrial Internet of Things

KETs = Key Enabling Technologies

VET = Vocational Education and Training

VR = Virtual Reality

WP = Work Package

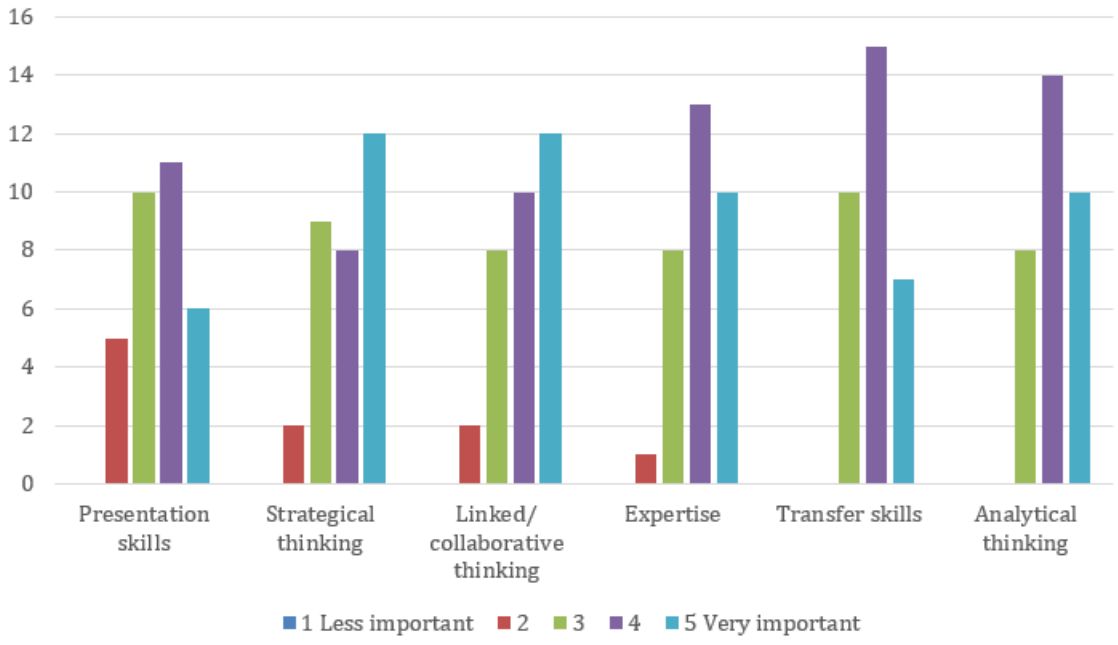
Introduction

The third section of the report includes skills and competencies that are required to work within the Advanced Manufacturing sector. A table of specific skills that include important aspects for people piloting an AM Workshop 4.0 is displayed in this section. Information regarding existing educational conditions relevant to Industry 4.0 and the educational effect on the Industry sector are presented as a part of an earlier EXAM 4.0 report.

List of AM relevant skills required to work in an AM Workshop 4.0

○ 3.1 AM soft skills/competencies

In this section requested Advanced Manufacturing soft skills/competencies, gathered from stakeholders in the consortium partners' countries, is presented. The information underneath is gathered from the results generated by the EXAM 4.0 focus group meetings. Representatives from different participating companies from each consortium partners' country were asked about the importance of various hard and soft skills regarding I4.0.



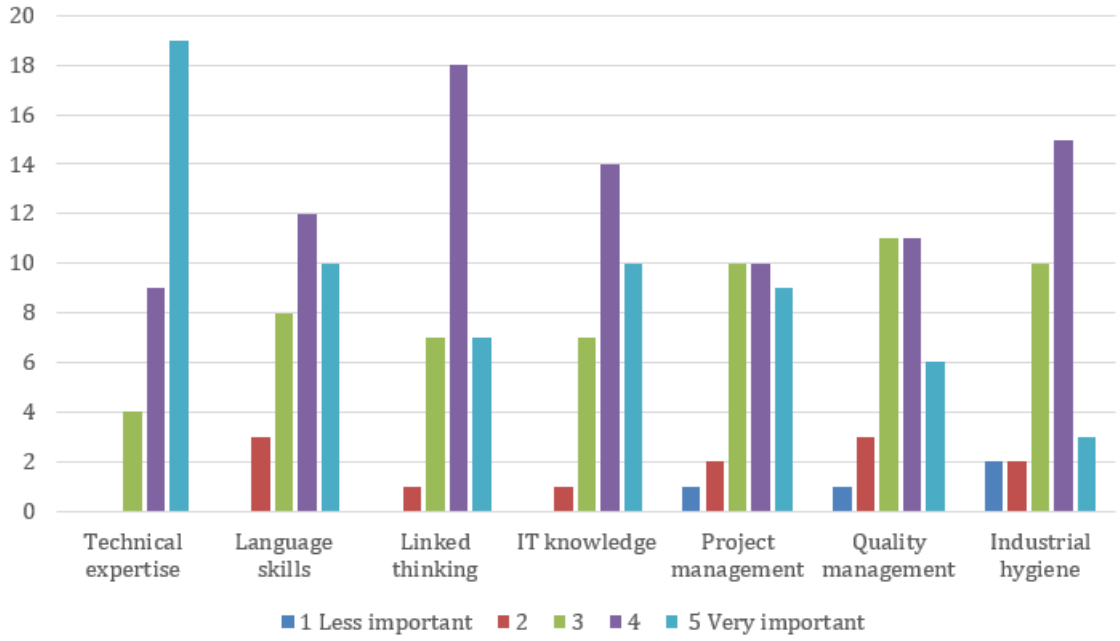
1. Graph: Importance of methodological competencies regarding a future production environment of I4.0

The different selectable methodological competencies were relatively equally important according to the participating countries' companies. Analytical thinking was however what the representatives found as the most important competence to obtain.

Problem-solving (which was not a selectable competence) is often known as a standard setup of blocks, these blocks are used to define a specific problem, setting a goal, deciding a solution for the problem and then applying the solution. Industry 4.0 is resulting in more complex problems, traditional problem-solving

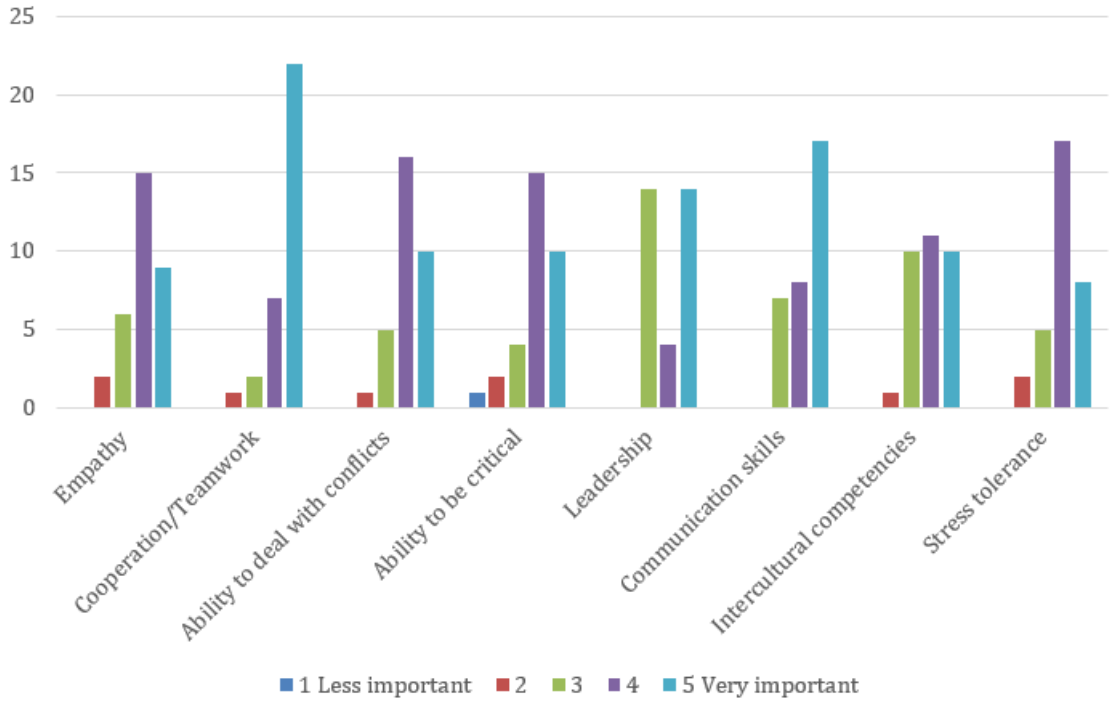
is consequently not always an adequate method. The industry is therefore, in these cases, in need of more advanced thought processes (Aventis Learning Group 2019).

There are suitable thought processes that are in need of improvement, these methods should be applied to effectively tackle intricate I4.0 problems. These thought processes are critical thinking, analytical thinking (which was observed as important by the representatives) and system thinking (Aventis Learning Group 2019).



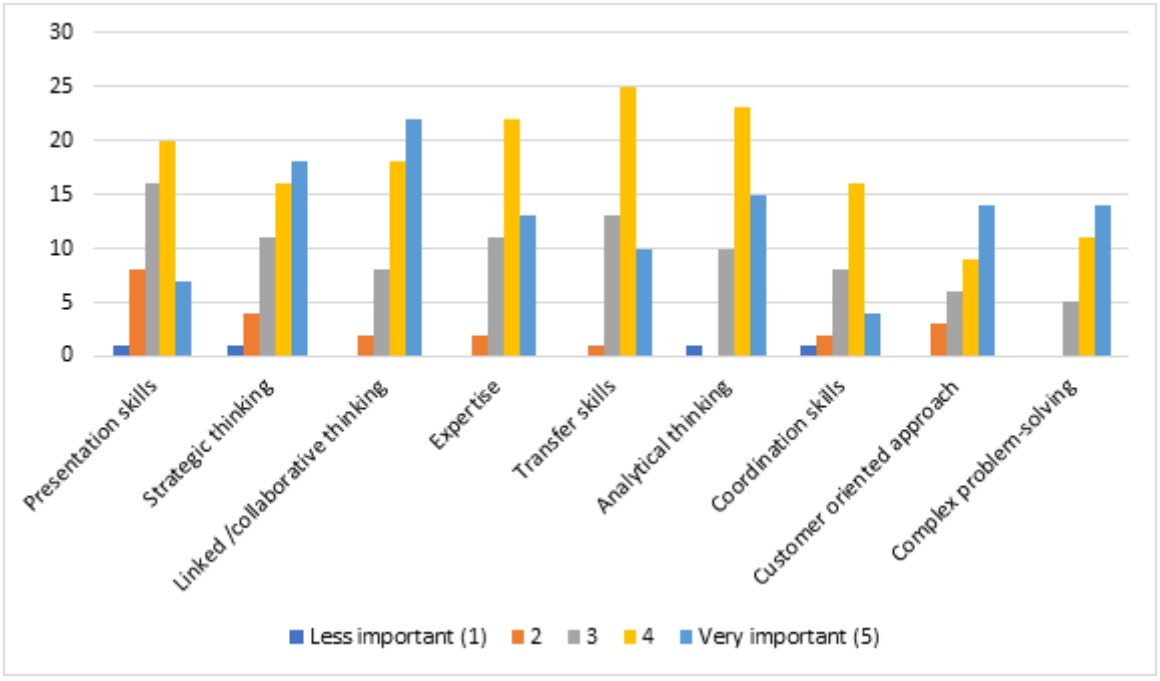
2. Graph: Importance of functional competencies regarding a future production environment of I 4.0

The answers of importance concerning the selectable functional competencies were not equally important as compared to the answers regarding methodological competencies. Technical expertise was considered the most essential functional competence with an average answer of 4,47, on a scale from 1 to 5 which represented the importance. The representatives believed that industrial hygiene was the least important competence, with an average of 3,53.



3. Graph: Importance of social competencies regarding a future production environment of I 4.0

Social competence is the most important competency to possess in order to be able to cooperate and work arbitrarily in a team according to the representative individuals participating in the interviews. Out of the 32 participants, 22 individuals answered that the competence "cooperation/teamwork" is "very important" for an employee to obtain. All the other social competencies were answered to be almost equally important except communication skills which were slightly more important.



4. Graph: Importance of personality competencies regarding a future production environment of I 4.0

All the different personal competencies were considered almost equally important. Innovation was however the competence that the representatives found most important regarding a future I4.0

production environment. Creativity was listed on Lead The Change Community to be the third most important skill (competence) to possess in 2020 regarding I4.0 (Lead The Change Community 2019), although it was not identified as very important by the representatives.

Similar focus group meetings have been performed within the same field, important competencies regarding I4.0. At a specific occasion, these interviews took place in Germany, Austria, Netherlands, Egypt and Switzerland. The representatives were lecturers with experience in areas like IT, IS, Economics and Engineering. These lectures and professors found behaviour competencies as the most vital, this study was however mainly directed to a different business group than the focus group meetings performed by EXAM 4.0. The behaviour competencies that the representatives found important were for instance communication competency, presentation ability and collaboration, these were important because they play a vital role in teamwork (Kienegger et al., 2017). These competencies are included in the survey performed by EXAM 4.0, mentioned in different categories, for example social competencies and methodological competencies.

Behavioural competencies will be most important regarding I4.0 according to the survey performed by Technical University Munich. They think that more research and analysing needs to be done regarding how already obtained competencies that students and employees have can be adapted for I4.0. The research should additionally be about new requirements for curricula and educational programmes concerning I4.0 (Kienegger et al., 2017).

○ 3.2 Learning outcomes

Requirements adjustments in VET/HVET to meet industry 4.0 demands

The curricula in VET/HVET have not adapted at the same rate as the industry. The VET/HVET centre graduates are not matching the direct needs of the industry according to stakeholders. Graduates cannot start work instantly, they must go across a money- and time-expensive training practice before they can accomplish tasks without direct guidance (CECIMO 2013, referenced in PwC 2020).

Nowadays, numerous education providers are barely considering evolving in order to match the educational demands of industry 4.0, even though successive methodologies exist and are addressed. Updating and refining the curriculum is a possible approach which involves complicated procedures. Organizing study programmes beyond faculties and divisions are challenging because of administrative complications. A lot of faculties and divisions have limited networks, thus not able to work beyond small groups because of 'silo thinking'. In order to successively face the demands, it is essential to work across faculties and divisions (Impuls Foundation 2019, referenced in PwC 2020).

Areas where change is necessary

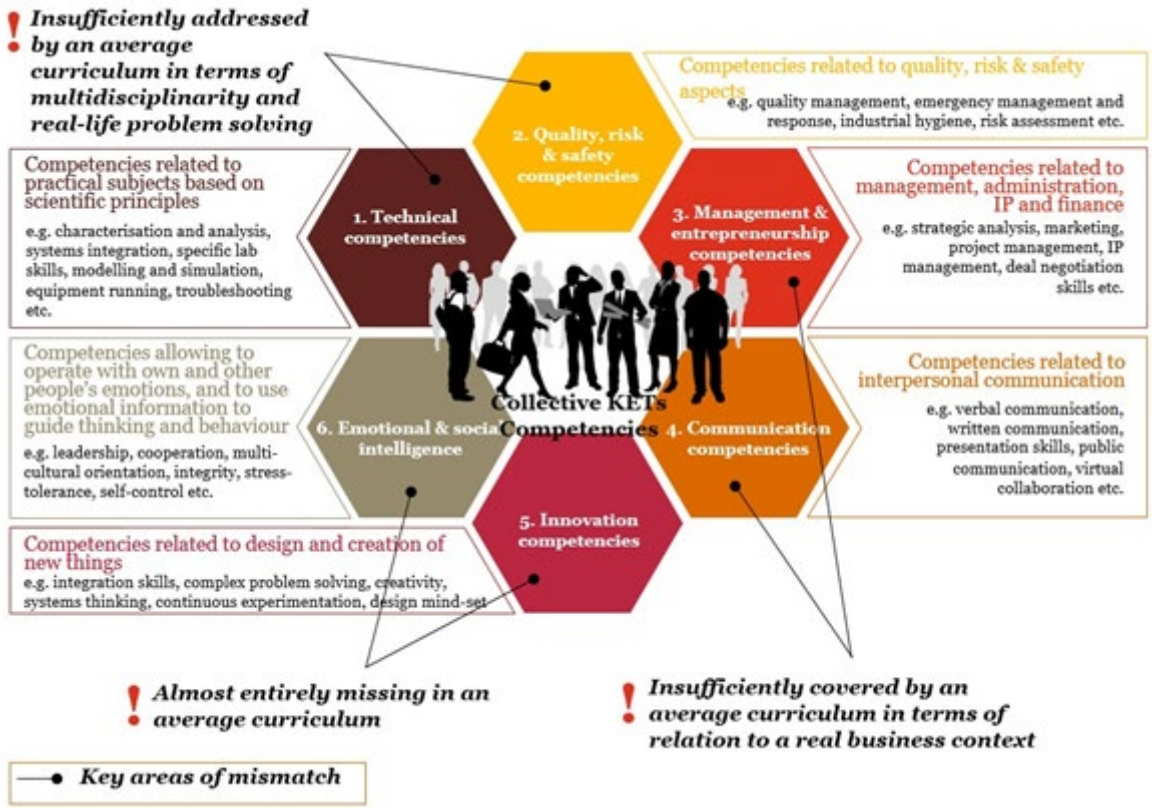


Figure 11 *Collective KETs competencies and key areas of mismatch* (PwC 2016, referenced in PwC 2020)

Figure 11 demonstrates a model of necessary changes in education required to succeed in teaching I4.0 required competencies.

In this model we can see what we need to address regarding learning outcomes:

1. Technical competencies
2. Quality, risk & safety competencies
3. Management & entrepreneurship competencies
4. Communication competencies
5. Innovation competencies
6. Emotional & social intelligence

Existing educational programmes do not include suitable and coveted non-technical- and technical skills which are vital for experts in the advanced manufacturing sector. Non-technical skills have turned out to be as essential as technical skills since there always are adjustments in the market-, legal-, cultural-, business-environment. To be able to provide service for purchasers from all over the world in larger teams are skills associated to problem solving, entrepreneurship, negotiation and communication essential (Impuls Foundation 2019, referenced in PwC 2020)

Regarding technical skills some students do not have the knowledge that is required to work in an actual organisation, this is often a result of outdated software and equipment used in education. With limited

access to new equipment students will lack the expertise required to work within the advanced manufacturing sector, thus not able to independently perform assignments at companies that use the latest versions of software and equipment.

FESTO points out that schools cannot keep up with the development speed of companies, graduates will therefore not have the right expertise when applying for a job. It is therefore necessary for schools to cooperate with companies or I4.0 organisations (FESTO n.d). Technical educational programmes are often missing non-technical skills such as leadership-, innovation-, entrepreneurship-, marketing- and sales skills. These skills do not get enough recognition compared to what is desired for a technical student regarding advanced manufacturing (PwC 2020).

Schools do frequently focus their education on learning specific facts and using problem-solving learning within a limited area of knowledge. The educational approach that is needed for advanced manufacturing results in a knowledge that can be used in multiple fields. Educational programmes need new ways of teaching, these new methods must change the current traditional ways of thinking. As a result, students will learn to see linkages between unconnected fields and be able to create linkages between these. Additionally, programmes do often struggle to teach students how to transform theoretical knowledge to real industrial problems, yet this is a highly desirable attribute in new advanced manufacturing, industry 4.0, recruits (PwC 2020).

Existing programmes often fail to find balance between quality and quantity when it comes to educational content and skills. Stakeholders argue that there is no approach that should always apply. Education requires a balance between specific and general knowledge and skills, companies prefer graduates with different degrees of specific knowledge (PwC 2020).

There are differences between occupational groups within advanced manufacturing, thus a lot of differences between the educational content. A specific occupation might require more general knowledge and skills while another occupation needs more specific knowledge and skills (PwC 2020).

Teaching modern skills in a modern way

The advanced manufacturing skills that are essential in the 21st century are not necessarily new. These skills have been around during the course of history (Rotherham and Willingham 2009, referenced in PwC 2020)

There is so much new knowledge generated that many stakeholders believe that the actual knowledge of information does not matter. They believe that the ability to find information is more important than possesingthe information. One is not more important than the other, possessing the information is just as important as the ability to find information. The task is to deliver information as well as skills to successfully enhance the learning outcomes for employers, employees and students. Information and skills should therefore be treated as equal when teaching (Rotherham and Willingham 2009, referenced in PwC 2020).

Skills and competencies to address regarding Industry 4.0

Industry 4.0 creates needs for a copious and various amount of skills (Fitsilis, Tsoutsa and Gerogiannis, 2018). The term skills in the context of industry 4.0 is most often used as the term competence, thus used incorrectly. More research has been done regarding important competencies for industry 4.0 than specific skills. The report therefore mainly focuses on competencies. Important skills follow the development of technologies, in this case industry 4.0, and are described with respect to them. Robotics is for example a key enabling technology of advanced manufacturing, knowledge regarding programming of robots is therefore essential.

The identified competencies are divided in four groups in Leinweber's study (Leinweber 2013, referenced in Fitsilis, Tsoutsa and Gerogiannis 2018).

There are many methodological competencies that are essential for technical students to encounter during education in the EXAM 4.0 LABs. According to Fitsilis, Tsoutsa and Gerogiannis the competencies creativity, entrepreneurial thinking, problem solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation are vital to be educated (Fitsilis, Tsoutsa and Gerogiannis 2018). There are certain

competencies that are necessary to teach in the EXAM 4.0 LABs. These are creativity, entrepreneurship, problem solving and decision making. Creativity, entrepreneurship and problem solving are described as important competencies according to Grzybowska and Łupicka (Grzybowska and Łupicka 2017). Grzybowska and Łupicka claim that creativity is vital for an employee in the 21st century (Grzybowska and Łupicka 2017). Creativity is crucial to see challenges in a new and helpful way, to come up with new solutions and make linkages between otherwise unrelated topics (Grzybowska and Łupicka 2017).

There is a need for a greater number of specialists (Vieweg 2011, referenced in Abele, Metternich and Tisch 2019). Studies show that there is a noticeable alteration in the direction of more jobs requiring competence and knowledge (CEDEFOP 2010, referenced in Abele, Metternich and Tisch 2019).

Fitsilis, Tsoutsa and Gerogiannis claim that intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to be compromising and cooperative, ability to transfer knowledge and leadership skills, social competencies are important for technical students to encounter (Fitsilis, Tsoutsa and Gerogiannis 2018). The most essential social competencies that need to be educated in EXAM 4.0 LABs is language and communication, teamwork and cooperating.

According to Fitsilis, Tsoutsa and Gerogiannis flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset and compliance are the most important personal competencies (Fitsilis, Tsoutsa and Gerogiannis 2018). The personal competencies that are required for every student to learn in EXAM 4.0 LABs are flexibility, open-mind towards life-long learning, to have a sustainable mindset and stress tolerance.

Fitsilis, Tsoutsa and Gerogiannis claim that all professionals working with advanced manufacturing are in need of constant training and development (Fitsilis, Tsoutsa and Gerogiannis 2018). Further Fitsilis, Tsoutsa and Gerogiannis claim that this is because of constant change regarding technological development, globalisation, industrial restructuring, increasing role of ICT and new patterns of work organisation (Fitsilis, Tsoutsa and Gerogiannis 2018). Professionals, in this case teachers, are in constant need of development to keep up with the requirements from advanced manufacturing organisations and companies. Fitsilis, Tsoutsa and Gerogiannis point out the necessity of life-long learning and the necessity it has for individual development (Fitsilis, Tsoutsa and Gerogiannis 2018).

Requirements for an industry 4.0 educator

The paragraph above will be used to summarize what is required from a teacher who teaches in an EXAM 4.0 LAB:

- A teacher educating **in an EXAM 4.0 LAB is required to pass through continuous advanced manufacturing courses. Alternatively stated as life-long learning.**
- A teacher educating in an EXAM 4.0 LAB is required to be **in possession of all competencies listed in earlier stated paragraphs as well as qualified to teach them.**

Curriculum Guidelines Framework

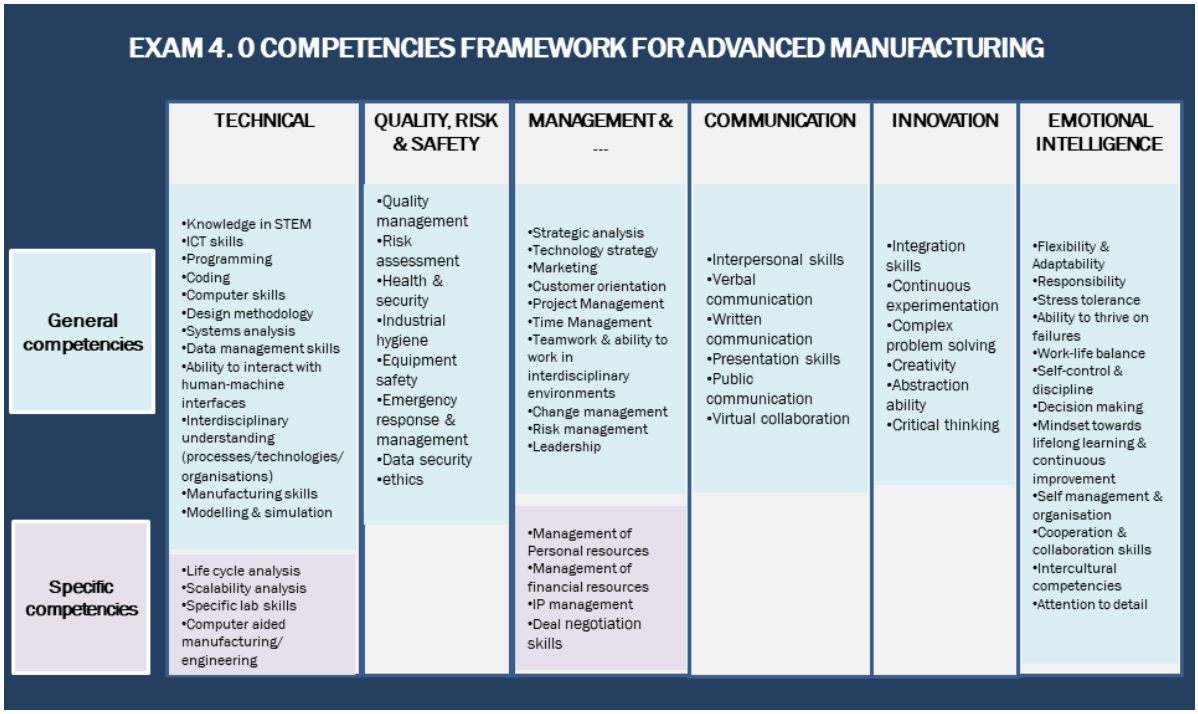


Figure 12 *COMPETENCIES FRAMEWORK FOR ADVANCED MANUFACTURING* (EXAM 4.0)

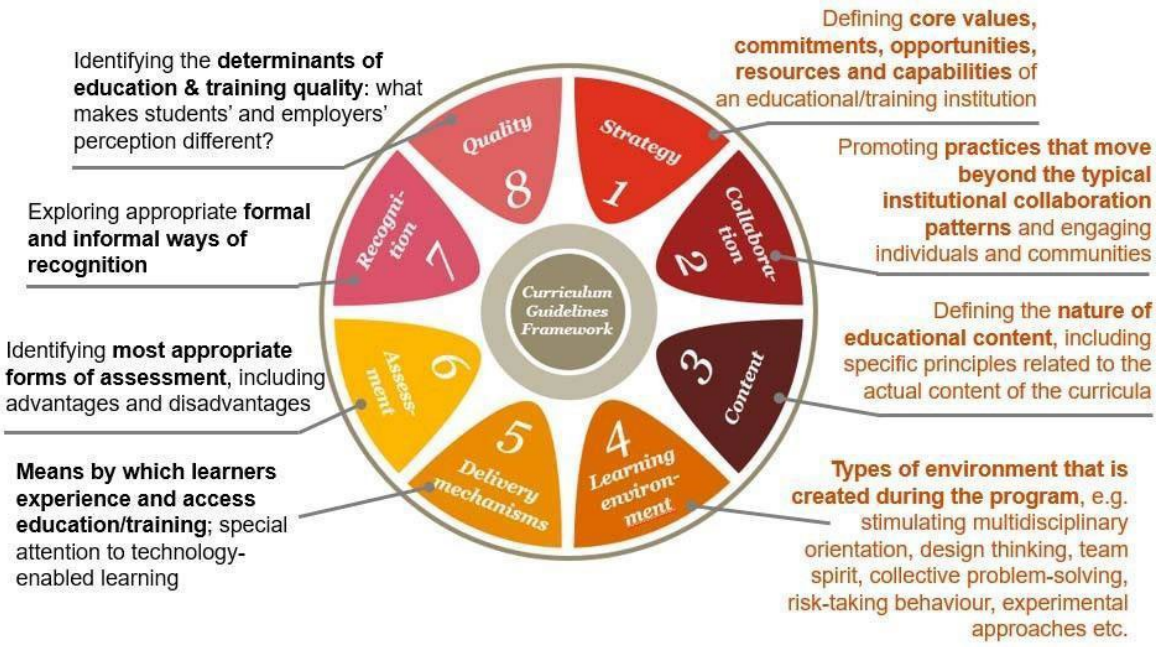


Figure 13 *Curriculum Guidelines framework* (PwC 2020)

PwC implies that "there is no one size fits all approach" (PwC 2020) in education (PwC 2020).

PwC indicates that the goal with the Curriculum Guidelines Framework is to deliver a complete view over all relevant aspects for the curriculum, to view the curriculum as the education capability of individuals during the course of their professional lives (PwC 2020).

The Curriculum Guidelines framework, figure 13, is based on eight unique but intertwined phases (PwC2020).

The first four phases are further described since they required key attention in order to reshape the curricula according to stakeholders (PwC 2020).

Strategy

- After the study programme the student should be ready for lifelong learning in other words possess the willingness and capability to participate in endless learning during the course of their career.
- Offers complete education, acknowledges the broader view of how the learning offer fits into the overall learning path and the labour market.
- Taking into account not only the learner's societal and characteristic needs but also the stakeholders' needs such as employability.
- In order to succeed with personal development, employment as well as in the presence of a knowledge society the learners need to transform knowledge to competencies.
- To present relevant personal and personalised training it is essential to reach beyond conventional curriculum goals and learning outcomes.
- To involve students in curriculum development and implementation.

Collaboration

- To expand and improve the collaboration between schools and stakeholders in order to increase the number of collaborations and the forms of collaboration.
- To concede the stakeholders part as employment, research and educational partners, guaranteeing that they take responsibility in the students' learning experience.
- To make it easier for schools to share experiences among them.
- To implement peer-to-peer learning in order to make the students learn from one another as well as together.
- To connect stakeholders by applying learning ecosystems.
- Transition from human-machine communication to human-machine collaboration as a developing form of collaboration.

Content

- To face the educational demands for industry 4.0, it is essential to upgrade the technical side of the curriculum.
- To implement non-technical competencies in the curriculum.
- To involve matters of sustainability, ethics, diversity and social inclusion.
- To offer a complete viewpoint of system and product lifespans.
- To educate students and workers to never stop retrieving information from the ever increasing "ocean" of data as well as how to use the information retrieved.
- To educate students and workers to be aware of their safety and ergonomics, thus the essential requirements to maintain good mental and physical health. To teach the probable results of risk exposure.

The learning environment

- To get the student to work with tasks without traditional solutions to learn to think freely, with help of problem-based learning.

- To teach creativity by forming an educational environment that would help the student form personal views and understandings.
- To create an educational environment where failure is acceptable, memorized as useful educational experiences.
- To make educational environments which can give the students practical experience.
- To offer students virtual and physical spaces for collaboration, learning with stakeholders for example.
- To encourage technology-enabled learning.

(PwC 2020)

3.3 Educational effect on the economy

Here are some examples pointing out the importance of education within industry 4.0 regarding economy and wealth:

- From an economic perspective, the quality of education improves the individual's income, competition between companies and economic growth (Gylfason 2001, Hanushek and Woessmann 2007, Barro 1996, referenced in Abele, Metternich and Tisch 2019).

- Managers' and engineers' knowledge and capability creates the base for the financial profit for today's and future companies (O'Sullivan, Rolstadås and Filos 2011, referenced in Abele, Metternich and Tisch 2019).

- It is said that when skills such as research skills, entrepreneurship skills as well as managerial skills are missing, it affects the innovation capability regarding fundamentally new products, process efficiency and quality (Tether et al. 2005, referenced in Abele, Metternich and Tisch 2019).

- Improved innovation ability, higher flexibility as well as more value-adding actions are examples of educational outcomes (Smith 2001, referenced in Abele, Metternich and Tisch 2019).

- The industry sector is essential for the economy in every nation. The industry in Europe stands for beyond 26% of the value-added share in the non-financial business economy (Eurostat 2016, referenced in Abele, Metternich and Tisch 2019).

- 75% of GDP and 70% of the jobs in Europe are associated with the industry (O'Sullivan et al. 2011, referenced in Abele, Metternich and Tisch 2019).

To summarize the educational effect on economics, education regarding production and manufacturing etc, is affecting the real industry. The industry is in turn affecting both the individual and worldwide economy. 70% of the jobs are estimated to be associated with the industry (O'Sullivan et al. 2011, referenced in Abele, Metternich and Tisch 2019). It is therefore vital to have appropriate education for the actual and future demands of the industry. The knowledge possessed by engineers and managers is what affects companies in a positive or negative way. It is therefore essential to acquire good quality and appropriate knowledge from education in order to create future financial growth for companies, individuals and nations.

3.4 AM technology in education

This is an example of how Advanced Manufacturing technologies can be utilized in order to educate competencies essential for Industry 4.0.

Results regarding evaluation of teaching methods from a research with focus on the fourth industrial revolution and the Korean National Competency Standards in South Korea showed that Virtual Reality is the prime method for development of competencies (Lee and Shvetsova 2019).

There are numerous games available for Virtual Reality, it is possible to educate via these games and virtually train real work tasks. The possibilities of games and non-limitations of simulation give the opportunity to educate numerous competencies.

Technical expertise:

Technical expertise is required to faultlessly be able to handle a state of art technology which is essential in the fourth industrial revolution. Learning to handle the actual VR-equipment, even without games, helps learners to receive more technical expertise.

IT knowledge:

There are numerous types of software for VR/AR learning. It is important to possess IT-knowledge to be able to use VR/AR associated software and to solve occurring problems. IT-knowledge obtained during VR-learning can be transferred into other situations related to IT, important for I4.0.

Communication and cooperation skills:

Development of communication skills is necessary to learn cooperation in VR since one important aspect of teamwork is communication. Communication skills can easily be educated via VR-games. VR is a useful method for educating cooperation/teamwork. The trainer can set up cooperative learning tasks to improve students' teamwork abilities. The tasks can be performed in online VR-rooms or between a non-using VR-student instructing a student using VR.

Problem solving:

It is vital to be an advanced problem solver in the fourth industrial revolution. New technologies require innovative minds to face the new complex problems. Developing the competence problem solving fits excellently with VR-learning since numerous learning games practically were designed for problem solving.

○ 3.5 Table of specific skills

Table of the specific skills linked to the profiles of people piloting the AM Workshop 4.0 designs

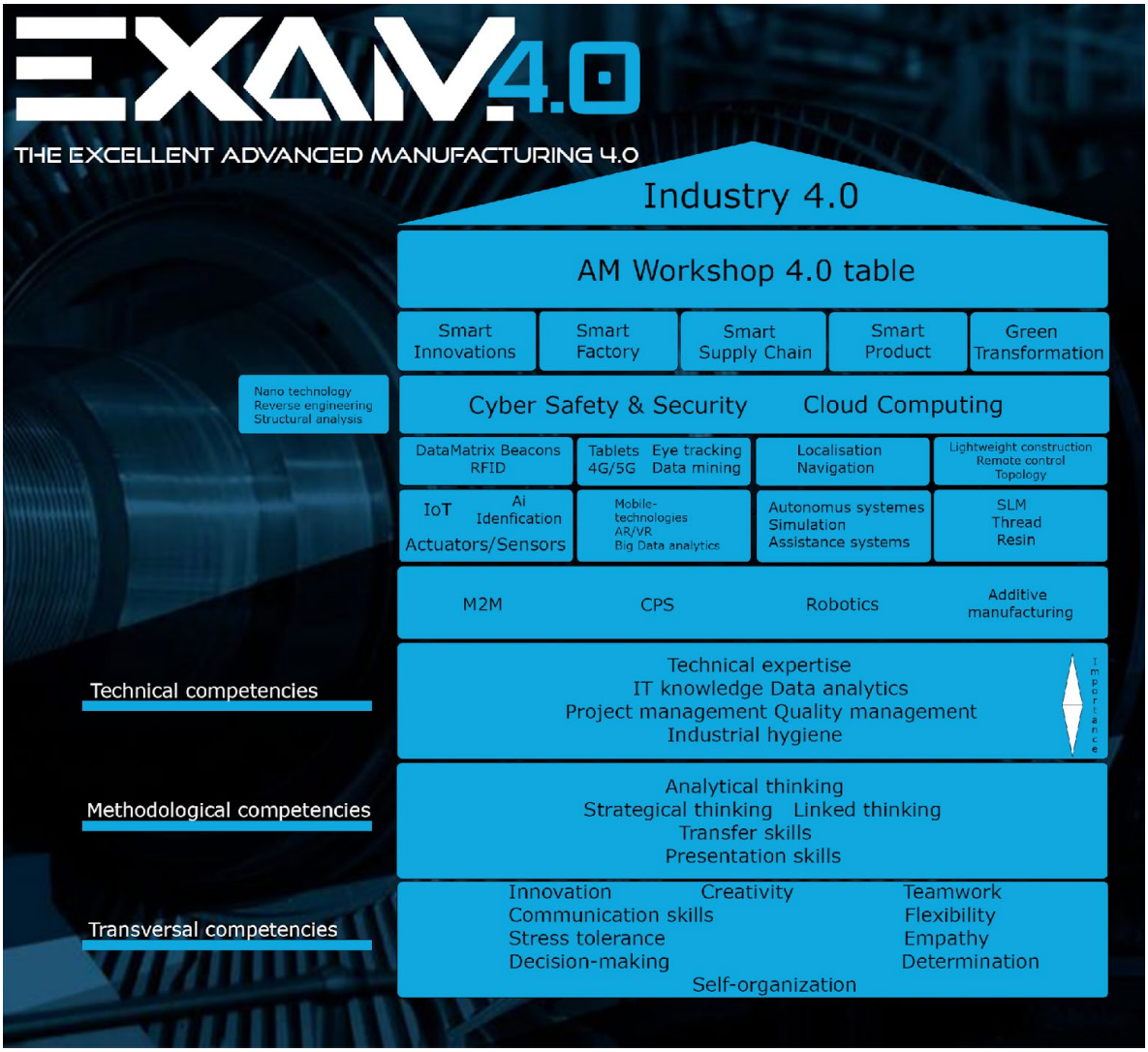


Figure 14 *Table of specific skills* (EXAM 4.0)

Competencies are one of the most important aspects regarding specific requirements for people piloting an AM Workshop 4.0, thus workers within the advanced manufacturing sector. Competencies make the foundation, the base of our house, of the figure 14 regarding Industry 4.0. The content of the table is that workers within Industry 4.0 need to have transversal, methodological and technical competencies in order to succeed in their career. The picture above shows the most important competencies within each of the three groups, separated into three different rectangles, according to both sources and internal research within EXAM 4.0. The competencies' importance is ranked by EXAM 4.0 researchers based on the aforementioned studies, the competencies are presented most important to least important from top to bottom. Transversal competencies refer to competencies that are not linked to a specific job, thus transferable between different jobs (Heron 2019).

Transversal competencies settle the foundation of competencies for an Industry 4.0 employee according to EXAM 4.0's table. It includes competencies such as creativity, innovation and teamwork that are important in many jobs consequently for an Industry 4.0 employee. Industry 4.0, advanced manufacturing, results in new technologies and methods. Competencies such as creativity and innovation are therefore vital to face new complex problems and challenges.

Methodological competencies constitute the second layer of competencies in the AM Workshop 4.0 model. These competencies are more specifically targeted towards specific work areas than transversal competencies and the methodological competencies in this table are essential for I4.0.

Technical competencies are competencies that are connected to a particular working area. Different job sectors require specific knowledge and therefore various specific competencies. It is important to obtain

technical competencies required for a specific field in order to become a well trained employee (Zamboni 2018). The technical competencies in the table are connected to Industry 4.0.

The middle part of the house shows layers of different technologies that the worker, depending on their working area, must have either knowledge or skills within. A worker who works with a specific I4.0 technology needs to have extraordinary knowledge within the matter unlike an employee who works with all I4.0 technologies in a more general way.

Example of a technology, Additive Manufacturing, and relevant skills

Skills:

- 3D Engineering
- 3D CAD: Designing, repairing, modifying 3D CAD data
- Finishing: Assembling, painting, sanding, enhancing a 3D model
- Scheduling: Managing multiple materials, shipments, machines, orders, etc
- Maintenance: Calibrating, repairing, and testing 3D printers
- Material Handling
- Parts Measuring

(Vulkov n.d)

Today's Additive Manufacturing engineers and designers were trained to use traditional production techniques to manufacture, in this way, they also have this conventional technique thinking embedded. Their creativity is limited because of this traditional way of thinking (Knezic 2017).

It is for example vital that the next generation of Additive Manufacturing designers and engineers develop creative thinking and, in this way, become able to think beyond conventional thinking regarding production techniques. Creative thinking is therefore one of the essential competencies for an I4.0 employer who works with Additive Manufacturing.

The upper part of the house shows different but very important aspects of industry 4.0. The worker must have knowledge within these aspects in order to succeed in the Advanced Manufacturing sector. These are Smart factories, Smart innovations, Smart supply chains, Smart products and Green transformation.

• Appendix

Difference between skills and competencies:

When searching for information regarding skills and competencies it is easy to get lost in what actually applies. The terms "skills", "hard skills", "soft skill" and "competencies" are frequently used, but in different contexts. There is not exactly a real definition of the specific meaning of the different terms and they are frequently used in different contexts. The terms skills and hard skills are in this report defined as synonyms and soft skills and competencies likewise, in order to reduce confusion for the reader.

	Definition	Examples
Skills	Specific learned abilities that you will require to perform a given job successfully	Handling accounts; coding; welding; writing tenders; computer programming; foreign language proficiency
Competencies	Knowledge and behaviours that lead you to be successful in a job	Analytical ability; problem-solving; initiative; negotiation; improving business processes; strategic planning; data-based decisions

Figure 9 *SKILLS VS. COMPETENCIES* (McNeill 2019)

Figure 10 *WHAT'S THE DIFFERENCE BETWEEN A SKILL AND A COMPETENCY* (McNeill 2019)

A skill is an ability that is necessary to physically handle a work task, for instance coding, welding or writing (McNeill 2019).

A competence is more in the context of knowledge or behavior in order for a person to be successful at the workplace. Examples of competencies are social competence, analytical thinking and creativity (McNeill 2019).

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EXAM4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0