EXAM4.0

THE EXCELLENT ADVANCED MANUFACTURING 4.0

Table of AM sectoral Skills and Profiles. ESCO

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EXAM 4.0 partners:

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1 Introduction

Industry 4.0 evokes many changes and developments concerning all economic sectors, as well as aspects of life. The changes impact the technical field of companies such as products, services, processes as well as qualifications, organizational and life aspects. The digitization of work provokes progressive mechanisation and developments of systems and devices. However, digitalisation not only evokes changes in technologies, but also leads to changes in skills and competences for future employees working in an advanced manufacturing environment. In the course of the research project EXAM4.0, a competence model was developed concerning future skills and competence requirements for employees. The European multilingual classification of skills, competences, occupations and qualifications provides information about 2 942 occupations and 13 485 skills on the plattform (CEDEFOP, 2015). The research in this report focuses on comparing future skills requirements concerning occupational groups referring to the AM sector, for example mechanical engineering technicians, computer scientists and industrial engineers, provided on ESCO to the EXAM4.0 Competence Model (CEDEFOP, 2015).

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EXAM 4.0 Competence

2.1. EXAM 4.0 Competence Framework

There are many different frameworks and models concerning future skill requirements. The models reach from a holistic view on changed requirements due to the transformational process to detailed lists of skills and competences referring to sectors or areas. However, the objective in EXAM4.0 is to define a competency model for employees working in the advanced manufacturing sector. In order to develop this specific framework, there was a study carried out with 54 participants. The study implied a questionnaire as well as focus group meetings with the respondents.

Based on the qualitative analysis of the results of the focus groups, questionnaires and the studies of PwC EU Services and the Technical University of Munich, a competence model for employees in an Industry 4.0 environment was created as a synthesis. Similar to the KETs Model, the EXAM4.0 Competence Framework is also structured into six competence categories. However, the competences assigned to the individual categories have been complemented with competencies displayed in the KETs competence model and the Prifti model (Prifti L. et al.).

The six competence categories are divided into technical expertise, quality/risk/safety, management & entrepreneurship, communication, innovation and emotional intelligence.

The first category of the competence model for workers in Industry 4.0 presents the largest number of competences and skills, similar to the model of the KETs Initiative study. The high relevance of technical competences in the future is also confirmed by the results of the survey. This category includes technical competences related to IT knowledge, technical expertise, programming, modelling, coding, system analysis and design methodology.

Moreover, this category also includes data management skills such as data analytics and interpretation as well as skills related to big data. An interdisciplinary understanding of processes, systems and organisations will also be relevant for employees in Industry 4.0 in the future. Furthermore, competences concerning specific technologies, such as skills in dealing with artificial intelligence, cloud computing, sensors or mobile devices, are summarised in this model under the term human-machine interface.

The second category, quality, risk and safety, implies competences such as quality management, safety and health for workers. Emergency management and industrial hygiene are also considered in the model. Data security was identified by participants from all partner countries as one of the biggest risks of Industry 4.0. Companies are

increasingly introducing intelligent systems and technologies that collect customer information and analyse relevant data. For this reason, skills in this area are crucial for employees.

Management and entrepreneurship skills are also relevant for future employees. This category includes, for example, a customer-oriented approach and analytical thinking, due to the continuously growing amounts of data and analyses. Furthermore, this category includes teamwork, marketing skills, project, time, risk, change management and leadership skills.

Communication presents the fourth competence category of the model, pertaining the interpersonal exchange of information. This includes verbal, written and public communication skills, as well as presentation skills and conflict management. Virtual collaboration will become increasingly important in the future, as employees in Industry 4.0 will predominantly work in teams that extend beyond national and company borders.

The fifth category, innovation, includes competences concerning integration, creativity, critical thinking and abstraction skills. In addition, complex problem-solving skills, transferability and collaborative thinking display further key competences in this category.

The last category includes competences such as adaptability and flexibility, self-discipline and control, cooperation, decision-making skills, sense of responsibility and self-management. In addition, intercultural competences and the ability to work in interdisciplinary teams as well as collaboration skills and stress tolerance also belong to this category.

Furthermore, the model displays a differentiation within the different competence categories. The categories imply basic and specific competencies, whereas specific competencies can refer to different occupations, subject aeras or tasks. Therefore, a differentiation into basic competences, which concern all employees in Industry 4.0, and specific competences is also implemented in this model.

In the first category of competences, specific competences relate to specialist areas or certain work tasks. Basic competences, such as programming, coding, handling human-machine interfaces or ICT skills, are key competences for working in an Industry 4.0 environment. Life cycle analyses, scaling skills or lab skills are related to specific fields of expertise and tasks. They are not needed by all employees in advanced manufacturing and are therefore specific competences. Furthermore, this category also includes technical expertise and the use of certain programmes and special technologies, for example CAD and CAE programmes.

Furthermore, there is another differentiation of competences concerning management and entrepreneurship. In this competence category, however, the differentiation does not take place with regard to technical expertise, but refers to the respective position or EQF levels. Employees who work in middle or higher management are required to occupy skills such as personnel or financial management in addition to technical expertise and competences due to their leadership function.

Moreover, the use of technology and systems enables businesses to cooperate internationally and beyond company borders, as information and data can be obtained and presented in real time. As a result, negotiation skills and competences in financial resources and IP (intellectual property) management are required for future employees in managerial positions.

	TECHNICAL	QUALITY, RISK & SAFETY	MANAGEMENT	COMMUNICATION	INNOVATION	EMOTIONAL INTELLIGENCE
GENERAL COMPETENCIES	Knowledge in STEM ICT skills Programming Coding Computer skills Design methodology Systems analysis Data management skills Ability to interact with human-machine interfaces Interdisciplinary understanding (processes/ technologies / organisations) Manufacturing skills Modelling & simulation	Quality management Health & security Industrial hygiene Equipment safety Emergency response & management Data security ethics	Strategic analysis Analytical thinking Technology strategy Marketing Customer orientation Project Management Time Management Teamwork & ability to work in interdisciplinary environments Change management Risk management Leadership	Interpersonal skills Verbal communication Written communication Presentation skills Public communication Virtual collaboration Ability to deal with conflicts	Integration skills Continuous experimentation Complex problem solving Creativity Abstraction ability Critical thinking Transfer skills Collaborative thinking	Flexibility & Adaptability Responsibility Stress tolerance Ability to thrive on failures Work-life balance Self-control & discipline Decision making Mindset towards lifelong learning & continuous improvement Self management & organisation Cooperation & collaboration skills Intercultural competencies Structured & systematic working approach
SPECIFIC COMPETENCIES	Life cycle analysis Scalability analysis Specific lab skills Computer aided manufacturing/ engineering		Management of Personal resources Management of financial resources IP management Deal negotiation skills			

Table 6: I4.0 Skills Framework Source: Exam 4.0 2020

2.2. ESCO

ESCO is the European multilingual classification of skills, competences, occupations and qualifications (ESCO). The objective of the platform is to contribute to a better understanding of education and training providers concerning what skills are required by labour markets so they can adapt their curricula accordingly to prepare students better for their working lives and labour markets. Furthermore, ESCO presents a useful platform not only for education and training providers but also helps potential employers to get insights of students' learning outcomes regarding respective qualifications. The platform contributes to a better understanding between employers and institutions and fosters transparency regarding required skills and competences when working in specific occupations, the demand of qualifications on the labour market as well as learning outcomes of qualifications. The database presents an extension of the International Standard Classification of Occupations (ISCO). On the website it provides 2 942 occupations and 13 485 skills linked to the occupations. Within the occupational profiles displayed on the platform, ESCO lists definitions and explanations of the respective jobs as well as required skills, knowledge and competences. There can be a similar observation regarding the required skills, competencies & knowledge, ESCO also differentiates between essential and optional skills, knowledge and competences.

In the following, occupational profiles of ESCO referring to different jobs in the AM sector will be compared to the EXAM4.0 competence framework.

2.3. Occupational Profiles in Industry 4.0

2.3.1. Mechanical Engineering Technicians

The occupational field of mechanical engineers opens up a broad spectrum of career paths and presents a high level of diversification and field of application. Employees referring to this occupational group pertaining technicians and the ISCO level 3, are working in different economic sectors such as agriculture, marine industry or production industry. Therefore, the provided list displaying optional competences, skills and knowledge of mechanical engineers is more extensive than the list presenting essential knowledge, skills and competences of this occupational group. According to ESCO, essential skills

and competences of mechanical engineers imply designing engineering components as well as adjusting and reading engineering designs, analysing test data and liaise with engineers. The first presented skills and competencies concerning design can be compared to the competence of design methodology in the EXAM4.0 Competence model. Regarding the EXAM4.0 model, the competence of systems analysis implies the skill of analysing test data. The essential skill of liaising with engineers can be compared to the ability to work in interdisciplinary environments and the category of communication competences. According to ESCO, troubleshooting is also an important skill to obtain by mechanical engineering technicians that can be compared to complex problem solving skills in the EXAM4.0 competence model. Employees referring to this occupational group should also occupy knowledge regarding engineering principles and processes, mechanical engineering and mechanics. Interdisciplinary understanding of processes, technologies and organisations also presents an important competence regarding the EXAM4.0 model. In addition, knowledge of mechanical engineering principles and math can also be found in the model, for example concerning manufacturing skills and knowledge in STEM. With regard to optional skills of mechanical engineering technicians, the EXAM4.0 Competency model implies the majority of displayed skills and competences in ESCO. For example regarding the competence of equipment safety, it implies skills such as maintenance of equipment and ensuring their availability. Furthermore, performing test runs and testing equipment can be compared to the competence of modelling & simulation as well as data management concerning record of test data. Overseeing quality control presents another optional skill on ESCO that can be compared to quality management in the EXAM4.0 model. Regarding the competence category of Management & entrepreneurship, analysing production processes for improvement refers to the competence of strategic analysis. Concerning optional knowledge of mechanical engineering technicians, health and safety in workplaces are important and can be compared to the competences of health & security as well as industrial hygiene.

Furthermore, the occupational profile displays specific competences for example CAE and CAD skills and management of financial resources. With regard to specific competences concerning the competence category of management and entrepreneurship of the EXAM4.0 model those competences do not apply to all but employees working in higher or middle management whereas mechanical engineering technicians usually do not occupy managerial responsibilities. According to the occupational profile, employees referring to this occupational field can assess operating costs which can be compared to management of financial resources.

The EXAM 4.0 Competence model implies a vast majority of essential as well as optional skills, competences and knowledge presented in the occupational field of mechanical

engineering technicians on ESCO. Although, there are some skills missing in the model, for example managing and ordering supplies. The competence of supply chain management should be added to the model. However, inverse the occupational profile of ESCO does not include competences concerning the category of emotional intelligence or innovation, but complex problem solving skills. Moreover, general competences concerning management are also missing as well as data security.

2.3.2. Computer scientist

In comparison to mechanical engineering technicians' employees working in this occupational group refer to an ISCO level 2 pertaining to an academic occupation. The occupational profile of a computer scientist displays a smaller scope of skills, competences, and knowledge. According to ESCO, writing research reports and proposals presents an important remit of computer scientists. Essential skills such as conducting literature, qualitative, quantitative, and scholarly research as well as research interviews equate to a structured and systematic working approach and strategic analysis. The latter competence of the EXAM4.0 competency model also implies the application of statistical analysis and knowledge of scientific research methodology, displayed in the occupational profile. Conducting research interviews and writing research proposals refer to communication competences for example in verbal or written form. Moreover, applying reverse engineering and executing ICT users research activities refer to ICT skills regarding the EXAM4.0 model. According to ESCO developing a professional network presents a relevant skill for computer scientists. Networking or developing professional networks are not specifically listed in the EXAM4.0 Competence Model but included in skills such as cooperation and collaboration, teamwork, and communication.

In the occupational profile, ESCO also lists optional skills and competences for computer scientists, for example data mining and processing data. Those skills are implied in the competence of data management in the EXAM4.0 model. Regarding the category of innovation, creating solutions and innovating in ICT present further skills applied by computer scientists. An open mind-set towards lifelong learning and continuous improvement will be crucial for employees working in an advanced manufacturing environment. Asa result, knowledge in and keeping up to date about emergent technologies is important for computer scientists. About the displayed skills, competences and knowledge of computer scientists, an interesting observation can be made. The occupational profile

evinces a lack of competences referring to categories such as quality, risk & safety and emotional intelligence. Skills such as flexibility & adaptability, responsibility, stress tolerance, decision making, intercultural competences, as well as quality management, equipment safety, health & security and data security are not presented in the profile. Regarding the further categories, there are only a few interfaces between ESCO and the EXAM4.0 model. In addition, employees of this occupational group refer to higher qualifications but do not present managerial responsibilities. However, the list of optional knowledge implies several topics, for example different computer languages required in specific fields and sectors which are not yet included in the EXAM4.0 model.

2.3.3. Industrial engineer

Similar to computer scientists, employees referring to the occupational group of industrial engineers pertain to a professional level of occupations. In contrast to the latter occupational group, industrial engineers present a high level of diversification and open up to a broad field of applications. Employees of this occupation can work in several economic sectors for example aircrafts, agriculture, automotive, and further production industries. Essential skills and competences of this group imply adjusting and approving of engineering designs, using technical drawing software, and performing scientific research. Listed skills such as adjusting and approving of engineering designs as well as using software for technical drawings can be compared to the competence design method, whereas performing scientific research equates to a structured and systematic working approach and strategic analysing competence. According to ESCO, it is important for industrial engineers to occupy interdisciplinary understanding and knowledge concerning engineering principles, industrial engineering, technical drawings and processes pertaining engineering, manufacturing and production. In the EXAM4.0 Competence model, manufacturing skills referring to technical competences include a comprehension of manufacturing processes and applications. The optional skills, competences and knowledge for this occupational group appear more extensive compared to the other occupational profiles due to the high level of diversification possibilities. Regarding the displayed skills and competences on ESCO, the category of management and entrepreneurship of the EXAM4.0 model implies skills such as time and project management, as well as coordinating and encouraging engineering teams, which equates to leadership and teamwork skills. Identifying customer needs, advising customers and performing market research can be compared to marketing skills and the

competence of technology strategy implies consulting technical resources. Skills such as conducting quality control analysis, maintenance of equipment, ensuring health & safety, implementation of quality management systems, inspecting quality and equipment and managing health & safety standards compare to several competences referring to the category of quality, risk, and safety. Communication presents another relevant competence for industrial engineers for example communicating with different groups such as engineers, managers, suppliers and customers as well as technical communication skills. Innovation presents another category of the EXAM4.0 Competence Model implying skill such as creating solutions to problems, encouraging teams for continuous improvement and troubleshooting.

Furthermore, the occupational profile of this group also displays specific competencies referring to technical competences such as life cycle analysis and CAE/CAD skills as well as referring to the category of management & entrepreneurship. Managing human resources, coordinating staff, and training employees and identifying training needs equate to management of personal resources. In addition, managing budgets and maintaining financial records compare to management of financial resources, presenting a specific competence referring to higher qualifications likewise. As a result, employees working in this occupational field require a wide variety of technical as well as non-technical skills. However, skills such as data security, ethics, flexibility, stress tolerance, intercultural competences, change and risk management are not included in the ESCO occupational profile.

2.4. Conclusion

ESCO provides a lot of data and information about different occupational groups. Training and education providers get information about required skills and competences for respective occupations and employers receive insights what students and graduates learned regarding respective qualifications. The occupational profiles displayed on ESCO provide information about the hierarchical structure and specification possibilities as well as essential and optional skills, competences, and knowledge, referring to specific areas and occupational fields. Due to the distinction between competences, skills and knowledge on ESCO, it is rather difficult to compare the required skills and competences in the occupational profiles to the EXAM4.0 Competence Model, which presents a more abstract list of competences required for employees working in an advanced manufacturing

environment. However, the displayed skills, competences and knowledge do not display all skills required in an I4.0 environment for employees of the respective occupational groups (CEDEFOP, 2015). Especially soft skills and non-technical skills are not presented in the respective profiles. Skills concerning the competence category of emotional intelligence such as decision making, stress tolerance, intercultural skills, mindset towards lifelong learning, flexibility or the ability to thrive on failures are not listed in the profiles of the mechanical engineering technicians, computer scientists or industrial engineers. In the future, communication skills will become more important, both virtual as well as conventional exchange of information. Innovation will also be increasingly important for future employees. This competence implying skills like integration , experimentation, abstraction, critical thinking and transfer skills will be crucial in order to be optimally equipped for the increasingly complex work environment. The developments of I4.0 and the progressing implementation of linked and interconnected technologies and machines evoke a great risk regarding data security and safety. Therefore, skills referring to the competence category of quality, risk & safety will be required of future employees to prevent new forms of crime and threat.

In comparison, the EXAM4.0 Competence Model also does not imply competences referring to supply chain management and networking. Those competences should also be added to the model.

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